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(Formation Works, Bridge Works and P.Way Works)

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Chapter- 1

Earth Work

1.1 EARTHWORK – GENERAL

Earthwork for Railway Formation (Embankment and Cutting) shall be as per RDSO's Guidelines and Specifications for Design of Formation for Heavy Axle Load, Report No. RDSO/2007/GE : 0014, November 2009 and Guidelines For Earthwork in Railway Projects Guideline No. GE : G-1 July 2003 with latest correction slips, as applicable for suitability of soil, construction processes, sampling, testing and acceptance. This has been summarized hereunder for general guidelines and for details, aforesaid Guidelines may be referred to.

1.1.1 Site Clearance : Before work is started, the whole area between the toes of banks or tops of cuttings plus 2m in on both sides shall be properly and effectively cleared by the contractor of all small trees (of girth upto 30 cm), roots, bushes, heavy grass etc. The Contractor shall also clear the site of all buildings, abandoned structures etc. as directed by the Engineer, for which extra payment will be made unless otherwise stated in the agreement. The Contractor shall arrange removal of rubbish and other excavated material excluding earth upto a distance of 50m from the periphery of the area under site clearance. High portions of the ground shall be cut down and hollow depressions filled upto the required level with the excavated earth so as to give an even neat and tidy look. The work of this nature will be covered by the initial rate for earth work, unless stated to the contrary in the agreement.

1.1.1.1 Trees of girth over 30 cm, measured at a height of 1m above ground level, shall be considered as large trees. Cutting down of large trees shall be paid extra at the rate specified when stumps are grubbed up in addition. Large trees shall not be cut without specific orders from the Engineer. As few trees shall be cut as is absolutely necessary for the execution of work. The roots of trees and saplings shall be removed to a depth of 60 cm below ground level or 30 cm below formation level or 15 cm below subgrade level, whichever is lower. All holes or hollows formed due to removal of roots shall be filled up with earth rammed and levelled. Trees, shrubs, poles, fences, signs, monuments, pipe lines, cable, etc. adjacent to the area which are not required to be disturbed during site clearance shall be properly protected by the contractor at his own cost and nothing extra shall be payable. In case any damage to the pipe lines, cables, etc. is done due to negligence on part of the contractor the necessary damage charges will be recovered accordingly.

1.1.1.2 Any trees cut down or building materials released from dismantling of structures shall be stacked by the contractor within a distance of 100 metres outside the periphery of the area under site clearance as per instructions of the Engineer. The contractor shall have no claim to the trees or other material removed during site clearance and the same shall be the property of the Railway.

1.1.2 Demarcation and Profiles: The contractor, before starting work, is to demarcate with a deep furrow, at least 20 cm wide and 15 cm deep, 1m away

from the toes of slopes of banks and the outside limits of cuttings on both sides of the centre line, the boundaries of the bottom and the top of the slopes of the borrow pits. This is to be considered as part of the setting out of work, and preliminary to contractor being allowed to start the work; and this dag belling is to be maintained and renewed by contractor as and when necessary, or when ordered by the Engineer. The cost of this is included in the initial rate for earth-work.

1.1.2.1 The centre line will be initially set out by the Railway. The contractor shall, at his own expense, provide all building materials as cement, stone chips, sand, bricks, steel plates, nails, markers, stakes, bamboos, strings, pegs and labour necessary for setting out the centre line and profiles required for the correct execution of work and for marking out borrow pits and slopes and will be responsible to ensure that they are maintained in proper order. The costs of providing and maintaining the above including all materials and labour is included in the initial rate for earth-work.

1.1.2.2 The contractor before starting any work, shall take charge of all bench marks, centre line, demarcation and other field stones and reference pegs and be responsible for their subsequent preservation, and should they disappear or be destroyed after he has taken them over, he shall pay the cost of their replacement or replace them at his own level in consultation with the department.

1.1.3 Maintenance: Banks and cuttings are to be correctly dressed and finished in profile with slopes as specified in each case. Where gullies or water-cuts commence to form on the slopes of embankments or cuttings, the erosion is to be checked as early as practicable and made good with suitable material well rammed into place. Where a gully or water-cut has not been checked at its commencement, it may be advisable to cut it out or step it before filling it in, and to further protect the place by turfing, pitching or other means as may be ordered by the Engineer. Work, before being finally paid for, is to be checked by the Engineer as having been correctly brought up, or carried down, to the proper level and to be otherwise complete in all respects in accordance with the specifications, and with the proper allowance for settlement as specified in **para 1.2.6.**

1.1.3.1 As soon as the work has been satisfactorily completed, the Engineer shall issue a certificate of completion in respect of the work as specified in Clause 48 of the General Conditions of Contract. Unless otherwise specified in the Tender conditions, the contractor shall maintain the banks / cuttings for a period of six months or as per conditions of contract and handing over of banks / cuttings to Railway in proper condition and where necessary, for their restoration to such condition, at the end of maintenance period. Until then, contractor is responsible for all ~~losses~~ due to subsidence, wastage or guttering due to rain, wind, wear, wash or from any other cause whatsoever and he shall have no claim for any extra work or payment on this account.

1.1.4 Spoil from Cutting to Bank: Up to the normal lead of 50 metres, material from each end of every cutting shall be led forward into the adjoining bank as a matter of course, and the rate to be paid for such material shall be the rate

for cutting only. Both bank and cutting will not be paid for. The Engineer shall specify in each case from what point in each cutting to what point in the adjoining bank, spoil shall be led out, payment being made only for the excess lead over and above the initial lead included in the rate for cutting. The Engineer can modify these limits at any stage of the work and all such changes shall be binding on the contractor without any claim for any extra payment on this account. Dressing and compaction of the bank will, however, be paid for in addition.

1.1.5 Classification of Soils: The classification of soils met with in executing the work shall be made by the Engineer/ Engineers' representative authorized by the Engineer for this purpose subject to the approval and final decision of the Engineer, if not made by him. The rates to be paid to the contractor in his bills shall be based on these classifications.

Earth work can be divided under the following heads :

1.1.5.1 Soft / Loose Soil : Generally any soil which yields to the ordinary application of pick and shovel, or to phawra, rake or other ordinary digging implements; such as vegetable or organic soil, turf, gravel, sand, silt, loam, clay, peat, etc.

1.1.5.2 Hard/Dense Soil : Generally any soil which requires the close application of picks or jumpers or scarifies to loosen; such as stiff clay, compact moorum, macadam surfaces of any description, (water bound, grouted, tarmac etc), kankar soil, shingle and boulder studded soil and soft conglomerate etc.

1.1.5.3 Mud (Soil) : A mixture of soil and water in fluid or weak solid state and where inflow of sub soil water is not involved.

1.1.5.4 Soft/Disintegrated Rock (Not Requiring Blasting): Rock or boulders which may be quarried or split with crow bars. This will also include laterite and hard conglomerate.

1.1.5.5 Hard Rock (Requiring Blasting) : Any rock for the excavation of which blasting is required.

1.1.5.6 Hard Rock (Blasting Prohibited) : Hard rock requiring blasting as described under **sub para 1.1.5.5**, but where blasting is prohibited for any reason and excavation has to be carried out by chiselling, wedging or any other agreed method.

1.1.6 Measurements : Cutting and banks are to be excavated and made up neatly to the lines shown in the cross section as per approved construction drawing. No payment will be made for excess work done outside these lines except when such work is so ordered in writing by the Engineer. However, if any bulges are left in the slopes of cuttings due to practical difficulties and are permitted, deduction as per actual measurements will be made. Similar action will be taken in case of concave surfaces in the slopes of embankments, if permitted.

1.1.6.1 Should the Engineer so desire, he may, at any stage of the work, order the Contractor to increase or reduce the slopes of any cutting or bank or alter the formation level, in which case the amount of work actually done will be paid for in accordance with the specifications and the Schedule of Rates.

1.1.6.2 Unless otherwise specified the initial rate for Earth work is inclusive of an initial lead upto 50 metres and lift of 1.5 metres.

1.1.6.3 Additional lead for the purpose of payment will be measured from the centre of gravity of excavation to the centre of gravity of the bank or spoil heap, and shall be measured along the shortest practicable route and not necessarily the route actually taken.

1.1.6.4 Additional lift for the purpose of payment will be estimated by dividing the cross section of the bank or cutting into successive stages of 1.5m high or deep respectively from the natural ground level and only the quantity contained in each strip shall be paid for at the rate appertaining to its height or depth above or below the natural ground level, respectively. Lift from the borrow-pit to the ground level or from ground level to the spoil bank shall not be taken into account in any payment for lift unless the depth of the borrow-pit or the height of the spoil bank has been made in excess of 1.5m under instructions from the Engineer, and in such cases, only the portion of the borrow-pit below 1.5m depth or of the spoil bank above 1.5m height as measured from the natural ground level, shall be, measured separately for payment of lift on the same basis as for cuttings or banks respectively. No extra payment will be made for descent, ascents, crossing of nallahs and ridges.

1.1.6.5 For purpose of payment, cuttings shall be assumed to be composed of such soil / soils only, as stand exposed on both or one side of the finished cuttings, depending upon whether the cutting is box type or one sided on a transversely sloping ground. The content of each type of soil thus assigned to any cross section shall be determined as indicated below. It is to be noted that no portion of cutting will be payable for any such type of soil as is not exhibited on the finished side slope, where the side slope exists.

(a) For box type cutting: The centre line of the alignment will be marked vertically on the cross section and the content of each type of soil will be determined by computing the area of the strip, formed by joining the points, which form the extremity of occurrence of the particular soil on the finished side slope of cutting, by straight horizontal lines terminating on the centre line. **Figure No.1.1** is illustrative of the manner in which payment is to be made.

(b) For one sided cutting on a transversely sloping ground : Content of each type of soil will be determined by computing the area of the strip, formed by joining the points, which form the extremity of occurrence of the particular soil on the finished side slope of the cutting, by straight lines to the zero point. **Figure No.1.2** is illustrative of the manner in which the payment for the cutting will be made

(c) For widening of existing cuttings for one or more lines where the existing cutting slope disappears and a fresh slope stands: Before undertaking widening of the cutting, pre-classification of the existing cutting slope (which will disappear) should be done after clearing and cleaning the surface and the strata met marked on the cross-section sheets. After completion of the work various strata as stand exposed on the new finished slope of the cutting shall again be marked on the cross-sections. Then the demarcation points of adjacent strata as determined by classification of the existing slope and the final slope should be joined as shown in **Figure No. 1.3.**

The cross-sectional areas for different strata may be worked out and quantities payable classification-wise assessed accordingly.

(d) For extension to the existing cutting where no fresh cutting slope is available after work: Before execution of the work pre-classification of the existing cutting slope which will not be finally available, should be done and recorded in the initial cross-section. **Figure No. 1.4** is illustrative of the manner in which the payment for the cutting is to be made for soil of different classifications.

1.1.6.6 Classification in the above manner shall be made only at such points where the cross sections giving the ground profile have been recorded. The classification as recorded in the above manner in case of cuttings shall be signed by the contractor in token of his acceptance. The classification as recorded by the Authorized representative of the Engineer in the above cases for cuttings is subject to confirmation by the Engineer, whose decision shall be final and binding on the contractor. Where there is disagreement between the Contractor and the Authorized representative of the Engineer on classification of soil, payment shall be effected “on account” as per lower classification as made by the Authorised representative of the Engineer. Payment for extra at the rate for higher classification shall be made after final decision by the Engineer on the admissibility of the Contractor’s claim for higher classification.

1.1.6.7 In computing the quantity of earth work in cuttings and side drains, no cognizance will be taken of the additional excavation, which may be necessitated during the progress of the work due to the presence of boulders or other material, and payment will only be made for the quantity as per cross sections required to be provided.

1.1.6.8 Where cutting spoil is utilised for making the bank, stones over 15 cm size, which are not to be used in the bank, shall be stacked separately at a site to be indicated by the Engineer. To determine the quantity of cutting spoil led out for making the bank, the sectional quantity of the cutting shall be reduced by the volume of stones and boulders stacked outside, which will be arrived at by deducting 50% for voids from the stack measurements of these stones and boulders. The stacking of these stones and boulders including lead upto 50 metres and lift upto 1.5 metres is covered by the initial rate of Earth work.

1.1.6.9 Stones and boulders over 15 cm size shall not be used in making embankments. In embankments where payment is made on the basis of cross

section measurements, the stones and boulders over 15 cm size shall be stacked separately, and their volume, after deducting 50% for voids from the stack measurements of these stones and boulders, shall be included as extra, for payment for earthwork in excavation from borrow pits.

1.1.6.10 Payment : It must be clearly understood that the Contract rates are intended to cover the full cost of finished work. Banks and cuttings are to be carefully dressed to formation with such slopes as may be specified in each case. The payment for the quantity of earth work in cutting / bank shall normally be made on cross sectional measurements. The existing ground / bank profile shall be taken and plotted by the Authorised representative of the Engineer in the presence of contractor or his authorized agent before commencement of the work. The profile of the bank or the cutting required to be provided including allowance of settlement in case of embankment, shall also be plotted on the same sheets. The levels and cross sections shall be signed by both the Authorised representative of the Engineer and the contractor / his authorized agent. (The profiles of the bank or cutting as required to be provided are for the guidance of the contractor and not for the purpose of measurements).

The profiles of the finished and plotted bank/ cutting shall like-wise be taken in the presence of the contractor or his authorised agent and super-imposed on the original ground profile. These profiles are to be taken at locations as directed by the Engineer, at least at 25m intervals on straight and at least at every 15m on Curves with radii sharper than 600m and at extra locations in special cases such as irregular or side long ground etc. The gross volume of earth work shall be calculated from the original and finished profile of the bank/ cutting. For the purpose of payment the gross quantity thus calculated shall be reduced by 10% towards shrinkage allowance for earth work in embankments only, but no such deductions shall be made for earth work in cuttings. Where the embankment has been compacted by heavy machinery as stipulated in subsequent **Para 1.9** or in accordance with any other special specifications, on the specific instructions of the Engineer in writing, shrinkage allowance shall be deducted at the rate of 5% of the gross quantity of earth work. Irrespective of the type of soil, number of monsoons passed over the embankment, shrinkage / compaction which may be caused due to base settlement, wash out, mode of working, i.e. use of trucks, camel carts, donkeys etc, and other reasons, whatsoever and the actual shrinkage allowance provided in setting out the profiles in different sections.

As it may, at times, be difficult to measure by means of cross sections the quantity of rock excavated by blasting or chiseling, owing to its irregular configuration or intermixture with other materials, the quantity of rock may be measured after stacking the excavated rock spoil. The same procedure also applies to any other type of soil, which requires to be measured separately from the material constituting the bulk of the spoil. In all such cases, the payable quantity of the stacked material is to be arrived at by making suitable deductions for voids from the measured cubical contents of the stacks as specified below:-

	Type of soil stacked	Deduction
(a)	Rock spoil of different sizes	30 per cent
(b)	Sandy materials	7 ½ per cent
(c)	Black cotton soil	20 per cent
(d)	Other soils, including coal ashes	15 per cent

To facilitate measurement, all stacks to be measured shall be made rectangular in plan and of uniform height, on level ground or ground levelled for this purpose. The stacking of spoil shall be done in a compact manner to the satisfaction of the Engineer. The rates provided shall include all charges on account of such stacking as well as any lead or lift, as also the re-stacking of stacks or portions of stacks which the Engineer considers, in his sole discretion, as not properly stacked.

As far as possible spoils from cuttings fit for embankment shall be used to make up the bank. If however, this is found to be uneconomical due to excessive lead or lift, the earth if available from the borrow pits in Railway land it may be used, if permitted. If sufficient quantity of good earth fit for embankment is not available from the source of cut spoils and the source of borrow pits, Contractor's earth shall be utilised. As far as possible each stretch of bank should be made of earth from only one source so as to avoid mix up. If however, this is not possible due to exigencies of work, earth from one source should be utilised first and compaction done before earth from the next source is allowed to be dumped. Initial cross section of bank and cross section after compaction of earth from each of the sources should be taken. Based on the cross sectional areas, the gross quantity of earth work embankment executed by utilising the earth from different sources shall be determined. The net quantity shall be assessed after deduction of shrinkage allowance at the rate of 10%/5% as the case may be, depending upon the type of compaction done.

Final measurements shall be taken only after the bank/ cutting has been completed to the required profile as directed by the Engineer irrespective of the period of completion and number of monsoons that may pass during execution. Shrinkage allowance shall be applied on these final measurements for banks.

1.1.6.11 At the end of final measurements, following certificate shall be recorded in the Measurement Book by Authorised representative of the Engineer.

"Certified that necessary allowance for shrinkage as prescribed was made while giving profiles to the contractor for doing earth work and the same has been provided by the Contractor".

1.1.6.12 Where, for any reason at the discretion of the Engineer, borrow-pit measurements are resorted to, all matams and roads and excess earth work, such as bulges in the slopes of the banks / cuttings, shall be excluded from the measurements.

1.1.6.13 Nothing extra shall be paid for :

(i) Excavation for insertion of planking and strutting.

(ii) Removing slips or falls in excavations

(iii) Bailing out water in excavations from rains, ordinary springs not requiring pumping etc.

(**Note**: Pumping out water caused by powerful springs, tidal or river seepage, broken water mains or drains and the like, shall be paid separately if provided for in the Agreement)

(iv) Unauthorized battering or benching of excavations.

(v) Forming steps in sides of deep excavations and their removal after measurements.

(vi) Protective measures for protection against risk of accidents to the public due to open excavation.

(vii) Protective measures / precautions taken to avoid damage to existing Signal / Electrical / Telecom / other Miscellaneous Cables, Pipes, installations etc.

1.1.7 Dressing Surface :

1.1.7.1 This specification is applicable to Surface dressing executed as a separate work for purposes other than Earthwork for Embankment or Cutting. In case of Earthwork for Embankment or cutting, provisions of **Para 1.1.1** will apply and the surface dressing will be covered by the initial rate of earthwork unless stated to the contrary in the Agreement. This specification shall also be applicable only to work involving Soft / Loose soil and Hard / Dense soil.

1.1.7.2 The terms “Dressing Surface” shall be taken to mean the cutting down of high portion of a specified area of ground and using the excavated earth to fill up the hollows and the depressions. The maximum depth of excavation or filling shall be restricted to 15 cms.

1.1.7.3 The levels to which the ground is to be dressed shall be such that the quantity filled is nearly equal to the quantity cut and the finished surface is even and tidy with such slopes as may be necessary for proper drainage. Before the work is commenced the proposed levels shall be set up at regular intervals both for the cuts and for the fills, by suitable means as directed by the Engineer and these shall be got checked and approved by him.

1.1.7.4 Unless otherwise provided for in the Contract, the rates shall be inclusive of removal of rubbish upto a distance of 50m outside the periphery of the area cleared.

1.2 EARTH WORK IN EMBANKMENTS

1.2.1 Embankment in Water-logged ground etc. : When embankments are to be carried across water-logged or swampy ground or to be made in soil which requires special protective measures, it rests with the Contractor in all such cases to bring these facts to the notice of the Engineer concerned who will direct on the methods to be adopted and the rates to be paid, and will arrange for a special agreement for the same if necessary.

1.2.2 Selection of Earth : If due to non availability of adequate quantity of earth from Railway land, the contract provides for contractor's earth the contractor shall get the prior approval of the Engineer for the quality of earth and where Contract Conditions provide for lead based on the distance from the sources of supply to site, the lead to be paid. The disturbed / undisturbed soil samples along with the test results as per specifications will be submitted by the contractor for approval of the source from where the earth is proposed to be borrowed before the Earth work in embankment is started or in case of change in location of the source.

1.2.3 Formation Width : The formation widths are to be as shown in the drawings.

1.2.4 Side Slopes : The side slopes will ordinarily be 2:1, but the Engineer or his Authorised representative may, by order in writing, vary this slope to suit local conditions. The side slopes shall be carried up simultaneously with the rest of the work and not filled in afterwards. This can only be ensured by insisting on the whole width of embankment from the toes of the slope coming up simultaneously. The slopes of banks composed of sand shall, if directed by the Engineer be covered by a layer of not less than 30 cm thickness of Moorum or other good soil to facilitate turfing and extra payment will be made for the same.

1.2.5 Profiles : Profiles for banks shall be set out where-ever cross section has been taken. These profiles shall be set up at least every 25m on the straight and every 15m on curves with radii shorter than 600m. Profiles shall also be set up at any additional places if ordered by the Engineer.

1.2.6 Allowance for settlement : In width of formation 50mm extra should be provided for each 30 cm of the height of the bank as shown on the section upto a maximum of 0.60m. This does not affect the width at the toes of the slopes, which will be set out from the height given on the section. In setting up profiles for bank, due allowance for settlement must be made and added to the height of the profile over and above the height of formation as shown in the approved drawing. As a guide the following shrinkage allowances per metre height are suggested for adoption with different classes of soil:-The additional earth has to be removed after final dressing and it can be used elsewhere after a stretch of the work is completed, dressed to final profile and taken over by the railways.

Shrinkage allowance for work done manually per metre height

Bank made of rocky fills	0	to	2 cm
Bank made of moorum and sandy soils	8	to	12 cm
Bank made of fills with considerable clay content	16	to	20 cm

The Engineer will decide the scale of allowance for settlement for each section and shall be at liberty to vary the same during the progress of the work to suit the nature of soil met with, the method adopted for executing the earth work, the consolidation achieved during the progress of the work and any other factors affecting the earth work.

1.2.6.1 The above shrinkage allowances are only for the purpose of setting out of the work. For payment, the deduction for shrinkage shall be as specified in para **1.1.6.10.**

1.2.7 Borrow Pits : The Engineer concerned will direct from where material is to be obtained and has powers to refuse to allow any unsuitable material to be put into a bank. As far as possible, Bank should be made of homogeneous material with no mix of rubble or boulders with soil. No excavation for borrow pits shall be made within 2m of the limits of the acquired land. Borrow pits shall not be dug close to level crossings, bridges or culverts, telegraph poles, electric poles, or close to inhabited areas, unless they can be properly drained to prevent water stagnating. Borrow pits within station limits shall be avoided as far as possible. The earth is to be excavated and thrown to such width, depth and height and in such places as may be from time to time decided.

1.2.7.1 During excavation, the contractor shall take particular care to avoid damage to drains, water mains, cables or other underground work. Should any damage be caused, the Engineer shall be notified immediately and the damage shall be made good at the contractor's expense.

1.2.7.2 Borrow pits shall be excavated within the limits of railway land as directed by the Engineer. The pits must be rectangular or conform to the land boundaries. The sides of the pits next to the toe of the bank are to be sloped down at 2:1, and elsewhere at a slope of 1:1 unless otherwise directed by the Engineer. Any pits wrongly excavated shall be refilled by the contractor at his own cost, and in such a manner as the Engineer directs.

1.2.7.3 Borrow pits are not to be made of uneven depth but the whole area of each pit is to be neatly excavated to the same level. The outer or the most distant half of the borrow-pits is to be excavated first, so that in the event of the pits being flooded by rain, there will still be ground available for work.

1.2.7.4 A berm 15m wide is to be left untouched initially at every 85m between edges of borrow-pits, and is not to be encroached upon for any excavation except under the instructions of the Engineer. If it is necessary for drainage purposes to cut through the berm, the channel will be made on the side remote from the Bank.

1.2.7.5 In side long ground, the borrow pits are to be dug on the upper side of the bank, and are to be continuous to serve as catch water drains; and, if so

ordered, the contractor shall get the earth for the bank exclusively from such pits till the catch water drain is complete to the required length, section and level as prescribed by the Engineer.

1.2.7.6 When doing repair work to banks it is absolutely essential that diagonal bunds be kept, when digging fresh borrow-pits in the old ones, as a precautionary measure for correct assessment of the work. Diagonal bunds are also to be kept in borrow-pits for new works where payments are to be made on borrow-pit measurements. When doing earthwork repairs, Authorised representative of the Engineer should bear this point in mind and refuse to measure up any pit in which a diagonal bund has not been kept. For repair works it would save a large amount of unnecessary detailed measurements if all pits were excavated to a uniform size as far as practicable.

1.2.8 Bankexecuted manually : All banks, if executed manually shall be made in successive layers, not more than 30 cm in depth, over the whole width and slightly concave in section so as to retain water for subsidence. The subsequent top layer shall be started only when the previous layer has been completed for a length not less than 30m along the embankment.

1.2.9 Clods: All large clods (larger the 15 cm) shall be broken up in the borrow pits or bank by labour specially deputed for this work. This shall be strictly ensured.

1.2.10 Bunding of Bank Top : In banks executed manually/mechanically, before the commencement of monsoon, continuous longitudinal earth bunds, 25 cm high and 30 cm wide on the top with side slopes of 2:1, are to be made on the outer edges of the top of embankments, together with cross bunds of the same dimensions at every 15m, so as to impound rain water to expedite consolidation. This work shall be paid for separately at the rate for soft/loose soil and may be left un-compacted.

1.2.11 Benching : In widening an existing bank, steps 30cm in height and approximately 60 cm wide, shall be cut in the existing bank before any new earth is placed, to form a bond between the new and old earth work. Similar benching is to be provided in side-long ground of which the slope at right angles to the alignment of the banks is 3 Horizontal to 1 vertical or steeper or if ordered by the Engineer. The benching in side long ground will not be separately measured or paid for, but is deemed to be covered by the initial rate for earth work.

1.2.12 Stream Diversions : When it has been decided to divert a stream adjoining the bank, the excavation for this work is to be undertaken and completed before any borrow pit work is done at site and all earth from such diversion is to be put into the main bank, if so ordered. If earth excavated from the drain is led into the bank, payment will only be made for the quantity excavated including lead and lift if any and not for both cut and fill. In excavating for diversion of stream, care must be exercised by the Engineer that such diversion does not start a land slip.

1.2.13 Backing to Bridges: In carrying embankments over a bridge or a culvert intended to be covered by the work, the earth work shall be brought up evenly

on both sides of the structure so that the pressure may be equalised. In filling in the approaches of a bridge, or the spandrels between small arches, the earth filling shall be raised simultaneously with the wing walls in the former case and with the face walls in the latter, in order that the filling may be well trodden down under the feet of the labourers, and in filling in foundations and backing to revetments, the earth work shall similarly be brought up level as the masonry proceeds. Filling for the backing of bridges or culverts will conform to specifications under **Para 1.6**, and subsequent sub paras, or as ordered by the Engineer. Cast iron rammers should be used to consolidate the earthwork where mechanical compaction can not be done due to practical constraints.

1.2.14 Dressing: Aftercompletion of earth work the slopes shall be neatly dressed to the correct profiles, and shall be made up where required during the maintenance period. The top should be neatly dressed off sloping at an inclination of 1 in 30 either side from the centre line unless otherwise specified in the drawings.

1.2.15 Turfing: Turfing of banks shall be done during the monsoon season, preferably after a heavy shower, when it can be ensured that the bank slopes will remain wet for a long time after planting the grass. Turfing shall be paid for separately. Turfing shall not be commenced without the prior written permission of the Engineer. The stretch of embankment where turfing is to be done should be completed in all respects and should be so recorded in the level books and profiles. Contractor should be given permission in writing to this effect before starting the Turfing.

1.2.15.1 Before turfing is commenced, the side slopes are to be dressed to the specified section. This dressing is included in the initial rate for earth work, and should a contractor stop work before dressing the bank, he shall be debited with the estimated cost of the dressing to be done by another contractor or departmental labour, as decided by the Engineer. Where the slope is already consolidated, it should be loosened for a depth of about 4 cms before the sods are laid.

1.2.15.2 Turfing shall consist of sods, not less than 10 cm thick and 20 cm square well beaten into the bank till they get a proper hold and form a level and compact mat. The contractor shall be responsible for watering where necessary to ensure that the turf grows properly; and in the event of it not doing so, he will returf such parts as have not grown, at his own cost. The turfing shall be measured and taken over only after the grass has rooted well and has formed a sufficiently dense growth over the earth slopes. Turing with sarkanda or other varieties of locally available grass may also be permitted by the Engineer Incharge depending upon the local conditions.

1.2.15.3 Turfing of side slopes of cuttings if ordered by the Engineer shall be carried out in a manner similar to Turfing of bank.

1.2.16 Sarkanda or similar type of planting on bank slopes : Where Sarkanda is planted on bank slopes, the minimum distance centre to centre in rows shall be 40 cm in either direction. The plantation in adjacent rows will be staggered

for proper coverage of the area. For other types of plantation, the local practice shall be followed as directed by the Engineer. Where directed to be done, this item will be paid for extra.

1.3 EARTH WORK IN CUTTINGS

1.3.1 Formation width : The formation widths, exclusive of side drains, are to be as shown in the drawings :

The top width of each side drain will ordinarily be 120 cm at formation level and depth 30 cm, unless shown otherwise in the drawing. For longer drains specially designed sections will be adopted depending upon the catchment area, length and slope of the drain which should be finalized before completion of the cuttings.

1.3.2 Side Slopes: The side slopes will ordinarily be 1:1 unless otherwise ordered by the Engineer.

1.3.3 Excavation :

1.3.3.1 When so ordered, the centre portion of gullet of the cutting shall be first taken out to the full width of formation to enable the Engineer to determine the slopes suitable to the full length of the particular cutting or to different lengths of it. When the gullet is cut out to its full depth in shallow cuttings, or to the depth of the first cut in deep cuttings, the side portions or triangular sections up to the slopes may be excavated. In deep cuttings, the, second cut will not be started until the top portion is thus completed.

The necessity of excavating cuttings in this manner is evident as, in the event of heavy rain occurring with work partly completed, and the bottom of the excavation uneven and incapable of drainage, excessive delay might occur or excessive pumping might become necessary. The contractor is solely responsible for any such contingency and the railway will not be liable for any compensation.

1.3.3.2 All cuttings shall be taken down carefully to the precise level and section as delineated in the drawings or as ordered by the Engineer. In case the bottom of the cutting is taken down deeper than is necessary by over sight or neglect of the contractor or due to blasting operations, the hollow must be filled up to true depth with selected material and rammed, at contractor's expense. Cuttings with the formation in rock will be excavated upto 15 cm (Max.) below the true formation and filled up to true level with cutting spoil to ensure that no lumps of solid rock project above formation level. The bottom sloping from centre towards side drains shall be as given in Sub **Para 1.3.3.3** below. Payment will, however be made for earth work in cutting up to the true formation level only.

1.3.3.3 In soft soil the excavation of cuttings shall, in the first instances be carried to about 15 cms short of the full depth, so much being left for dressing the bottom

true to the formation. The side slopes shall be dressed true and straight and the bottom shall then be completed by sloping if from the centre line towards the side drains to a slope of 1 in 30 or any other slope as shown in the drawing.

1.3.4 Drainage of cuttings :

1.3.4.1 In excavating cuttings, special precautions are to be taken to ensure that the excavations drain themselves automatically. To ensure this, the central block of earth or gullet is to be excavated first. This will be done in such a manner that the bottom of the excavation shall, where possible, slope downwards from the centre of the cutting towards the ends. It will be made in such cuts or steps as may from time to time, be directed. Generally, in deep cuttings the first cut or step will approximately follow the surface of the ground, where this will secure the necessary slope for drainage, and will be excavated to such depth not exceeding 3m as may be ordered, with perpendicular sides leaving pathways for workmen along the sides of the cut parallel to the central line about every 15 m. In shallow cuttings, not exceeding 2m in the deepest part, the gullet may be cut out at once to formation level.

1.3.4.2 Side drains according to the cross section shown in the drawing shall be provided at the toe of the slope in all cuttings to ensure proper drainage. Excavation to the required cross section and longitudinal slope to form the side drain will be paid for at the same rates for cutting.

1.3.5 Catch-water drains : Where required, catch water drains cut to the section and profile prescribed, shall be constructed on the up hill side leaving a berm of one metre from the boundary of the railway land or as decided to suit the local conditions and shall be paid for at the same rates as for cutting. The cross sectional area of the catch water drain shall normally not exceed 0.75 sqm.

The spoil from the catch water drain will be deposited to make a uniform slope from the edge of the cutting towards the drain. The material derived from the catch water drain will be used to the extent required to provide the slope and the surplus earth should be deposited in the spoil bank of the cuttings. Unless ordered to the contrary by the Engineer, the Catch water drain must be excavated before the cutting is started.

1.3.6 Berms and spoil banks : No spoil shall be deposited within a distance of 10 m from the top edge of the slope of any cutting duly taking into account the location of the catch water drain, if any. While doing so, the Engineer may bear in mind the side on which the doubling may eventually be done and may be suitably increased.

1.3.6.1 The spoil heap shall be roughly but neatly dressed off to a slope of 1 ½: 1, and shall form a continuous bund along the top of the cutting. In country where there is any cross fall, sufficient spoil shall be thrown on the up hill side of the cutting to supplement the catch water drain and assist in keeping drainage out. This work must be done first.

1.3.6.2 (a) All material excavated from cuttings suitable for pitching, ballast, masonry or any other purpose whatever, shall be the property of the Railway, and shall be stacked, as also disposed off, as directed by the Engineer, within the limits of lead specified for stacking of spoil. This is included in the rate for cutting.

(b) Any finds of archaeological interest such as relics of antiquity, coins, fossils or other articles of value shall be delivered to the Engineer and shall be the property of the Railways.

1.3.7 Springs or Inflow : Should springs or inflow of water appear in cuttings, or should they be flooded, the contractor must arrange for bailing, pumping or drainage of water, without obstruction to adjacent works. Payment for the same shall not be made unless otherwise provided for in the Agreement with the Contractor.

1.3.8 Protections : Excavation, where directed by the Engineer, shall be securely fenced and provided with proper caution signs, conspicuously displayed during the day and properly illuminated with red lights during the night, to avoid accidents. The Contractor shall take adequate protective measures to see that the excavation operations do not damage the adjoining structures or dislocate the services. Water supply pipes, sluice valve chambers, sewerage pipes, manholes, drainage pipes & chambers, communication cables, power supply cables etc. met within the course of excavation shall be properly supported and adequately protected, so that these services remain functional.No extra payment will be made for taking such measures unless otherwise specifically provided for in the Contract.

Excavation shall not be carried out below the foundation level of adjacent buildings until underpinning; shoring etc. is done as per the directions of the Engineer for which payment shall be made separately. The temporary arrangement drawings should be submitted by the contractor and got approved before undertaking such excavation.

1.3.9 Blasting : If any blasting operations are necessary, they shall be carried out in accordance with the Explosives Act and the Rules as amended upto date. Extracts from the Explosives Rules 1983 are kept at **Annexure 1.1** for strict adherence by the Contractor's staff as well as Railway employees engaged in blasting operations. For general guidance, the instructions contained in Chapter X of Indian Railways Works Manual may be referred to. The following specifications are supplementary to the above.

1.3.9.1 Where hard rock is met with and blasting operations are considered necessary, the contractor shall obtain the approval of the Engineer in writing for resorting to blasting operation.

Note : In ordinary rock, not requiring blasting, blasting operations shall not be generally adopted. However, the contractor may resort to blasting with the permission of the Engineer, but nothing extra shall be paid for such blasting operations.

The contractor shall obtain license from the competent authority for undertaking blasting work as well as for containing and storing the explosive as per the Explosive Act, 1884 as amended upto date and the Explosive Rules, 1983. The contractor shall purchase the explosives fuses, detonators etc. only from a licensed dealer. Transportation and storage of explosive at site shall conform to the aforesaid Explosive Act and Explosive Rules. The contractor shall be responsible for the safe custody and proper accounting of the explosive materials. Fuses and detonators shall be stored separately and away from the explosives. The Engineer or his authorised representative shall have the right to check the contractor's store and account of explosives. The contractor shall provide necessary facilities for this.

The contractor shall be responsible for any damage arising out of accident to workmen public or property due to storage, transportation and use of explosive during blasting operation.

1.3.9.2 Blasting operations shall be carried out under the supervision of a responsible authorized agent of the contractor (referred subsequently as agent on duty), during specified hours as approved in writing by the Engineer. The agent shall be a licensed blaster. In case of blasting with dynamite or any other high explosive, the position of all the bore holes to be drilled shall be marked in circles with white paint. These shall be inspected by the Contractor's agent. Bore holes shall be of a size that the cartridge can easily pass down. After the drilling operation, the agent shall inspect the holes to ensure that drilling has been done only at the marked locations and no extra hole has been drilled. The agent shall then prepare the necessary charge separately for each bore hole. The bore holes shall be thoroughly cleaned before a cartridge is inserted. Only cylindrical wooden tamping rods shall be used for tamping. Metal rods or rods having pointed ends shall never be used for tamping. One cartridge shall be placed in the bore hole and gently pressed but not rammed down. Other cartridges shall then be added as may be required to make up the necessary charge for the bore hole. The top most cartridge shall be connected to the detonator which shall in turn be connected to the safety fuses of required length. All fuses shall be cut to the length required before being inserted into the holes. Joints in fuses shall be avoided. Where joints are unavoidable, a semi-circular ditch shall be cut in one piece of fuse about 2 cm deep from the end and the end of other piece inserted into the ditch. The two pieces shall then be wrapped together with string. All joints exposed to dampness shall be wrapped with rubber tape.

The charges shall be fired successively and not simultaneously. Immediately before firing, warning shall be given and the agent shall see that all persons have retired to a place of safety. The safety fuses of the charged holes shall be ignited in the presence of the agent, who shall see that all the fuses are properly ignited.

Careful count shall be kept by the agent and others of each blast as it explodes. In case all the charged bore holes have exploded, the agent shall inspect the site soon after the blast but in case of misfire, the agent shall inspect the site after half an hour and mark red crosses (X) over the holes

which have not exploded. During this interval of half an hour, nobody shall approach the misfired holes. No driller shall work near such bore until either of the following operations have been done by the agent for the misfired boreholes.

(a) The contractor's agent shall very carefully (when the tamping is of damp clay) extract the tamping with a wooden scraper and withdraw the fuse, primer and detonator.

(b) The holes shall be cleaned for 30 cm of tamping and its direction ascertained by placing a stick in the hole. Another hole shall then be drilled 15cm away and parallel to it. This hole shall be charged and fired. The misfired holes shall also explode along with the new one.

Before leaving the site of work, the agent of one shift shall inform the agent relieving him for the next shift, of any case of misfire and each such location shall be jointly inspected and the action to be taken in the matter shall be explained to the relieving agent.

The Engineer shall also be informed by the agent of all cases of misfires, their causes and steps taken in that connection.

1.3.9.3 General Precautions: For safety of persons, red flags shall be prominently displayed around the area where blasting operations are to be carried out. All the workers at site, except those who actually ignite the fuse, shall withdraw to a safe distance of at least 150 metres from the blasting site. Audio warning by blowing whistle shall be given before igniting the fuse.

Blasting work shall be done under careful supervision of a licensed blaster and trained personnel shall be employed. Blasting shall not be done within 100 metres of an existing structure, unless specifically permitted by the Engineer in writing. In such cases, the Authorised representative of the Engineer must be present to ensure that special precautions as may be prescribed by the Engineer and those stipulated by the licensing authority are taken and that necessary warning is given to the inhabitants.

All procedures and safety precautions for the use of explosives drilling and loading of explosives before and after shot firing and disposal of explosives shall be taken by the contractor as detailed in IS 4081, Safety code for blasting and related drilling operation.

1.3.9.4 Precautions against misfire : The safety fuse shall be cut in an oblique direction with a knife. All saw dust shall be cleared from inside of the detonator. This can be done by blowing down the detonator and tapping the open end. No tools shall be inserted into the detonator for this purpose.

If there is water present or if the bore hole is damp, the junction of the fuse and detonator shall be made water tight by means of tough grease or any other suitable material.

The detonator shall be inserted into the cartridge so that about one-third of the copper tube is left exposed outside the explosive. The safety fuse just above the detonator shall be securely tied in position in the cartridge. Water proof fuse only shall be used in the damp bore hole or when water is present in the bore hole.

If a misfire has been found to be due to defective fuse, detonator or dynamite, the entire consignment from which the fuse, detonator or dynamite was taken shall be got inspected by the Engineer or his authorised representative before resuming the blasting or returning the consignment.

1.4 EARTH WORK BY DEPARTMENTAL MATERIAL TRAINS:

Normally earthwork is not done by DMT these days.

1.5 EARTH FILLING IN FOUNDATION TRENCHES AND PLINTH, UNDER FLOORS AND BEHIND ABUTMENTS ETC.

1.5.1 Foundation Trenches : The space between the sides of the foundation trenches and the masonry is to be filled with sound impervious material such as moorum, chips, spawls, gravel or other sandy material well rammed in layers not exceeding 15 cm, each layer being watered, rammed and consolidated before the succeeding one is laid. Earth shall be rammed with iron rammers where feasible, and with the butt ends of crow bars / wooden ballies where rammers cannot be used. Earth used for filling shall be free from salts, organic or other foreign matter. All clods of earth shall be broken or removed.

1.5.1.1 Where there is likelihood of rain, the earth filling may closely follow the masonry until ground level is reached, but the contractor shall only do this after obtaining the written permission of the Engineer.

1.5.1.2 Where concrete foundations are brought up in reducing off-sets, it will be necessary to bring the earth filling up with the form walls but in such cases special care shall be taken that no earth is allowed to fall on the concrete surface, on which further concrete is to be laid.

1.5.2 Plinth filling or filling under floors: After allowing 7 days / 14 days setting time respectively for Cement / Lime masonry, filling in plinth or under floors shall be similarly done with earth in layers not exceeding 15 cm, watered and consolidated by ramming with iron rammers and with butt ends of crow bars / wooden ballies. Only sandy soil, free from salts, organic or other foreign matter and white ants shall be used for such filling. Where there is black cotton soil, this shall be removed to a depth of 60 cm as it is liable to absorb moisture and expand and thus ruin a floor. The top 30 cm immediately below or as shown in the drawings the floor shall be filled with sand or cinder. If earth of good quality fit for this filling is not available from earth generated by excavation for foundation etc, or from borrow pits from within the Railway land, good contractor's earth should be used.

1.5.2.1 To prevent future sinkage, and damage to the floor it is necessary, when convenient to do so, that the plinth area be flooded with water for minimum 3 days so as to enable the earth filling to consolidate thoroughly. In this case, however, the earth filling shall be allowed to dry and then rammed and consolidated, before the pucca flooring is laid.

1.5.2.2 In all fillings sufficient allowance shall be made for settlement of all materials and restoration of the surface to the required level.

1.5.2.3 The filling shall not be commenced until the recording of levels, measurements etc as maybe necessary in respect of the existing ground or of any work to be filled over or likely to be hidden by the filling has been completed and permission in writing has been given to the contractor by the Engineer to start the filling.

1.5.2.4 The finished level of the filling shall be kept to slope intended to be given to the floor.

1.5.3 Filling behind abutments etc. : Unless otherwise specified, the space next to the masonry at the back of all bridge abutments, wing walls and return walls is to be "Backed" or filled by hand packed graded coarse material such as boulders and cobbles, quarry rubbish, chips, spawls, hand packed dry rubble or other hard and drainable materials for a thickness of at least 60 cm. or to such thickness as may be shown in the drawings, or as directed by the Engineer with the smaller size material towards the back.

1.5.3.1 The space at the back of this packing is to be filled with granular material such as moorum, sand or sandy oil, well-watered and rammed in layers 15 cm or less thick. Under no circumstances is black cotton soil or any clayey or silty soil to be used for backing. Each layer shall have a slope of about 45^{o} towards the ground level, toe slope to commence from immediately behind the abutments. Compactions of the layers shall be done by vibratory plate compactors or as directed by the Engineer.

1.5.4 Dressing of surrounding ground : On the completion of a building, the ground all round up to a distance of 15m is to be carefully dressed, and when practicable, given a gentle slope outwards. This dressing will be paid for separately.

1.5.5 Use of earth from excavation : If the excavated earth from the foundations of a bridge is thrown up to form part of the guide bund, embankment or backing of a bridge, it is to be understood that the only items (over and above the rate for the excavation) to be paid for are any extra "Lift", "Lead" "Dressing" and "Compaction" which may be thus necessitated.

1.5.6 Filling of Trenches for Pipes etc. : The filling back of pipe-line trenches shall not be commenced until any testing as required to be done has been carried out and the pipe-line passed. The filling shall generally be done using the material excavated from the same trench. But any excavated rock used for filling back shall be mixed with finer material so as to fill up all the voids. In refilling, care shall be exercised to avoid damaging or disturbing the pipe line

or other work being covered up. The manner in which filling and consolidation are to be done shall, in other respects, be the same as laid down for foundation trenches. Where the trench carries a pipe-line or an arch barrel, sand or other stable soil approved by the Engineer shall be used upto a height of 15 cm above the top of the pipe or barrel. This height shall be increased to 30 cm in the case of trenches cut in rock. In case of sand filling as per drawing additional payment as per relevant item will be made.

1.5.7 Measurement : The measurement shall in all cases be of the space filled and all the hidden details required for the same shall be measured up before being filled over and deductions made accordingly. No deduction shall be made for shrinkage or subsidence, provided the Engineer is satisfied that the consolidation has been done properly, as specified in each case. In the filling for foundations and other trenches, any extra work done on account of over cuts, slips, etc. shall not be paid for.

1.5.8 Rates : The rate for each type of filling shall include the cost of all the operations as described above for each, except that in cases where the excavated earth available within the initial lead and lift is not adequate for the filling, the procurement of the extra earth required will be a matter of special agreement.

1.6 SHORING OR TIMBERING FOR TRENCHES

1.6.1 General : In case of deep trenches, exceeding 2 metres or where the soil is soft or slushy, the sides of trenches shall be prevented from collapsing by stepping, sloping and / or shoring or timbering as may be decided by the Engineer or the Authorized representative of the Engineer. Timbering shall be **"Close"** or **"Open"** depending on the nature of soil and the depth of the trench and the type of timbering shall be determined by the Authorised representative of the Engineer or the Engineer. It shall be the responsibility of the contractor to take all necessary steps to prevent the sides of trenches from collapsing. Guidance may be taken from IS 3764 for designing the shoring and strutting arrangements.

1.6.2 Close Timbering : Close timbering shall be done by completely covering the sides of the trench generally with short, upright members called 'polling boards'. These shall be 25 cm x 4cm section or as directed by the Engineer. The boards shall generally be placed in position vertically in pairs, one board on each side of cutting, and shall be kept apart by horizontal wallings of strong wood at 1.0 to 1.2m spacings, cross strutted with ballies or as directed by the Engineer. The length of the ballies shall depend upon the width of the trench. Typical sketch of close timbering is given in **Figure Nos. 1.5A & 1.5B.**

1.6.2.1 In case the soil is very soft and loose, the boards shall be placed horizontally against the sides of the excavation and supported by vertical wallings, which shall be strutted to similar timber pieces on the opposite fact of the trench. The lowest boards supporting the sides shall be taken into the ground. No portion of the vertical side of the trench shall remain exposed, so that earth is not liable to slip out.

1.6.2.2 The withdrawal of the timber shall be done very carefully to prevent the collapse of the trench. It shall be started at one end and proceed systematically to the other end. Concrete or masonry shall not be damaged in the removal of timber. Where planking and strutting are required to be left permanently in position as directed by the Engineer, extra payment will be made under the relevant schedule item. In cases where there is no such specific directive of the Engineer no claim shall be entertained for any timber, which cannot be withdrawn and is lost, damaged or buried.

1.6.3 Open Timbering : In case of open timbering, the entire side of the trench is not required to be covered. The vertical boards of 25 cm width shall be spaced sufficiently apart to leave unsupported strips of 50 cm average width. The detailed arrangement, sizes of the timber and the distances apart shall be subject to the approval of the Engineer. In all other respects, specifications for close timbering shall apply to open timbering. A typical sketch of open timbering is given in **Figure Nos. 1.5A & 1.5B.**

1.6.4 Measurements : The area of longitudinal section of the timbered trench shall be measured for the purpose of payment. This shall be the area of one side of the trench timbered on both sides. In case of basements, where the opposite sides, are not connected by struts but, each side is supported by slanting struts and toe supports, the measurements for timbering shall be taken for the area of all the walls supported by timbering. The dimensions shall be measured correct to a cm.

1.7 PUDDLE

1.7.1 Composition: Puddle shall consist of good adhesive and stiff clay containing nearly 20% sand by weight. So called 'Sodium Clays', containing sodium carbonate shall generally be preferred. If adequate quantity of sand is not present in the clay, suitable amount of sand may be mixed with the clay after it has been weathered and pulverised. The clay shall be free from roots, turf, shale and other injurious materials, and should be approved by the Engineer.

1.7.2 Preparation: The clay should be dry and exposed to the sun and pulverised with rammers. Additional sand if necessary shall be uniformly mixed with the powdered clay two days previous to that on which the clay is required for use. The clay and sand mixture shall be wetted and thoroughly worked up into a plastic homogeneous mass of the toughest consistency, in a pug mill or under men's feet.

1.7.3 Laying as soon as possible after it has been worked up into puddle it shall be deposited in place, spread in even layers 15 cm thick, each layer laid out to its full extent, rammed, trodden and if necessary, cross cut and made perfectly water-tight.

1.7.3.1 The puddle shall be carried in baskets or wheel-borrow as convenient. Each batch shall be well consolidated with rammers or trodden under feet until it is thoroughly integrated with the batch already in place. Stones, bricks, roots, grass, etc. shall not be allowed to remain in the puddle.

1.7.3.2 If at any time the puddle surface should become dry/hard or soft, it shall be excavated and removed from the work before another layer is laid. Puddle walls must be supported on each side by selected material.

1.7.4 Protection : All puddle after placing shall be protected from the strong rays of the sun by covering with wet gunny bags or mats.

1.7.4.1 Contractor's liability and maintenance : The contractor shall make good at his own expense any defect that may occur either in the puddle or in its junction with the ground or walls whether during the construction stage or during the period of maintenance.

1.8 MECHANICAL COMPACTION OF EARTHWORK

Earthwork for Railway Formation (Embankment and Cutting) shall be as per RDSO's Guidelines and Specifications for Design of Formation for Heavy Axle Load, Report No. RDSO/2007/GE: 0014, November 2009 and Guidelines For Earthwork in Railway Projects Guideline No. GE : G-1 July 2003 with latest correction slips.

1.8.1 Orders for compaction : Depending upon the height of the embankment the type of the soil, time available for completing the embankment, the importance of the line and other relevant factors such as axle load, permitting higher speeds within a limited time etc, the Engineer shall decide whether Mechanical compaction is to be done for the full or part height of the embankment.

1.8.2 Advantages of Compaction :

1.8.2.1 Compaction is the process of increasing the density of soil by mechanical means by packing the soil particles closer together with reduction of air voids and to obtain a homogeneous soil mass having improved soil properties. Compaction brings many desirable changes in the soil properties as follows:

a) Helps soils to acquire increase in strength in both bearing resistance and shear strength.

b) Reduces compressibility, thus minimizing uneven settlement during services.

c) Increased density and reduces permeability, thereby reducing susceptibility to change in moisture content.

d) Reduction in erodibility

e) Results in homogeneous uniform soil mass of known properties.

f) Reduction in frost susceptibility in cold regions.

1.8.3 Factors affecting Compaction in the field:

Compaction of a particular soil is affected by moisture content, compacting effort, type of roller etc as explained below:

(a) **Compacting Effort** : In modern construction projects, heavy compaction machinery is deployed to provide compaction energy. Types of machinery required are decided based on type of soil to be compacted. The method of compaction is primarily of four types viz kneading compaction, static compaction, dynamic or impact compaction and vibratory compaction. Different type of action is effective in different type of soils such as for cohesive soils, Sheep's foot rollers or pneumatic rollers provide the kneading action. Silty soil can be effectively compacted by Sheep's-foot roller / pneumatic roller or smooth wheel roller. For compacting sandy and gravelly soil, vibratory rollers are most effective. If granular soil has some fines both smooth wheeled and pneumatic rollers can be used.

(b) **Moisture Control :** Proper control of moisture content in soil is necessary for achieving desired density. Maximum density with minimum compacting effort can be achieved by compaction of soil near its OMC (Optimum Moisture Content). If natural moisture content of the soil is less than the OMC, calculated amount of water should be added with sprinkler attached to water tanker and mixed with soil by motor grader for uniform moisture content. When soil is too wet it is required to be dried by aeration to reach upto OMC.

(c) **Soil Type :**Type of soil has a great influence on its compaction characteristics. Normally, heavy clays, clays and silts offer higher resistance to compaction, whereas, sandy soils and coarse grained or gravelly soils are amenable for easy compaction. Coarse-grained soils yield higher densities in comparison to clay. A well-graded soil can be compacted to higher density.

(d) **Thickness of Layer :** Suitable thickness of soil of each layer is necessary to achieve uniform compaction. Layer thickness depends upon type of soil involved and type of roller, its weight and contact pressure of its drums. Normally, 200-300mm layer thickness is optimum in the field for achieving homogeneous compaction.

(e) **Number of Passes :** Density of soil will increase with the number of passes of roller but after optimum number of passes, further increase in density is insignificant for additional number of passes. For determination of optimum number of passes for given type or roller and optimum thickness of layer at a predetermined moisture content, a field trial for compaction is necessary which will be arranged by the Engineer for which the Contractor shall make all arrangements and bear the cost of test / tests as required.

1.8.4 Compaction procedure for Different soils

The embankments are constructed with locally available soil provided it fulfils the specified requirements. Procedure of compaction to be adopted will depend on the type of soil being used in construction. General guidelines to deal with compaction of various types of soils for attaining optimum dry density/

relative density at minimum effort, have been briefly given as under. The procedure to be adopted will be decided by the Engineer for strict adherence by the Contractor.

1.8.4.1 Compaction of Cohesion less gravely and Sandy soil

i) Sandy & gravely soils should be compacted with vibratory rollers. If fines are less in these types of soils, it can be compacted with minimum number of passes of vibratory rollers without strict control of moisture to achieve desired Relative Density. With higher percentage of fines, sandy and gravely soils need to be brought to OMC level to get effective compaction. Uniformly graded sand and gravel are difficult to be compacted. Top layer of sand and gravel remains loose in vibratory compaction. Therefore, in final pass the roller should move smoothly without vibration. Dry densities attained in field trials normally should be around MDD/ specified Relative Density as obtained from laboratory tests and should form the basis for specification and quality control.

ii) Poorly graded sand and gravel with Cu<2.0, should not be used in earthwork for the banks to safeguard against liquefaction under moving loads or especially due to earthquake tremor. Generally, fine sand is prone to liquefaction. This aspect should be specifically examined to prevent possibility of any liquefaction.

1.8.4.2 Compaction of Silty- Clayey Soils

Silty soil is a fine-grained soil. These can be plastic or non-plastic depending upon the clay content in it. Silts and fine sands with high water content have a tendency to undergo liquefaction under vibrating rolling due to the pore water pressure generated by mechanical work. Silty soils can be compacted satisfactorily near about OMC either with smooth rollers or vibratory rollers. Vibratory roller will give high degree of compaction and higher lift. Compaction of silty clays will have to be handled in a manner similar to clays.

1.8.4.3 Compaction of Clays

i) Water content plays very important role in compaction of clays. Main objective of compacting predominantly clays is to achieve uniform mass of soil with no voids between the lumps of clays. If moisture content is too high, roller tends to sink into the soil and if too low the chunks would not yield to rolling by rollers. Appropriate water content i.e. OMC of the soil is in the range of about plastic limit plus two percent. Sheep's-foot rollers are most effective in breaking the clods and filling large spaces.

ii) Thickness of layer should not be more than depth of feet of roller plus 50mm. Pad foot vibratory roller with drum module weight of 7 tonne (total static weight of 11 tons) for a lift thickness of 30 cm is found quite effective for compaction of clays. For better results, initial rolling with static pad foot roller followed by 15 tons vibratory roller can be tried.

iii) In case of such soils, the MDD and OMC as determined in the Laboratory may not be very relevant and therefore achievable MDD and practicable moisture content at which such soils can be compacted should be determined by conducting field trials for which the Contractor shall make all arrangements and bear the cost of field trials as required.

1.8.5 Selection of Compacting Equipment :

The performance of roller is dependent mainly on type of soil used in construction. Guidelines on selection of compacting equipment are given in **Annexure 1.2.** Vibratory rollers which can be used in static as well as dynamic mode with plain and pad drum, are now being manufactured by reputed Indian Companies also. Salient features of some of models are given in **Annexure 1.3**. The Contractor should get the Engineer's approval for the type of equipment to be deployed for compaction.

1.8.6 General aspects of Mechanical Compaction

a) The spreading of material in layers of desired thickness over the entire width of embankment should be done by mechanical means and finished by a motor grader. The motor grader blade shall have hydraulic control suitable for initial adjustment and maintain the same so as to achieve the slope and grade.

b) Thickness of layer is decided based on field compaction trials. However, as a good practice thickness of layer should be generally kept as 300mm for fill material and 250mm for blanket material in loose state before compaction.

c) If natural moisture content (NMC) of the soil is less than the OMC, calculated amount of water based on the difference between OMC and NMC and quantity of earthwork being done at a time, should be added with sprinkler attached to water tanker and mixed with soil by motor grader or by other means for obtaining uniform moisture content. When soil is too wet, it is required to be dried by aeration to reduce moisture content near to OMC. Efforts should be made to keep moisture content level of the soil in the range of OMC $\pm$ 2% at the time of compaction.

d) Fill shall be placed and compacted in layers of specified thickness. The rate of progress should be, as far as possible, uniform so that the work is completed to final level almost at the same time.

e) The rolling for compaction of fill material should commence from edges towards center with minimum overlap of 200mm between each run of the roller. In final pass, roller should simply move over the surface without vibration so that top surface is properly finished.

f) Extra bank width of 500mm on either side shall be rolled to ensure proper compaction at the edges. The extra soil would be cut and dressed to avoid any loose earth at the slopes. This should preferably be done with help of grade cutter. The earth so cut in final stages will not be paid but can be used at other places by the contractor.

g) At the end of the working day, fill material should not be left uncompacted. Care should be taken during rolling to provide suitable slope on toe of the bank to facilitate quick shedding of water and avoid ponding on formation.

h) During construction of formation, there may be rainfall to the extent that rain cuts may develop on the surface of formation due to erosion of soil. Care should be taken that these rain cuts are not allowed to develop wide and deep otherwise these locations will remain weak spots.

i) Top of the formation should be finished to cross slope of 1 in 30 from one end to other towards cess / drain in multiple lines and from center of formation to both sides in single line.

j) Once the top surface of the formation has been finished to proper slope and level, movement of material vehicle for transportation of ballast, sleepers etc. should be avoided since these movements will cause development of unevenness, ruts on the surface which will accumulate water and weaken the formation.

k) In conversion / doubling / rehabilitation projects, suitable benching of existing slope shall be done as provided for in the contract before new earthwork is taken up to provide proper bonding between old and new earthworks. It should be ensured that there is no humus material left on the benched slope. Care needs to be taken to avoid entry of rainwater into the formation from this weak junction, otherwise this would result in development of weak formation, slope failure, maintenance problem due to uneven settlement etc.

l) At locations where the water table is high and the fill soil is fine-grained, it may be desirable to provide a granular layer of about 30 cm thickness at the base, above subsoil across the full width of formation. This work will be carried out if directed by the Engineer for which extra rate will be paid.

1.8.7 Quality Control of Compacted Earth / Blanket layer

1.8.7.1 Compacted Earth : Degree of compaction of each layer of compacted soil should be ascertained by measurement of dry density / Relative Density of soil at locations selected in specified pattern. The method of sampling, frequency of tests, method of tests to be conducted and acceptance criteria to be adopted are as under.

a) Method of Sampling:

i) Various methods of selection of sample points for check of in-situ dry density are in vogue. The sampling adopted has to be such that effectiveness of proper compaction having been done for the entire area under consideration can be judged. For this, the Engineer will lay down in detail the method to be adopted in detail depending on site conditions and accordingly records of checks done are to be properly maintained. However, in absence of such procedure laid down, following method should be adopted.

Suggested Method of Sampling : For each layer, a minimum of one sample at a predetermined interval (in compliance with the requirement stated in next para) along the centre line of the alignment, would be taken in a staggered pattern so as to attain a minimum frequency of tests as given in sub para “b” below. For subsequent layer, the stagger should be such that the point of sampling does not fall vertically on the earlier sampling points of the layer immediately below. Additional sampling points can be taken, as considered necessary.

ii) In case of bank widening, sampling should be done at an interval of minimum 25 metres on widened side(s) of embankment.

b) Frequency of Tests :

Density check would be done for every layer of compacted fill / blanket material as per following minimum frequency:

i) At least one density check for every 200 sqm for blanket layers and top one metre of sub-grade.

ii) Atleast one density check for every 100 sqm for other than blanket and one metre of sub-grade.

In case of bridge approaches or special locations closer frequency may be adopted.

c) Method of In-situ Dry Density Measurements

Any of the following methods could be adopted as per the requirements at site. RDSO’s guidance may be taken for adoption of other methods such as by use of Nuclear Moisture Density gauge and Compact Meter fitted on rollers.

Method Of Measurement	Procedure Of Test	Parameters To Be Measured	Remarks
Sand Replace-ment Method	As per IS-2720 (Part 28) 1974	In-situ Dry Density Moisture content	May be adopted for all type of soils
Core Cutter Method	As per IS-2720 (Part 29) 1975	In-situ Dry Density Moisture content	In some of the coarse grained soils (with little fines) taking core cutter samples is difficult. In such cases, sand replacement method may be used for density measurement.

d) **Acceptance Criteria :**

i) Coarse grained soils which contains fines passing 75 micron IS Sieve, upto 5 percent should have the Density Index (Relative Density) a minimum of 70% as obtained in accordance with IS:2720 (Part-14)-1983.

ii) For other soils, field dry density should not be less than maximum attainable dry density obtained in field compaction trial. However, in field compaction trial, the maximum attainable dry density should not be less than 98% of MDD values as obtained by Heavy Compaction Test (IS 2720 (part 8) – 1983) in the laboratory.

In case, there are difficulties in achieving 98% of the MDD values as obtained by Laboratory test, in the field trials, the same may be relaxed upto 95% of MDD with the specific approval of the Engineer, recording reasons of such relaxation.

iii) During widening of bank in case of gauge conversion and rehabilitation of unstable formation, compaction of earthwork should be minimum 95% of MDD as obtained by Laboratory test as per Heavy Compaction Test (IS:2720 (part 8) – 1983) or 70% Relative Density for cohesion less soil (IS:2720 (Part 14) – 1983).

1.8.7.2 Formation Level : Finished top of sub-grade level may have variation from design level by $\pm$ 25 mm and finished top of blanket layer may also be permitted to have variation from design level by plus 25mm. The ballast should be placed only on level formation without ruts or low pockets.

1.8.7.3 Cross Slope : Cross slope should be within 1 in 28 to 1 in 30.

1.8.7.4 Side Slopes : Side slope should in no case be steeper than designed side slope. Provision of berm width should not be less than the designed width.

1.8.7.5 Formation Width : Formation width should not be less than the specified width.

1.9 BLANKETING

Note : Based on RDSO's RDSO's Guidelines and Specifications for Design of Formation for Heavy Axle Load, Report No. RDSO/2007/GE : 0014, November 2009 to which reference may be made for further details.

1.9.1 Scope : Where the drawings provide for a Blanket of coarse and granular material of thickness as shown therein over the full width of formation, the contractor shall arrange for the supply of the materials at site, spreading over the formation earthwork and for consolidation as detailed below. The thickness of blanketing layer shall be fixed in light of the Guidelines dated July 2005 of RDSO referred to in the Note above.

1.9.2 Sample for Material : The successful contractor should submit for approval by the Engineer samples of the Blanketing material in three wide mouth sealed

glass jars of a quantity of 0.035 Cum. each. The material to be used by the contractor for blanketing should strictly adhere to the quality of material as approved by the Engineer.

1.9.3 Specifications of Blanket Material

Blanket material produced in a plant should generally conform to following specifications :

a) It should be coarse, granular and well graded.

b) Skip graded material is not permitted.

c) Non -plastic fines (particles of size less than 75 micron) are limited maximum to 12%, whereas plastic fines are limited maximum to 5%.

d) The blanket material should have particle size distribution curve within one of the bands of enveloping curves shown in **Figure 1.6** or the percent passing of the material through each IS sieves should lie between the upper and lower limit of blanket material as given in the **Table 1.1**

e) The material should be well graded with C_u& C_c as under :

Uniformity coefficient, $C_u = D_{60}/D_{10} > 7$

Coefficient of curvature, $C_C = \frac{D_{30}^2}{D_{60} x D_{10}}$ between 1 and 3

f) Particle size distribution must follow one of the gradation ranges tabulated below.

Table 1.1 : Particle size distribution ranges for different grades of blanket material

SL	I.S. Sieve size	Percentage passing		
		Grade A	Grade B	Grade C
1.	40 mm	100	95-100	95-100
2.	20 mm	100	93-100	80-100
3.	10 mm	95-100	85-95	65-85
4.	4.75 mm	92-99	70-92	43-70
5.	2 mm	65-90	46-65	22-46
6.	600 micron	33-50	22-33	08-22
7.	425 micron	28-40	18-28	05-18

8.	212 micron	16-27	10-16	00-10
9.	75 micron	00-12	00-10	00-08

1.9.4 Selection of Blanket Material

Depending on the source of material, the blanket material can be categorized in the following categories:

- Natural material
- Machine manufactured material
  - Crushed material
  - Blended material

1.9.4.1 Proper survey of area close to projects needs to be carried out to identify suitable sources of blanket material required for the project. Aim of such source identification survey is to use naturally available material, or select alternatives of machine manufactured blanket material through crushing, blending or a combination, which is cheap and conforms to the specifications laid down.

1.9.4.2 The parent material of the blanket material so chosen should be chemically inactive and sturdy in normal working environment. Brickbats, factory slag, weak dissolvable stones like lime, shale, laterite etc. need not be selected as blanket material.

1.9.4.3 The choice of gradation as provided in 1.9.3 (f), above, may be exercised judiciously, based on the availability of material. It may be advisable to choose the grade A for finest subgrade soils (requiring 1.0m thick layer of blanket), and grade B or C for coarser subgrades (requiring less thickness of blanket).

1.9.5 Mechanical Production :

The Blanket can be produced by adopting either crushing methodology or Blending Methodology as described in “Appendix – C” of RDSO’s Guidelines and Specifications for Design of Formation for Heavy Axle Load, Report No. RDSO/2007/GE : 0014, November 2009 and to which reference can be made for any details. Crushing Methodology is resorted to in the event of non availability of natural source of blanket materials and involves crushing the rock / boulder to produce crushed blanket material. Blending methodology involves proper blending of two or more soils or in combination with soils crushed material like stone chips or quarry dust.

1.9.6 Quality Control on Blanket Material at Production site

1.9.6.1 The source of blanket material, detailed in para 1.9.4, needs to be identified based on tests & studies conducted and conformity of the material to the Specification as laid down in para 1.9.3.

1.9.6.2 It is desirable to have a check on quality of material at source/manufacturing point so that major deviation in quality of the material being sent to site does not exist. It would be in the interest of the supplier to have such tests conducted on his own to avoid any complication at a later stage.

1.9.6.3 The frequency of such test could be laid down by the engineer in-charge, if need be. In the absence of any other instructions, at least one test may be performed per day to check the particle size gradation at the point of loading into the trucks. However, the final acceptance of the blanket material should be at the site where it is laid, as per para 1.9.6.6.

1.9.6.4 The supplier/ Engineer may also lay down proforma for 'Incoming Material Register ' to be maintained at manufacturing point for having a control on utilization of different grades of material, especially where blending is done using crushed as well as local material.

1.9.6.5 Test for Quality : Blanket material should be tested as per IS: 2720 (Part 4) of a minimum of one test per 500 cum. or part thereof to plot particle size distribution curve, so as to assess its suitability. It would be necessary to carry out wet analysis to assess actual percentage of fines. To expedite testing work, dry sieve analysis may be carried out if variation between results of dry and wet analysis is not significant and adequate margin exists with respect to acceptance criteria. However, in such cases also, wet analysis has to be carried out at frequent interval to verify the extent of variation. In any situation, acceptance of blanket material would be based on wet analysis only. The sample for wet analysis should be prepared as per para 4.3 of IS: 2720 (Part 4).

1.9.6.6 Acceptance Criteria :

The material should generally conform to specification as given at para 1.9.3.

1.9.7 Transportation:

The blanket material should be transported wet after mixing water in order to achieve OMC, in tippers for direct unloading on formation.

1.9.8 Laying, Spreading and Compacting

1.9.8.1 The blanket material must be spread with a tractor mounted grader or a paver-finisher in layers of uniform thickness, before allowing compaction.

1.9.8.2 Compaction to specified levels of RD or percentage of MDD (para **1.9.10.3**) will be carried out through a number of passes of vibratory rollers of 100-120 kN static weight or equivalent capacity. A combination of vibrating rolling initially and static finishing rolling may be established through trials. Speed of roller shall not exceed 5 km/hr.

1.9.8.3 Proper control of moisture is required to optimize the compaction effort. Optimum moisture content may be established through Modified Proctor Apparatus (IS: 2720, part 8) and moisture may be added by sprinkling at the plant or at site as per the requirement.

1.9.8.4 Rolling is to be carried out in layers of not more than 300 mm each, following the same camber profile as provided in the subgrade layer and to be maintained upto the top layer.

1.9.8.5 No provision for uncompacted portion may be made on the edges of embankment. The sides may be hand rammed with a suitable rammer.

Note : The engineer should generally expect to get MDD above 2.1 gm/cc, and OMC in the range of 5-9%, as matter of guidance.

1.9.9 Quality Control Checks on Finished blanket work :

1.9.9.1 Degree of compaction of each layer of compacted blanket should be ascertained by measurement of dry density/Relative Density of soil at locations selected in specified pattern. The method of sampling, frequency of tests, method of tests to be conducted and acceptance criteria to be adopted are as under.

1.9.9.2 Method of Sampling :

(a) The sampling adopted has to be such that effectiveness of proper compaction having been done for the entire area under consideration can be judged. For this, the Engineer in-charge should lay down the method adopted in detail depending on site conditions and accordingly records of checks done are properly maintained. However, in absence of such procedure laid down, following method should be adopted:

(b) Suggested method of sampling : For each layer, a minimum of one sample at a predetermined interval (in compliance with the requirement stated in next para) along the centre line of the alignment would be taken. The checking points may be staggered to the extent possible.

(c) Frequency of Tests : Density check would be done for every layer of blanket material as per following minimum frequency:

At least one density check for every 200 sqm of blanket layer. (say, every 18 to 30 m for single line, or doubling work and every 12 to 16 m for a double line construction.)

1.9.9.3 Method of in-situ dry density measurements :

Any of the following methods could be adopted as per the requirements at site -

Method of measurement	Procedure of test	Parameters to be measured	Remarks
Sand Replacement Method	As per IS-2720 (Part 28) 1974	a) In-situ Dry b) Density c) Moisture content	May be adopted for all type of material
Core Cutter Method	As per IS-2720 (Part 29) 1975	a) In-situ Dry Density b) Moisture content	In some of the coarse-grained soils (with little fines) taking core cutter samples is difficult. In such cases, sand replacement method may be used for density measurement.
Nuclear Moisture Density Gauge	As issued by RDSO	a) Bulk density b) Moisture content c) Dry density d) Degree of compaction	May be used in consultation with RDSO
Compaction meters fitted on roller (On roller continuous compaction control)	As issued by RDSO	As issued by RDSO	May be used in consultation with RDSO

1.9.10 Acceptance Criteria :

1.9.10.1 1.9.1 to 1.9.4 above.

1.9.10.2 The blanket material, which contains fines passing 75 micron IS Sieve, upto 5 percent should have the Density Index (Relative Density) a minimum of 70% as obtained in accordance with IS: 2720 (Part 14) – 1983.

1.9.10.3 For other materials, field dry density should not be less than maximum attainable dry density obtained in field compaction trial. However, in field compaction trial, the maximum attainable dry density should not be less than 98% of MDD values as obtained by Heavy Compaction Test (IS: 2720 (part 8) – 1983) in the laboratory. In case, there are difficulties in achieving 98% of the MDD values as obtained by Laboratory test, in the field trials, the same may be relaxed upto 95% of MDD with the specific approval of Chief Engineer, recording reasons of such relaxation.

1.9.10.4 During widening of bank in case of gauge conversion and rehabilitation of unstable formation, compaction of blanket layer should be minimum 95% of MDD as obtained by Laboratory test as per Heavy Compaction Test (IS: 2720 (part 8) – 1983) or 70% Relative Density for cohesion less soil (IS: 2720 (Part 14) – 1983).

1.9.11 Measurement :

1.9.11.1 Measurement of blanket material should be done on the basis of finished cross section after the material and workmanship have been accepted as per the above criteria. No deduction is to be made towards voids.

1.9.11.2 In very rare cases, where it is not possible to take blanket material on finished subgrade, measurement may be done on the basis of stack measurement with the permission of Chief Engineer in-charge. It may be necessary to frame different schedule items for different methods of measurement. There should be no occasion to change the method of measurement unless specifically provided for in the tender documents duly approved by competent authority.

1.9.11.3 Method of measurement in case of stack measurement may be the same as in case of ballast incorporated in "Specification for track ballast-1999".

1.9.11.4 It is advisable to tally the quantity and quality measured at site with the ' Incoming Materials Register' maintained at plant (para 1.9.6.4) as a means of double check.

1.10SPECIFICATIONS OF BIAXIAL GEOGRIDS FOR TRACKBED STABILIZATION

Biaxial Geogrids of Punched & oriented type with large aperture with below mentioned specifications are to be used for track bed stabilization application.

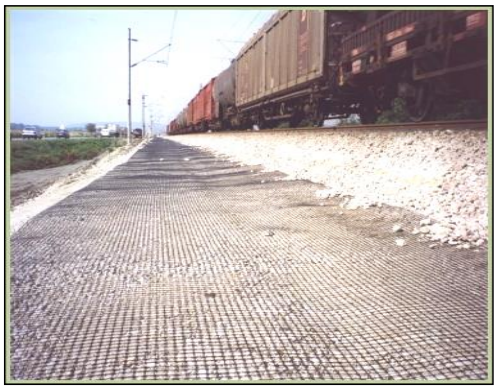
Biaxial Geogrids shall be manufactured from carefully selected polypropylene (PP). Grade of PP used shall in manufacturing of Geogrids shall combine optimum values of strength, stiffness, toughness and durability. Biaxial Geogrids shall be made by extruding a sheet of PP to very precise tolerances, punching an accurate pattern of holes, then stretching the sheet under controlled temperature, firstly in longitudinal direction, then in transverse direction. Process shall create a geogrid with square or almost square apertures by stretching in two orthogonal directions.

The polymers long chain molecules shall be orientated in the direction of stretching resulting in a dramatic increase in both strength and stiffness. This orientation shall pass through both the narrower ribs and the thicker nodes. The resulting product shall be monolithic grid with square edged ribs and integral junctions which possesses both geometrical and molecular symmetry; critical for consistency in manufacture and efficient load transfer in service.

The geogrid shall be supplied in standard width of 3.8m and roll length of minimum 40m.

SL	Property	Test Method	Values	Testing Facilities At
	General Properties :			
1.	Polymer	Polypropylene / HDPE or similar polymer		IIT-Chennai, IIT-Delhi, IIT-Bombay, BTRA-Mumbai, BICS-Hyderabad, BTTG-Ahmedabad, SASMIRA-Mumbai, CBRI-Roorkee, CIPET-Chennai
2.	Carbon Black	BS 2782 Part-4 Method 452B:1993	2% (min.)	
3.	Mass Per Unit Area	IS:14716 / ASTM D : 3776	320 g/m^2 (min.)	IIT-Chennai, IIT-Delhi, IIT-Bombay, BTRA-Mumbai, BICS-Hyderabad, BTTG-Ahmedabad, SASMIRA-Mumbai, CBRI-Roorkee
4.	Aperture Size	Square opening of suitable size with tolerance of ±10% : Size of 60mm to 70mm at the interface of ballast & blanket, i.e. for ballast reinforcement application, such that effective interlocking takes place with existing ballast particles.		
5.	Rib Profile & Thickness	Rectangular with 1.5mm rib depth (min.)		
6.	Roll Width	3.8m to 4.0m, as per site requirement and width attachment to BCM		Not Applicable
7.	Roll Length	40m to 50m *(However, it has to be ensured that final roll dia does not exceed 350mm or else geo-grids may get struck underneath the sleepers during installation on existing tracks)*		Not Applicable
	Mechanical Properties :			
8.	Ultimate Tensile Strength (CD & MD)	IS:13162 Part-5 & IS:13325 And ASTM D 6637/ BS EN ISO 10319:1996	30 kN/m (min.)	IIT-Chennai, IIT-Delhi, IIT-Bombay, BTRA-Mumbai, BICS-Hyderabad, BTTG-Ahmedabad, SASMIRA-Mumbai, CBRI-Roorkee
9.	Strain at Ultimate Tensile Strength (CD & MD)		8% To 12%	
10.	Load at 5% Strain (CD & MD)		21.0 kN/m (min.)	

11.	Junction Efficiency (CD & MD)	GRI-GG2-87 and GRI-GG1-87	95 %	IIT-Chennai, IIT-Delhi, IIT-Bombay, BTRA-Mumbai, BICS-Hyderabad, BTTG-Ahmedabad, CBRI-Roorkee
12.	Radial Stiffness at low strain, (@ 0.5% strain)	ISO 10319:1996	350 kN/m (min.)	IIT-Chennai, IIT-Delhi, IIT-Bombay, BTRA-Mumbai, BICS-Hyderabad, BTTG-Ahmedabad, SASMIRA-Mumbai, CBRI-Roorkee
13.	Aperture Stability	U.S. Army Corps of Engineers Methodology for measurement of Torsional Rigidity	3.5 Kg-cm/deg (min.)	BICS-Hyderabad, BTTG-Ahmedabad, Tensar – UK
14.	Resistance to Installation Damage	BS 8006:1995 & ISO 10319:1996	> 90 %	IIT-Chennai, IIT-Delhi, IIT-Bombay, BICS-Hyderabad, BTTG-Ahmedabad, CBRI-Roorkee
15.	Resistance to Chemical Degradation	EPA 9090	100 %	IIT-Chennai, IIT-Delhi, IIT-Bombay, BTRA-Mumbai, BICS-Hyderabad, BTTG-Ahmedabad, SASMIRA-Mumbai, CBRI-Roorkee, CIPET-Chennai
16.	Resistance to UV Light Weathering	ASTM D4355	100 %	





1.10.1 Installation Methodology

The formation shall be prepared as per Indian Railway standards. It shall be free from stumps, stones or other large protrusions which could cause damage to the grids.

Biaxial Geogrids shall be placed over the formation just below the ballast.

Adjacent rolls are secured along both the longitudinal and transverse edges by forming 300mm overlaps. Ballast must be placed over Geogrid so that it is able to fully interlock with the grid to ensure continuity of strength between adjacent rolls.

1.11 WOVEN GEO-TEXTILE AS SEPERATOR TO SUBGRADE AND BLANKET LAYER

The geotextile shall be made from polypropylene multifilament yarns, woven together into a stable fabric structure with a superior combination of mechanical and hydraulic properties. Finished product shall have excellent resistance to biological and chemical environments normally found in soils and shall be stable against short-term exposure to ultraviolet radiation.

The woven geotextile shall conform to property values listed below :

Specifications of Multifilament Woven Geo-textile

SL	Property		Test Method	Value (MARV)
I	**Polymer Composition, Structure and Physical Properties**			
1	Polymer		Polypropylene	
2	Structure		Woven with multifilament yarn in both warp and weft directions	
3	Mass per unit area		ASTM D 5261	240 g/m^2
II	**Mechanical Properties**			
1	Tensile strength	Warp	IS 1969	55 kN/m
		Weft		40 kN/m
2	Elongation at specified Tensile Strength	Warp		25 %
		Weft		25 %
3	Trapezoid tearing strength	Warp	ASTM D 4533	1100 N
		Weft		750 N

4	Puncture strength	ASTM D 4833	600 N
III	**Hydraulic Properties**		
1	Apparent opening size	ASTM D 4751	150 microns
2	Water flow rate normal to the plane	ASTM D 4491	32 l/m^2/s
Roll Dimensions		Standard roll length : 100m, Standard roll width : 5m	

1. Values listed are minimum average roll values except for II-2 and III-1, which are maximum average roll values.

2. The elongations reported are the actual fabric elongations at the specified tensile strength measured over a gauge length of 100mm marked at the center of specimen.

3. Roll length and Roll width may vary as per requirement.





1.11.1 Installation of Woven Geotextile as Separator

The woven geotextile shall be laid directly on the site, having removed major protrusions such as rocks and bush stumps and also having filled local hollows and depressions with the approved fill.

The geotextile rolls of specified width shall be laid in the longitudinal direction (parallel to the track) on the prepared subgrade. A 300mm overlap shall be provided between any joint of two geotextile rolls (transversely or longitudinally).

After laying the geotextile, first layer of blanket layer as per drawing is to be constructed and compacted.

1.12 Jute Geotextile

Jute Geotextile improves performance of soil. It imparts strength to soil by not allowing soil particles to migrate on one hand and by easing out water through

its pores on the other. Jute Geotextile is capable of performing functions of separating drainage and initial reinforcement.

The application of Jute Geotextile in slopes of Railway embankment is to be done in accordance with RDSO‘s guidelines for application of jute geotextile in Railway embankments and hill slopes vide RDSO‘s report no. RDSO/2007/GE:G-0008 or its subsequent versions including earth work and fixing arrangement.

The guidelines for application of jute geotextile for Rain water erosion control in road & Railway embankment and hill slopes have also been issued by Bureau of Indian Standard (BIS) vide (IS-14986-2001) and woven geotextile Specifications (IS-14715:2000 under revision), these may be referred to for further guidance and application.

Tests

The sample of jute geotextile may be got tested at Institute of Jute Technology (IJT)

Kolkata or Indian Jute Industries Research Association (IJIRA) or any authorized jute testing laboratory.

ANNEXURE 1.1

EXTRACTS FROM THE EXPLOSIVES RULES, 1983

4. **Safety distance categories of explosives**

(1) Explosives are divided into tour categories according to the risks which they present when initiated, namely—

I. Category X — those explosives which have a fire or a slight explosion risk or both but the effect of which will be local.
II. Category Y — Those explosives which have a mass fire risk or a moderate explosion risk, but not the risk of mass explosion.
III. Category Z — Those explosives which have a mass explosion risk and major missile effect.
IV. Category ZZ. — Those explosives which have a mass explosion risk and minor missile effect.

(2) If any question arises as to whether any explosive belongs to Category X, Category Y, Category Z or Category 22, the matter shall be referred to the Chief Controller whose decision shall be final.

General Provisions

7. Restriction on delivery and dispatch of explosives —

(1) No person shall deliver or dispatch any explosive to anyone other than a person who —

(a) is the holder of a licence, to possess the explosives or the agent of a holder of such a licence duly authorised by him in writing in this behalf; or

(b) is entitled under these rules to possess the explosives without a licence.

(2) The explosives so delivered or dispatched shall in no case exceed the quantity which the person to whom they are delivered or dispatched is authorised to possess with or without a licence under these rules.

(3) (i) No person shall receive explosives from any person other than the holder of a licence granted under these rules.

(ii) No person shall receive from or transfer explosives to any person for a temporary storage or safe custody in a licensed premises, unless prior approval is obtained from the Chief Controller.

11. Competent person to be Incharge of operations — Every person holding or acting under a licence granted under these rules shall, whenever explosives are loaded, unloaded or handled, depute a competent person experienced in the handling of explosives to be present at and to conduct the operations in accordance with these rules.

12. Precautions to be observed in handling explosives— (1) The floor of any place or any carriage or vessel in which any explosive is or is to be laid and the ground gangway, decks and other places over which the explosive is to be conveyed during loading or unloading shall be —

(i) carefully examined to ensure that there is nothing thereon in contravention of these rules or likely to endanger the safety of the consignment;

(ii) thoroughly cleaned and swept before and after use,

(2) The packages containing the explosives shall not be thrown or dropped down or rolled or pulled along the ground or floor but shall be passed from hand to hand and carefully deposited and stored.

(3) Where a package is to be slung**,** due precaution shall be taken to slung it in such a manner as effectively to prevent the possibility of a fall**.**

(4) After the handling of explosives has commenced, the operations shall proceed with due diligence and without unnecessary stoppage.

13. Restriction on handling of explosives after sunset — No person shall handle or cause to be handled any explosive between the hours of sunset and sunrise:

Provided that nothing in this rule shall apply to handling of explosives during the dark hours if proper illumination is provided in the area and the place is guarded,

14. Prohibition of smoking, fires, lights and dangerous substances — No person shall smoke, and no fires, lights or articles or substances of a flammable nature or liable to spontaneous ignition, or to cause or communicate fire or explosion such as acids, petroleum, carbide of calcium, compressed gases or such other hazardous substances, shall be allowed —

(a) at any time within 15 metres from a place where an explosive is stored; or

(b) at any place where an explosive is handled, during transport, one hour before and during such handling:

Provided that nothing in this rule shall apply to the use on a ship of —

(i) an engine room fire, if such fire has been previously carefully banked up or

(ii) any artificial light or ship's signal lights or of a type approved in writing by the Chief Controller in areas outside port limits and by the Conservator of the Port within port limits.

15. Prohibition of matches etc. — No person on, in, or near any place where explosives are stored or handled or on any carriage conveying explosives shall —

(a) have in his possession any matches, fuses or other appliances for producing ignition or explosion or any knives or other articles made of iron or steel; or

(b) wear boots or shoes with iron nails or shod or strengthened with iron, unless such boots or shoes are covered with leather, rubber, felt or other material, in the form overshoes or other.

41. Protection from fire or explosion —

(1) No carriage or aircraft or vessel shall be used for transporting explosives unless all iron or steel therein with which a package containing any explosive is likely to come in contact is effectually covered with lead, leather, wood, cloth or other suitable material.

(2) Where the weight of the explosives transported in any carriage exceeds 1000 kg, they shall be placed in the interior of the carriage which shall be enclosed

on all sides with wood or metal so as effectually to protect the explosives from communication of fire and the carriage shall be locked.

(3) Where the weight of explosives transported in any vessel exceeds 1000 kg. they shall be placed in the hold of the vessel which shall have a closed deck and closely fitting hatches and double water-tight bulk heads shall be provided at each end of the hold where the explosives are stowed and the hatches shall be locked.

(4) Where the explosives carried in carriage or vessel do not exceed 1000 kg. in weight, the explosives shall, unless they are conveyed in the manner specified in sub-rule (2) or sub-rule (3), as the case may be, be completely covered with fireproof cloth tarpaulin or any other suitable material as effectually to protect the explosives from communication of fire.

(5) All doors, hatches and coverings of every compartments or hold containing explosives in or on any carriage or vessel shall be kept closed and secured except when explosives are being loaded or unloaded into**,** onto or from it.

(6) When explosives are being carried in or on a carriage or aircraft or vessel, they shall be kept away from anything whether in the carriage or vessel or elsewhere that would be liable to cause them to ignite or explode.

42. Delay in transit to be avoided — If the quantity of explosives transported in any carriage or vessel exceeds 2.5 kg**,** the person or persons in charge of such carriage of vessel shall not stop or delay at any place for a longer time than may be reasonably necessary, nor stop unnecessarily at any place where such stopping would be attended with danger to public.

44. **Small quantities of fireworksexempted** —Nothing contained in Rules 35, 40 and 41 shall apply to the transport of manufactured fireworks in the custody of a person entitled to possess them without a licence under Rule 14 provided that not more than 2.5 kg of manufactured fireworks, securely packed, shall be so transported in any motor vehicle licensed for conveyance of more than six passengers.

113. Licence for possession, sale and use —

(1) No person shall possess, sell or use any explosive except under and in accordance with a licence granted under these rules.

(2) The licensee shall be responsible for all operations in connection with the possession, sale or use of explosives which may be conducted in the premises covered by the licence.

114. No licence needed for possession and sale in certain cases -

(l) not withstanding anything contained in Rule 113, no licence shall be necessary for the possession.

(a) of any explosive by a carrier or other person for the purpose of (transport, when the same is being kept or transported in accordance with the provisions of Chapter IV regulating transport of such explosives: or

(b) by any person of manufactured fireworks in any quantity not exceeding 25 kg. Provided that the fireworks -

(i) are obtained and intended by such person for immediate use and not for sale and are possessed by him for a period not exceeding 14 days; and

(ii) are kept in substantial receptacle which is exclusively appropriated to the keeping of explosives and is closed and secured so as to prevent unauthorised person from having access to the explosives; or

(c) by any person for his own private use and not for sale of gunpowder not exceeding 5 kg and 50 metres of safety fuse for blasting in any State, other than Bihar, Kerala, Tamil Nadu and West Bengal, and of small arm nitre-compound not exceeding 5 kg except in the State of Kerala and Tamil Nadu;

(d) by Railway Administration for flare lights or other explosives for its own use and not for sale to any other person by transfer or otherwise for maintaining railways, tracks, tunnels, provided that the provisions of the Act and these rules or otherwise complied with;

(e) of any explosive, which is not for sale and is required solely for the navigation of aircraft, when kept in an aircraft for use | therein, or for distribution to other aircraft or to aerodromes or at an aerodrome for use there or for distribution to aircraft or to other aerodromes, provided that the maximum quantity so possessed shall not exceed 25 kg when carried in an aircraft and 50 kg, when kept at an aerodrome;

(f) and sale from a shop of am forces (an explosive of Class 7 and division 2) in quantity not exceeding12.5 kg, Provided that in respect of clauses (b) and (c) the Central Government may prohibit the possession of any explosive or prescribe any conditions under which the explosives can be possessed without a licence when considered necessary for the security of public peace.

(2) Notwithstanding anything contained in Rule 113, no licence shall be necessary for the sale of such explosives manufactured by the Armed Forces of the Union and Ordnance Factories or other establishment of such Forces as are sold or delivered to any person who is in possession of a valid licence issued under these rules for the class and quantity of the explosives so sold or delivered.

116. Protection from lightning —

(1) Every magazine shall have attached thereto one or more efficient lightning, conductors designed and erected in accordance with the specification laid down in Indian Standard Specification No. 2309 as amended from time to time.

(2) The connections to various parts of earth resistance of the lightning conductor terminal on the building to the earth shall be tested at least once in every year by a qualified electrical engineer or any other competent person holding a certificate of competency in this behalf from the State Electricity Department. A certificate showing the results of such test and the date of the last test shall be hung up in conspicuous place in the building-

117. Precautions during thunderstorm - Whenever a thunderstorm appears to be imminent in the vicinity of a magazine or store house every person engaged In or about such magazine or store house shall be withdrawn to a safe distance from such magazine and store house and the magazine and the store house shall be kept closed and locked until the thunderstorm has ceased or the threat of it has passed.

119. **Maintenance of records** — Every person holding a licence granted under these rules for possession, sale or use of explosives shall maintain records in the prescribed Forms and shall produce such records on demand to an inspecting officer.

120. Repairing of licensed magazine or store house — Before repairs are done to any magazine or store house or part thereof used for storage of explosives, that magazine or Store house shall be cleaned by removal of all explosives and by thorough washing.

122. Premises to be kept locked —

(1) Any licensed magazine or store house shall be kept securely closed or locked at all times except when goods, are being placed in or taken from it or when it must be kept open for some other purpose in connection with the management of such premises.

(2) The keys of the licensed magazine shall, at all times be kept secured in license's, own custody or of his authorised agent and shall be produced for opening the magazine or store house whenever so required by an inspecting officer. The name and address of the person with whom the keys will be kept shall be intimated to the licensing authority and the controller of Explosives having Jurisdiction.

123. Guards to be provided —

(1) The licensee shall at his own expenses provide for round the clock safe custody of the magazine or store house a guard which shall be of such strength as the District Authority may consider it to be sufficient.

(2) The licensee**,** shall provide a shelter for the watchman on duty near the magazine or store house,

124. Repacking or opening of packages —

(1) No packages containing explosives shall be opened in magazine or store house.

(2) Repacking of explosives shall be done**,** where the necessary in an approved open sided shed having smoothly finished cemented floor at a distance as approved by licensing authority**.**

125. Explosives not **to be kept in damaged boxes —** The licensee of every magazine or store house shall ensure that the explosives are always kept in their original outer package. In case the outer package gets damaged so that the explosives contained therein cannot be stored or transported, such explosives shall be repacked only after the same are examined by a Controller of Explosives.

126. Storage of explosives In excess of licensed quantity —

(1) The quantity of any kind of explosives kept in any licensed magazine or store house shall not exceed the quantity entered in the licence against such kind of explosives,

(2) Notwithstanding anything contained in sub-rule (1), the Chief Controller may issue a permit, on payment of the prescribed fee to a holder of licence in Form 22 and such holders of licence in Form 21 who also have licence in Form 20 (for the class of explosives) for keeping of explosives in excess of the licensed quantity entered in the licence when he is satisfied that such excess storage is essential and unavoidable due to circumstances beyond the control of the licensee. The validity of such permit shall not exceed 30 days

(i) the licensing authority shall not issue any permit for excess storage of explosives if the magazine or store house cannot observe the requisite safety distances for the total quantity entered in the licence plus the additional quantity of the explosives so permitted.

(ii) no permit for storage of explosives in excess of the licensed capacity shall be granted if the specified distances on the licence around the magazine or store house or the floor space in the specified rooms for storage of each kind of explosives is not adequate for keeping of the total quantity of explosives, including the excess quantity applied for.

(iii) The licensing authority may refuse to grant a permit for excess storage of explosives if such excess storage is of a repeated nature.

(iv) No explosive in excess of the licensed quantity shall be stored in the magazine or store house unless a permit in this behalf is obtained from the licensing authority by a letter or telegram.

129. Storage in a magazine — An explosive if stored in a magazine shall be stored either in Mode 'A' or Mode 'B' magazine as specified in Schedule VII.

130. Restriction, on use of Mode 'B' magazine — Mode 'B' magazine shall be used for storage of explosive required (or use for a temporary period for a specific purpose and such magazine shall not be used for sale of explosives.

131. Mound of magazines — A substantial mound shall be provided near a magazine, if so required by the licensing authority. Such mound shall be of a type approved by the licensing authority and shall always be maintained in good condition to provide effective protection.

135. Construction of premises :

(1) All explosives on the premises shall be kept in a brick, stone or concrete building which is closed and secured so as to prevent unauthorized person from having access thereto.

(2) The premises shall have a floor area of minimum nine square metres.

(3) The premises shall have independent entry and exit.

(4) If the premises are situated in a building used for other purposes also, such premises shall not be situated under a staircase and shall be so located as not to obstruct any passage in from or to the building in case of fire or accident.

(5) The premises shall be situated at ground level.

ANNEXURE1.2

Typical Compaction Characteristics for natural soils, rocks and artificial materials (Ref: BS: 6031-1981, Table 4)

Material	Major Divisions	Subgroups	Suitable type of compaction plant	Maximum number of passes for satisfactory compaction	Maximum thickness of compacted layer (mm)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rock-like materials	Natural rocks	All rock fill (except chalk)	Heavy vibratory roller not less than 180 kg per 100mm of roll Grid roller not less 180 kg per 100mm of roll	4 to 12	500 to 1500 depending on plant used	If well graded or easily broken down then this can be classified as a coarse-grained soil for the purpose of compaction. The maximum diameter of the rock fragment should not exceed two third of the later thickness.
		Chalk	See remarks	3	500	This material can be very sensitive to weight and operation of compacting effort and spreading plant. Less compactive effort is needed than with other rocks
Artificial	Waste material	Burnt and unburnt colliery shale	Vibratory roller Smooth wheeled roller Self-propelled tamping roller	4 to 12 depending on weight of plant	300	
		Pulverized fuel ash	Vibratory roller Self - propelled tamping roller Smooth wheeled roller Pneumatic tired roller			Includes lagoon and furnace bottom ash
		Broken concrete, bricks, steel works, slag, etc.	Heavy vibratory roller Self-propelled tamping roller Smooth wheeled roller			Non-processed sulphide brick slag should be use with caution

Coarse-grained soils	Gravel sand, gravelly soils	Well graded gravel and gravel/ sand mixture: little or no fines Well graded gravel / sand mixtures with excellent clay binder Uniform gravel: little or no fines Poorly graded grave and gravel / sand mixtures: little or no fines. Gravel with excess fines, silty gravel, clayey gravel, poorly graded gravel / sand / clay mixtures	Grid roller over 540 kg per 100mm of roll. Pneumatic tired over 2000 kg per wheel Vibratory plate compactor over 1100 kg /Sq.m. of base plate Smooth wheel roller Vibratory roller Vibrorammer Self-propelled temping roller	3 to 12 depending on type of plant	75 to 275 depending on type of plant	
	Sand and sandy soils	Well graded gravel and gravel/ sand mixture: little or no fines Well graded gravel / sand mixtures with excellent clay binder Uniform gravel: little or no fines Poorly graded grave and gravel / sand mixtures: little or no fines. Gravel with excess fines				
	Uniform sands and gravels	Uniform gravels; little or no fines. Uniform sands; little or no fines. Poorly graded sands; little or no fines. Sands with fines, silty sands, clayey sands, poorly graded sand / clay mixtures	Smooth wheeled roller below 500 kg per 100mm of roll. Grid roller below 540 kgper 100mm of rolling. Pneumatic tired roller below 1500 kg per wheel. Vibratory roller. Vibrating plate	3 to 16 depending on type of plant	75 to 300 depending on type of plant	

			compactor Vibro-tamper			
Fines soils	Soils having low plasticity	Silts (inorganic) and very fine sands, rock flour, silty or clayey fine sands with slight plasticity Clayey silts (inorganic) Organic silts of low plasticity	Sheep-foot roller Smooth wheeled roller Pneumatic tired roller Vibratory roller over 70 kg per 100 mm of roll Vibratory plate compactor over 1400 kgs./sqm. of base plate Vibro tamper Power rammer	4 to 8 depending on type of plant	100 to 450 depending on type of plant	If water content is low, it may be preferable to use vibratory roller. Sheep- foot rollers are best suited to soils at water contents below their plastic limit.
	Soils having medium plasticity	Silty and sandy clays (inorganic) of medium plasticity Clays (inorganic) of medium plasticity				Generally unsuitable for Earthworks
		Organic clays of medium plasticity				
	Soils having high plasticity	Micaceous or diatomaceous fine sandy and silty soils, plastic silts Clay (inorganic) of high plasticity, fat clays				Should only be used when circumstances are favorable
		Organic clays of high plasticity				Should not be used for earthworks

Note: The information in this table should be taken only as a general guide. Field trials for compaction should be conducted for working out optimum layer thickness and number of roller passes for the type of compaction equipment being used. Compaction of mixed soils should be based on that subgrade requiring most compactive effort.

ANNEXURE 1.3

SALIENT FEATURES OF VIBRATORY ROLLERS MANUFACTURED IN INDIA

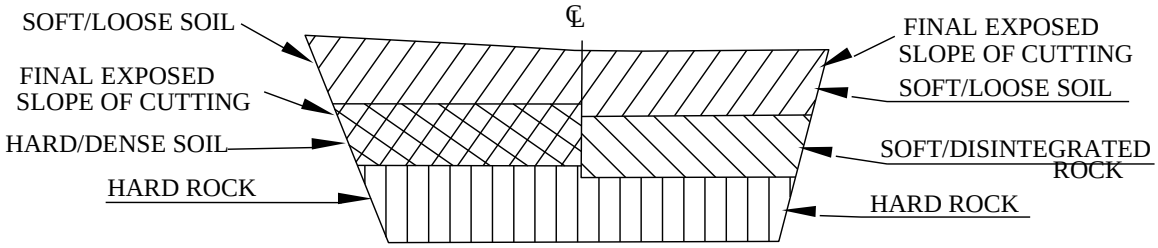
MAKE	MODEL No.	Operating Weight (Kg.)	Drum Detail			Normal Amplitude (Mm)	Vibrating Frequency (Hz)	REMARKS
			DRUM WIDTH (Mm)	AXLE LOAD (T)				
				Front	Rear			
ESCORTS	EC 5250 STD	9350	2130	5.050	4.300	1.72	30	
		9550	2130	5.250	4.300	1.72	30	It is used for better gradeability
		10500	2130	6.650	4.300	1.53	30	It is used for better gradeability& breaking clods
		9300	1680	4.650	4.300	1.27/0.75	0-30/42	
GREAVES BOMAG	BW 212-D-2 (2A)	10424	2100	6.463	3.961	1.67	40/31	It is used for better gradeability
	BW 212-PD-2	10879	2100	6.201	4.678	1.5	30	It is used for better gradeability&breaking clods
L&T	1104 STD	11150	2330	5.770	5.380	1.6/0.6	28/36	
	1104 D	11150	2330	5.900	5.535	1.6/0.6	28/36	It is used for better gradeability
	1104 PD	11835	2330	6.300	5.535	1.6	28	It is used for better gradeability& breaking clods
INGERSOLLRAND	ISD-100 STD	10740	2135	6.210	4.535	1.7	0-30	
	ISD-100 D	10830	2135	6.295	4.535	1.7	0-30	It is used for better gradeability
	ISD-100F	11740	2135	7.205	4.535	1.41	0-30	

NOTE: The rollers indicated above can also be used in Static mode. The list includes rollers manufactured by reported firms only.

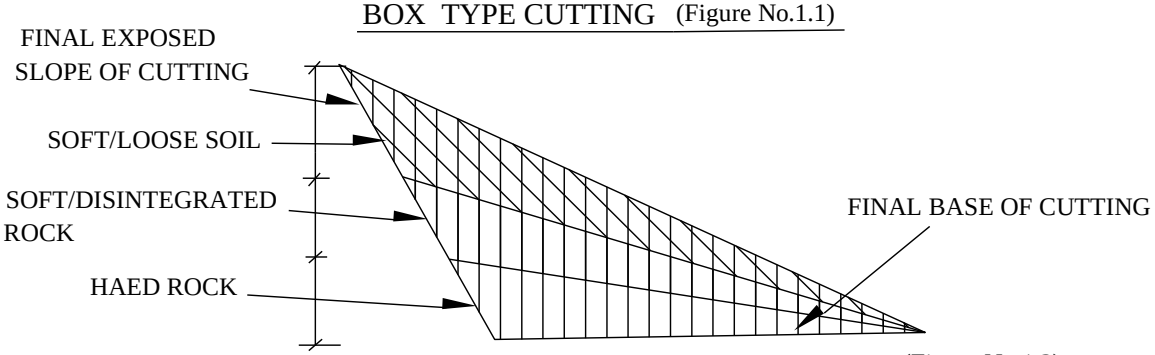
LEGEND : STD- Standard Type, D- Drum Type & PD - Pads + Drum Type

SKETCHES SHOWING MANNER OF COMPUTATION OF QUANTITIES OF VARIOUS CLASSIFICATIONS OF SOIL

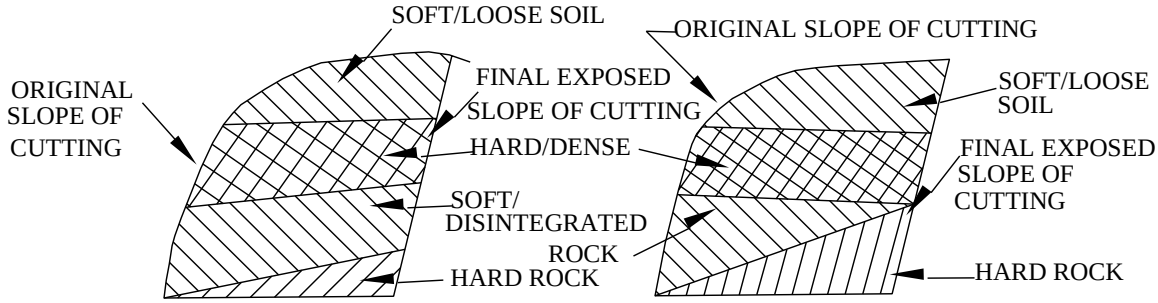
(FIG. NOS.1.1 TO1.4)



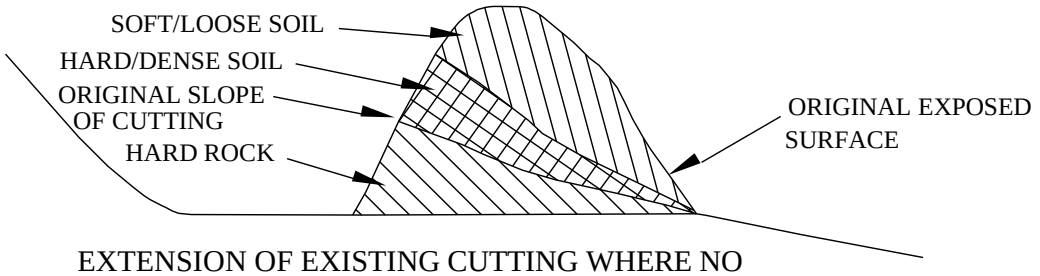
BOX TYPE CUTTING (Figure No.1.1)



ONE SIDED CUTTING IN A TRANSVERSE SLOPING GROUND (Figure No.1.2)



WIDENING OF CUTTING WHERE THE EXISTING CUTTING SLOPE DISAPPEARS AND A FRESH SLOPE ARISES (Figure No.1.3)



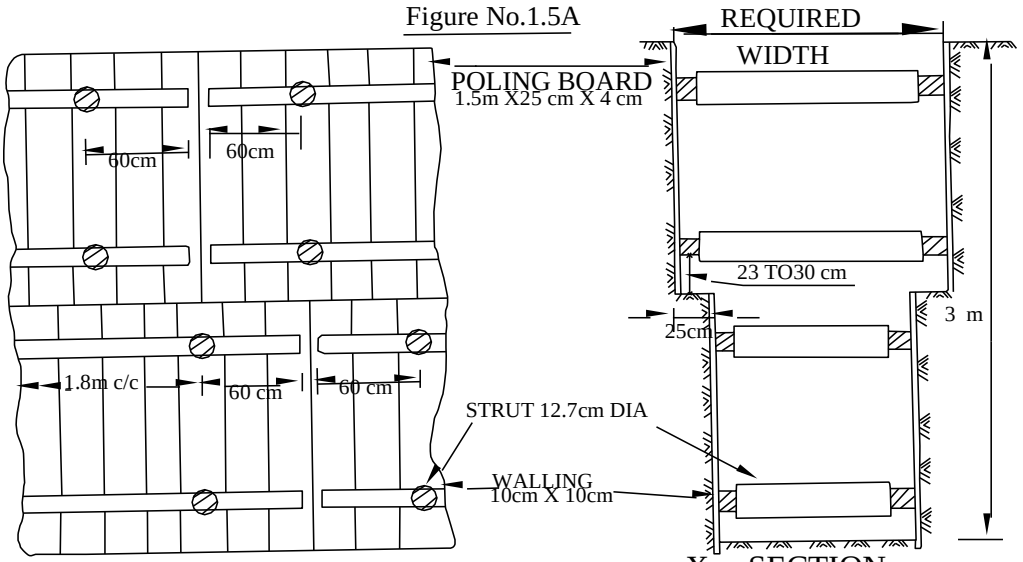
EXTENSION OF EXISTING CUTTING WHERE NO FRESH CUTTING SLOPE IS AVAILABLE AFTER THE WORK. (Figure No.1.4)

DETAILS OF CLOSE AND OPEN TIMBERING
(SECTIONAL ELEVATION & CROSS SECTION) NOT TO SCALE

DETAILS OF CLOSE & OPEN TIMBERING

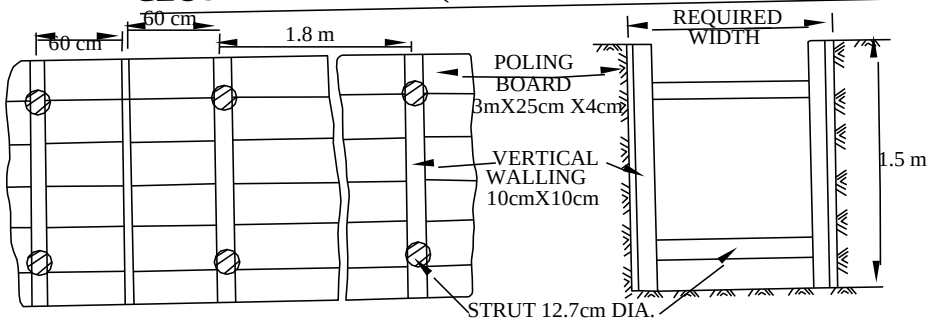
CLOSE TIMBERING (With vertical poling boards)

Figure No.1.5A



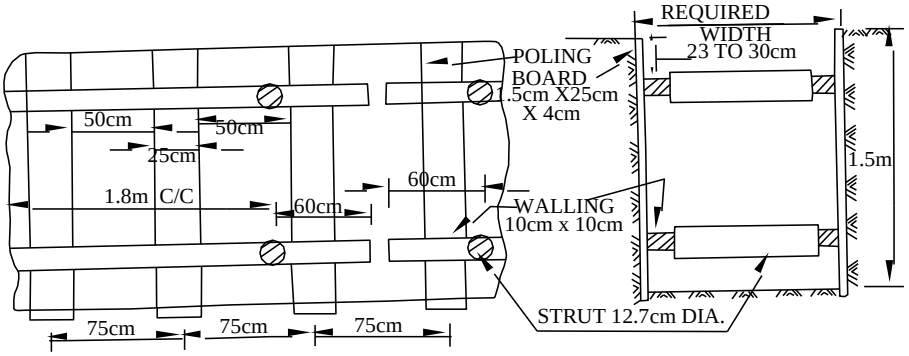
SECTIONAL ELEVATION X -- SECTION

CLOSE TIMBERING (WITH LONGITUDINAL POLING BOARD)



SECTIONAL ELE VATION X- SECTION

OPEN TIMBERING

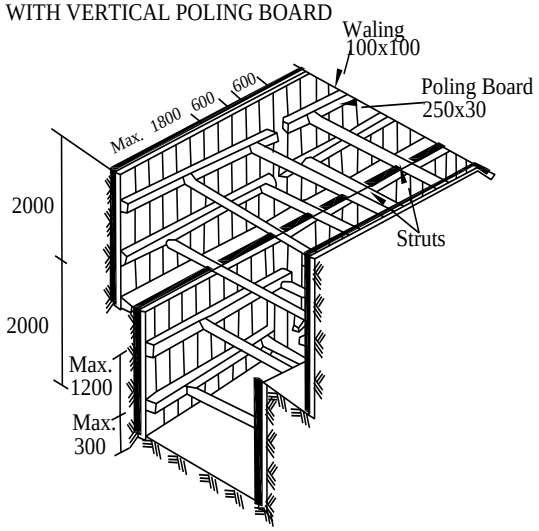


SECTIONAL ELE VATION X -SECTION

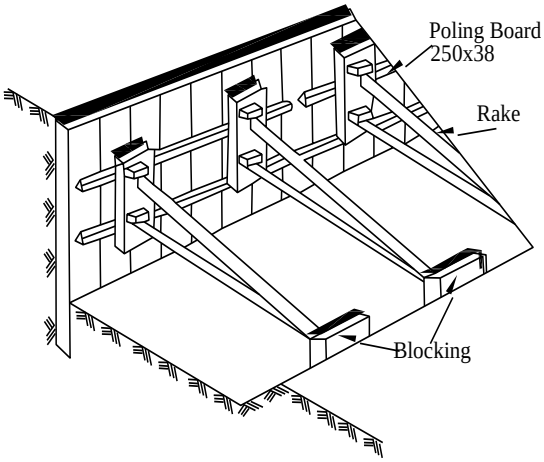
DETAILS OF CLOSE AND OPEN TIMBERING
(ISOMETRIC VIEW)

Figure No.1.5B

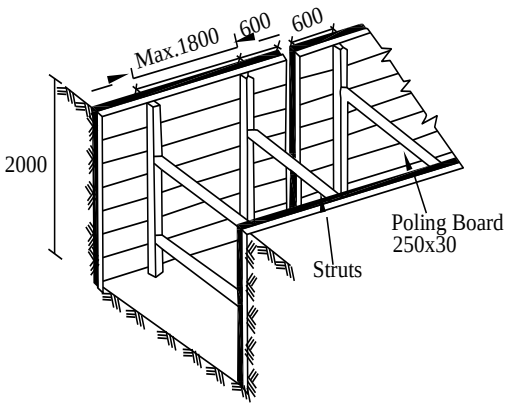
CLOSE PLANKING & STRUTTING
WITH VERTICAL POLING BOARD



PLANKING & STRUTTING FOR SHALLOW
WIDE EXCAVATION



CLOSE PLANKING & STRUTTING
WITH LONGITUDINAL POLING BOARD



OPEN PLANKING AND STRUTTING

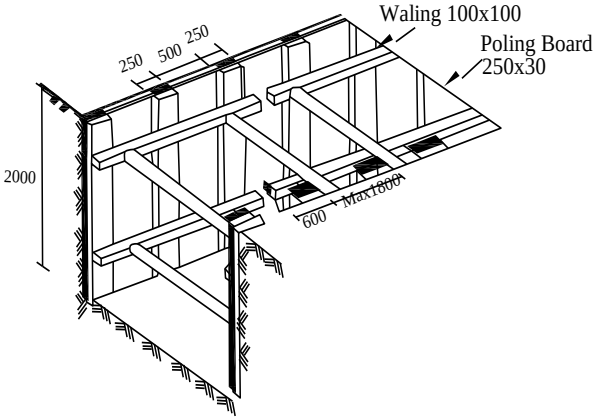
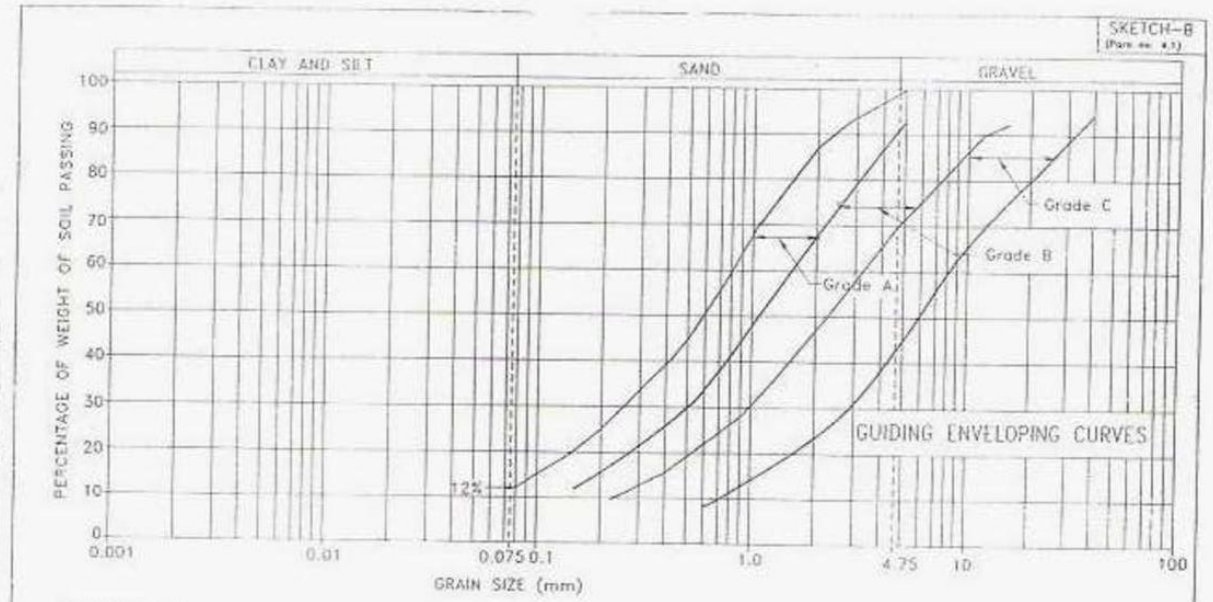


Figure No.1.6

SPECIFICATIONS FOR BLANKET MATERIAL



SPECIFICATIONS:

1. THE BLANKET MATERIAL SHOULD BE COARSE,GRANULAR AND WELL GRADED.
2. SKIP GRADED MATERIAL IS NOT PERMITTED.
3. PARTICLES FINER THAN 75 MICRONS CAN BE PERMITTED UPTO 5% IF FINES ARE PLASTIC AND THE LIMITS CAN BE INCREASED TO 12% IF THE FINES ARE NON PLASTIC.
4. UNIFORMITY COEFFICIENT (D_{60}/D_{10}), IN NO CASE SHOULD BE LESS THAN 7.
5. COEFFICIENT OF CURVATURE ($D_{30}^2/D_{60}XD_{10}$), SHOULD BE IN BETWEEN 1 AND 3.
6. THE PARTICLE SIZE GRADATION CURVE SHOULD LIE MORE OR LESS WITHIN ONLY ONE BAND

R. D. S. O.

GUIDELINES FOR EARTHWORK IN RLY. PROJECTS

SPECIFICATIONS FOR BLANKET MATERIAL (MECHANICALLY PRODUCED)

DRG NO: CT/SDP/0014/Rev.0/2003

Chapter- 2
Bridge Works : Substructure

2.1 GENERAL

2.1.1 Scope

The Specifications given in this chapter deal with items pertaining to all types of foundations for bridges and bridge superstructure viz., Piers, abutments, wing walls, bed blocks and ballast walls / dirt walls. A section is included at end to cover water supply wells and tube wells.

2.1.2 Types of Foundations

Bridge foundations can be of:

i) Open or Shallow Foundations including footings, blocks and raft foundations.

ii) Pile Foundations

iii) Well Foundations

Types of sub-structures:-

Abutment : i) Wall Type abutment
ii) Spill through abutment

Pier: i) Wall type
ii) Columns - Solid or hollow
iii) Trestle type

Wing Walls: i) Splayed Wing walls
ii) Box Type Wing walls

2.1.3 Design and inspection aspects of Bridges

Design and inspection aspects of bridges are not covered in these Specifications. User may refer to the Codes and Specifications listed above and Indian Railways Bridge Manual and departmental instructions for same. Provisions made in other chapters of the specifications are applicable to the extent they are relevant.

2.2 Setting Out for Foundations

2.2.1 Setting out for Minor Bridges and Culverts

Shall be carried out by a competent / qualified engineer, employed by the Contractor and checked by the Engineer's representative for all bridges and culverts. Contractor shall provide necessary instruments, linear tapes, pegs etc.

The setting out for foundations and sub-structure shall be carried out with a theodolite and steel tapes / Invar tapes in case of works not involving deep foundations or standing water. All levels will be measured using a precise levelling instrument. Errors in location of piers / abutments and fixing levels shall be within following limits.

Linear Measurements	$\pm$ 5 mm
Levels	$\pm$ 3 mm

2.2.2 Setting out for Major Bridges

a) Locations of piers and abutments along with the centre line of the bridge should be accurately laid out by establishing one or more base lines as directed and a system of pegs and posts. Also sufficient reference pegs and pillars should be established for checking the positions with ease during progress of work. Reference Bench Marks for levelling should be established nearby on a permanent structure or on a pillar to be built up in vicinity.

b) The principal reference lines and level pegs should be established at easily accessible locations. They include-

i) Longitudinal Centre line

ii) Transverse Centre lines of abutments and piers

iii) Tangent points of the curve at either end, if alignment is on a curve.

c) For Bridge Works involving deep excavations, pile driving or well sinking and / or where there is standing water, use of base line is obligatory. They should be preferably at right angle to centre line of bridge, with one on either end on high bank in case of long bridges or on one side bank of bridge for shorter ones.

d) In case of bridges of length exceeding 1000 Metres, base lines and reference towers will have to be established. Provision of all assistance in form of measuring instruments, linear tapes as may be required by the surveyor, technical and skilled staff and labour required to assist them, fixing pegs, pillars and towers including all building materials and maintaining and guarding them including supply of all materials, tools and plant shall be done by the Contractor at his cost. Nothing extra will be payable to them on this account. Important points to be observed in this activity are:

1. Linear Measurement shall be carried out with invar tape or electronic distance measuring instruments
2. Spring balances shall be used for giving specified tension to the tape. Tape readings shall be corrected for tension, temperature and slope.
3. Concrete pillars with steel plates fixed over them shall be located at intermediate points (at tape lengths) and ends.
4. Reference pillars at pier and abutment position along centre lines and reference pillars on base lines shall be to standards to be prescribed by the Engineer. During construction, since centre line pillars at abutment / pier locations will be disturbed, reference pillars and lines shall be fixed around each structure by the Contractor under Site Engineer's supervision. Reference diagrams at Annexures 4/1 and 4/2 and Clause 401 of IRBM shall be referred to for more details.

2.3 SOIL EXPLORATION

2.3.1 Shallow Foundations

1. Shallow Foundations are provided where sufficiently hard soil is available at shallow depths. They shall be taken down at least 1.5m below bed level or anticipated scour level except in case of pipe and Box culverts. The bearing capacity of soil and nature of soil should be ascertained by making trial pits at location of culvert/ bridge.

2. The depths of such pits shall extend for sufficient depth below the proposed founding level. If the soil in the pit by observation is found hard and stable plate load test shall be conducted at a level to be decided by the Engineer but not less than 0.60m below proposed foundation level for determining safe bearing capacity of soil and the characteristics of the strata in accordance with provisions of IS: 1888. (Plate Load Test)
3. In addition, at the discretion of the Engineer, exploratory bores or sounding shall be done for depth of about 1.5 times the proposed width of foundation below proposed founding level. In case of exploratory bores, sample shall be collected and laboratory tests conducted as detailed in Para 2.3.4.
4. The results of laboratory tests and of plate load tests and penetration tests shall be compared for conformity. It shall be ensured that no layer of soft soil is met with upto 1.5 times depth below the founding level.

2.3.2 Soil Exploration for Deep Foundations

1. At least one exploratory bore shall be drilled at the location of each pier. The bore shall be taken down to a minimum depth of 1.5 times the proposed width of foundation below design founding level. If rock is met with in the bore, the bore should be taken down at least 5m into the rock.

2. In case the rock layer is suspected to be sloping or dipping or fissures are noticed, more than one bore per foundation will be required to be done. Additional bores should be done as instructed by the Engineer.

3. Only rotary drills shall be used for drilling bore holes and collection of samples. Use of percussion or wash boring equipment may be permitted by the Engineer in certain types of soils, based on his judgement.

4. SPT tests and collection of undistributed samples shall be done at intervals of 1.5 m depth unless otherwise specified in contract or directed by the Engineer, and in accordance with IS:1892. Samples collected shall be properly protected, packed and sent for tests. Tests shall be conducted as per provisions in relevant part of IS: 2219.

2.3.3 Tests:- In-situ and laboratory tests listed below shall be carried out according to soil type and site requirement.

Cohesionless soils:

a) Classification tests, density etc.

Standard Penetration Test or Dynamic Penetration Test (as per IS 2131) when considered appropriate.

b) Laboratory Tests:

Triaxial or shear or box shear test on collected samples and saturated samples where sub soil water level is likely to reach that level.

Cohesive soils

a) Classification tests, density etc.

b) Field Tests

   i. Plate Load Tests

ii. Unconfined compression Test (IS 2720-Part IX)
iii. Vane Shear Test (IS 4434)
iv. SPT (IS 4968 Part III)

c) Laboratory Tests

i. Shearing strength Test Triaxial Tests (IS:2720-Part XI)
ii. Consolidation Test (IS 2720-Part XV)
iii. Special Tests

a) Permeability tests should be conducted on samples in case need for dewatering is expected for / during excavation / or well sinking.
b) Chemical tests of soils and sub-soil water where considered necessary
c) Look out should be maintained for presence of any gas, in case peaty soils are met with or otherwise suspected, specially when well foundations are proposed.

2.3.4 Coverage

a) The exploration shall cover the entire length of the bridge and also extend at either side for a distance of about twice the depth below bed of the lowest main foundations.

b) The depth of exploration should be at least 1 ½ times the minimum width of foundation below the proposed foundation level. Where such investigation ends in any unsuitable or questionable foundation material the exploration shall be extended to a sufficient depth into firm and stable soils or rock but not less than four times the minimum depth of foundation below the earlier contemplated foundation level. In case of good sound rock the stipulation of minimum depth may be decreased based on difficulty to conduct core drilling and the minimum depth may then be restricted to 3 metres.

c) Locations of Boring - Where the data made available by detailed exploration indicates appreciable variation or where variations in a particular foundation are likely to appreciably affect the construction (specially in case of bridge foundations resting on rock), it will be necessary to resort to additional bores / soundings to establish complete profile of the underlying strata. The additional borings / soundings shall be decided by the Engineer depending upon the extent of variation at a particular foundation location and should cover the entire area of the particular foundation.

2.3.5 Construction Stage Exploration

Whenever a change in the sub-soil strata / rock profile is encountered during construction, detailed explorations shall be resorted to establish the correct data for further decisions.

2.3.6 Logging of bore holes:- Logging of bore holes by radioactive methods shall be done for detailed investigations as specified in the contract or in special provisions.

2.4 EXPLORATION FOR BRIDGE FOUNDATIONS RESTING ON ROCK

2.4.1 Scope of Work

To arrive at the characteristic strength of rock mass, reliance shall be placed more on in situ tests in comparison to laboratory tests.

2.4.2 Identification and classification

Identification and classification of rock types for engineering purposes may in general be limited to broad, basic geological classes in accordance with accepted practice. Apart from strength of parent rock, investigation should cover study of spacing and distribution of discontinuities of the rock mass, such as the joints, bedding planes, faults and weathered seams. A major factor affecting the behaviour is the weathered zone at top.

2.4.3 Basic Information Required from Exploration in rock

i. Depth or rock strata and its variation over the site,
ii. Whether isolated boulder or massive rock formation.
iii. Extent and character of weathered zone,
iv. Structure of rock – including bedding planes, faults, fissures, solution cavities etc.
v. Properties of rock material-strength, geological formation, etc.
vi. Erodibility or rock to the extent possible
vii. Colour of water.

2.4.4 Extent of Exploration

The extent of exploration shall be adequate enough to give a complete picture of the rock profile both in depth and across the channel width to assess the constructional difficulties in reaching the foundation levels.

2.4.5 Depth of Boring

The depth of boring in rock should be such that it shall pass through the upper weathered or otherwise weak zone, well into the sound rock. Minimum depth of boring in sound rock shall be 3 metres.

2.4.6 Special Features in Drilling through Rock

During drilling through rock every care shall be taken to notice and record any small change during drilling. The time required to drill through a certain depth, amount of core recovery, physical condition, length of pieces of core, joints, colour of water residue, weathering and evidence of disturbance and other effects shall be carefully noticed and entered in the drilling log. For guidance, IS:5313 may be referred to. The data shall be presented in accordance with IS:4464. The cores shall be stored properly in accordance with IS:4078.

Laboratory Tests

The rock cores obtained shall be subjected to following laboratory tests:

i. Visual identification for texture, structure, composition, colour and grain size.

ii. Laboratory tests shall be done for specific gravity, porosity and moisture content and compressive and shear strength.

2.4.7 In-situ Tests

(a) In-situ tests shall be made in accordance with IS:7292; IS: 7317: and IS 7746. In addition, laboratory tests can also be made on samples. Use of in-situ tests for measuring strength and deformation characteristics shall be made. If required, bore-hole photography may be done to evaluate the presence of faults, fissures or cavities, etc.

(b) In some cases, the foundation behavior will be dominated by a possible mode of failure involving movement along some joint surface, fissures or weak layer within a generally strong rock system and also by possible weathering. In situ shear tests may be conducted wherever feasible, as such tests are likely to give more representative data than the shear tests conducted on core samples.

2.4.8 Special Cases

a) Investigation for conglomerate:

A drill hole shall be made same as for rock. The samples collected shall be subjected to suitable tests depending upon the material. Special care shall be taken to ascertain erodibility of the matrix. Where possible, especially for shallow foundation, Plate load Test shall be conducted.

b) Investigation for laterites:

The investigation shall be similar to that required for cohesive soils. Use of penetration tests shall be preferred, if suitable correlation charts are available. These may be static or dynamic penetration tests or vane shear tests. In the case of hard laterite, recourse will have to be made to core drilling as for soft rocks.

2.4.9 Presentation of Data

The data shall be given in diagrammatic form in 3 sheets giving the following details:

Sheet 1: Plan to scale (Site Plan) showing the position of bore-holes clearly marked so as to fix the position at a future date.

Sheet 2: This shall contain the bore-log chart and test results of the samples separately for each bore-hole / pit etc.

Sheet 3: This shall contain pictorial representation of the bore log data to get an overall picture of the soil profile at the cross section of the river.

2.5 RECORDS OF BORINGS AND TRIAL PITS AND SAMPLING

2.5.1 Field records

The field records for the preliminary and detailed exploration shall contain the date when the boring was made, the location of the boring with reference to a permanent system of coordinates and the elevation of the ground surface with respect to a permanent bench mark. They shall include elevation at which the water table and the upper boundary of each of the successive soil strata were encountered, the

investigator's classification of the layer on the basis of general information obtained from field examination and the Standard Penetration Test values at different depths. The type of tools used for borings shall be recorded. If the tools were changed, the depth at which the change was made and the reason thereof shall also be noted. Incomplete and abandoned borings shall be described with same care as for completed bores including information on any part of pipe or tool left behind in the bore. It should contain details of the job such as the elevation at which wash water was lost from the hole and any other significant information.

2.5.2 Contents of Report

For all borings and trial pits, necessary information as detailed below shall be given in the Reports. It shall include all drawings including site plan.

a) Agency
b) Location with reference map
c) Pit/ Bore-hole number
d) Reduced level (R.L.) of ground surface or other reference point
e) Dates of starting and completion
f) Name of supervisor
g) Scales of plans and sections
h) Dimensions, methods of advancing exploration such as by hand tools, blasting, boring etc.
i) General description of strata met with and RLs at which they were met
j) Position and altitude of contacts, faults, strong joints, slickenside, etc.
k) Inflow of water, methods of controlling the water, required capacity of pumps for dewatering
l) The level at which the sub-soil water was met with
m) Dip and strike of bedding and of cleavage
n) Visual description of strata
o) Results of field tests e.g. SPT, in-situ vane shear test etc.
p) Any other information and remarks

2.5.3 Record of Measurement

Upon removal of sampling tube, the length of the sample in the tube and the length between the top of the tube and the top of the sample in the tube shall be measured and recorded.

2.5.4 Methods of Sampling

a) The usual methods for sampling conforming to IS:1892 and IS:2132 are given below:

Nature of Ground	Type of Sample	Method of Sampling
Soil	Disturbed	Hand Samples
		Auger Samples

		Shell Samples
	Undisturbed	Hand Samples
		Tube Samples
Rock	Disturbed	Wash samples from percussion or rotary drilling
	Undisturbed	Cores

b) For proper identification of sub-surface material, sample should be recovered containing all the constituents of the materials in their proper proportion. In clayey deposits such samples could be collected by split spoon samplers. In the case of sandy deposits, sampling spoons shall be fitted with suitable devices for retaining samples. All data required for soil identification should be collected from the samples so extracted when undisturbed samples, which are more desirable for collection of some of the data, are not available. Penetration test should be carried out with the standard split spoon sampler or penetrometers, if the soil is coarse grained. When it is known in advance that the soil profile is fairly regular, preliminary and detailed investigation may be combined. Tube samplers can be used in place of split spoon samplers for collecting samples in clayey strata.

c) **Disturbed Soil Samples**

i) Disturbed samples of soil shall be obtained in the course of excavation and boring. For procuring samples from below the ground water level, where possible, special type of sampler shall be used. Where Standard Penetration Test is conducted, representative samples shall be obtained from the split spoon. While collecting disturbed samples from borrow areas it shall be ensured that the samples collected represent all types of borrow materials to be used in the construction of embankment and sub-grade.

ii) The size of sample generally required shall be as given in **Table 2.1**

TABLE 2 -1: SIZE OF SOIL SAMPLE REQUIRED

Sl. No.	PURPOSE OF SAMPLE	SOIL TYPE	WEIGHT OF SAMPLE REQUIRED (Kg)
1.	Soil identification, natural moisture content tests, mechanical analysis and index properties, chemical tests	Cohesive soils Sands and Gravels	1 3
2.	Compression tests	Cohesive soils and sand	12.5
3.	Comprehensive examination of construction material and borrow area soil including soil stabilization	Cohesive soils and sand Gravelly soil	25-50 50-100

iii) While taking out disturbed soil samples, Standard Penetration Test shall also be conducted to find out the bearing capacity of the sub-soils at specified levels.

d) **Undisturbed Soil Samples**

i) Samples shall be obtained in such a manner that their moisture content and structure do not get altered. This may be ensured by use of correctly designed sampler and by careful protection and packing.

ii) Standard Penetration Test may have to be conducted in each case to obtain additional data as directed by the Engineer. In soft clay, in-situ vane shear test as per IS:4434 may have to be conducted. Where all the three operations have to be carried out in one layer, the sequence shall be undisturbed soil sampling followed by in-situ vane shear test, followed by Standard Penetration Test.

iii) For compression test samples, a core of 40mm diameter and about 150 to 200mm length may be sufficient, but for other laboratory tests, a core of 100mm diameter and 300mm length shall be taken as far as possible, unless otherwise specified by the Engineer.

iv) The upper few millimeters of both types of sample shall be rejected as the soil at the bottom of the bore hole usually gets disturbed by the boring tools.

e) **Rock Samples**

i) Disturbed Samples:

The sludge from percussion borings or from rotary borings which have failed to yield a core, shall be collected for a disturbed sample. It may be recovered from circulating water by settlement in a trough.

ii) Undisturbed Samples:

Block samples taken from the rock formation shall be dressed to a size of about 90 x 75 x 50mm.

For core samples, undisturbed cores of rock shall be taken by means of rotary drills fitted with a coring bit with core retainer, if warranted.

2.6 EXCAVATION FOR OPEN FOUNDATIONS

2.6.1 Depth of Foundation

Depth of foundation shall be as shown in Drawing. If it is in erodible soil, the depth should be such that it has grip of not less than 1/3 depth of scour. The ground at final level should be inspected by the Engineer or his representative and approved before construction of pier or abutment is started.

2.6.2 Setting Out

The plan dimensions of the foundation shall be set out at the bottom of foundation trench and checked with respect to original reference line and axis. It shall be ensured that at no point the bearing surface is higher than the founding level shown on the drawing or as directed by the Engineer.

2.6.3 Preparation of Foundations

The last 300mm of excavation shall be done just before laying of lean concrete below foundation. In the event of excavation having been made deeper than that shown on the drawing or as ordered by the Engineer, the extra depth shall be made up with M15 concrete as specified in case of foundation resting on soil and

foundation grade concrete for foundations in rock, at the cost of the Contractor and shall be considered as incidental work. Special care shall be taken not to disturb the bearing surface. Open foundations shall be constructed in dry conditions and the Contractor shall provide for adequate dewatering arrangements to the satisfaction of the Engineer.

2.6.4 Laying of Lean Concrete base

The base of the pit should be tamped and compacted and kept dry before laying a base concrete or levelling course. A layer of minimum 10 cm thick lean concrete (1:3:6) or equivalent should be laid on the prepared base. After the concrete sets and hardens, the bottom profile of the base of footing shall be accurately marked and got checked by the Engineer before the formwork for footing is laid. Before laying of lean concrete layer, the earth surface shall be cleaned of all loose material and wetted. Care shall be taken to avoid muddy surface. Concrete M15 or as shown in the drawing shall be laid to the thickness as required. No construction joint shall be provided in the lean concrete.

Before laying foundation concrete, the lean concrete or hard rock surface shall be cleaned of all loose material and lightly moistened. Foundation concrete of required dimensions and shape shall be laid continuously upto the location of construction joint shown on the drawing or as directed by the Engineer. No form work is necessary for the lean concrete layer.

2.6.5 Special Provisions for Rocky strata

In rocky strata, foundation should be keyed in the rock for depths mentioned below unless otherwise specified or approved. In case of sloping rock, benching should be done so that the size of concrete is in level planes suitably stepped. Keying depths should be

(i) Hard rocks like igneous granites or gneissic rocks with crushing strength of 100 kg./ sq.cm or more - 0.6m

(ii) Other type of rocks with crushing strength of 20 kg / sq.cm. or more – 1.5m

(iii) Other cases to be decided by Engineer / Designer after considering presence of fissures, cavities, bedding planes and ultimate crushing strength.

(iv) Well foundation on rock shall be taken to adequate depth and seated evenly all around the periphery on sound rock and provided adequate embedment.

2.6.6 Formwork

Form work shall conform to relevant specifications. For foundation concrete work, side form work shall be used. Reinforcement shall be laid as shown on the drawing. Form work for top of the foundation concrete shall also be provided, if its top has slopes steeper than 1 (vertical) to 3 (horizontal). When concrete is laid in slope without top form work, the slump of the concrete shall be maintained so as to ensure that compaction is possible without slippage of freshly placed concrete down the slope. In certain cases it may be necessary to build the top form work progressively as the concreting proceeds up the slope.

2.6.7 Concreting

Providing concrete and steel reinforcement shall conform to relevant sections of Chapters of Concrete work & RCC of specification. Minimum grade of concrete shall be M 20 unless otherwise specified or directed. The concrete surface shall be finished smooth with a trowel. The location of construction joint and its treatment shall be done as per specification. Form work shall be removed not earlier than 24 hours after placing of concrete. Where form work has been provided for top surface, the same shall be removed as soon as concrete has hardened. Curing of concrete shall be carried out by wetting of form work before removal. After its removal, curing shall be done by laying not less than 10cm of loose moistened sand, free from clod or gravel and shall be kept continuously moist for a period of 7 days. Sides will be kept wet for the same period by spraying water or covering with wet gunny bag etc.

2.6.8 Backfilling

Before back filling around the foundation and structure is commenced, loose sand laid on foundation shall be removed and dispersed as directed by the Engineer. All spaces excavated and not occupied by the foundation or other permanent works shall be refilled with earth upto surface of surrounding ground in 150mm layers wetted and compacted by rammers, light rollers and as directed by Engineer. In case of excavation in rock, the annular space around foundation shall be filled with M 15 concrete or as specified upto the top of rock. Protection works, where provided, shall be completed before the floods so that the foundation does not get undermined.

2.6.9 Tests and Standards of Acceptance

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria. The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

No point of the surface of the lean concrete in the case of foundation on soil or the surface of hard rock in the case of foundation of hard rock, shall be higher than the founding level shown on the drawings or as ordered by the Engineer. Levels of the surface shall be taken at intervals of not more than 3 metres centre to centre, subject to a minimum of nine levels on the surface.

Tolerances

a) Variation in dimensions : +50mm - 10mm

b) Misplacement from specified position in plan : 15mm

c) Surface irregularities measured with 3m straight edge : 5mm

d) Variation of levels at the top : $\pm$ 25 mm

2.6.10 Measurement for payment

Excavation in foundation shall be measured in accordance with Chapter 1based on the quantity ordered or as shown on the drawing. Lean concrete shall be measured in cubic metres based on the quantity ordered or as shown on the drawing.Concrete in foundation shall be measured in cubic metres based on the quantity ordered or

as shown on the drawing.Reinforcement steel shall be measured in tonnes based on the quantity ordered or as shown on the drawing.Formwork shall me measured in square metres. All linear measurements will be made correct to nearest cm and areas computed to nearest 0.01 sqm and volumes to nearest 0.001 cum.

2.6.11 Rate

The contract unit rates for excavation in foundation, lean concrete, formwork, and concrete in foundation and reinforcement steel shall include all works as given in respective sections of these specifications and cover all labour, materials, tools and plant, transport, handling and all incidental items for furnishing and providing open foundation including curing and backfilling, as mentioned in this Section.

2.7 PILE FOUNDATIONS

2.7.1 General:

2.7.1.1 Work shall be done in accordance with IS:2911 Parts 1 to 4 unless otherwise specified herein or in Drawings and Contract specifications. Under reamed piles shall not be used for Railway bridges but used extensively in clayey and black cotton soils for buildings. The Construction of pile foundations requires a careful choice of the piling system depending upon sub-soil conditions and loading characteristics and type of structure. The permissible limits of total and differential settlements, unsupported length of pile under scour, impact / entanglement of floating bodies and any other special requirements of project are other important criteria for selection of the piling system. The method of installing the piles, including details of the equipment shall be submitted by the Contractor and got approved by the Engineer before start of work.

2.7.1.2 Sub-Surface Investigations

Borings should be carried upto sufficient depths so as to ascertain the nature of strata around the pile shaft and below the pile tip. However, unless otherwise specified or agreed to, depth of boring shall not be less than:

(i) 1.5 times estimated length of pile in soil but not less than 15m beyond the probable length of pile

(ii) 15 times diameter of pile in weak / jointed rock but minimum 15m in such rock

(iii) 4 times diameter of pile in sound, hard rock but minimum 3 m in such rock.

(iv) The investigation shall be adequate for the purpose of selection of appropriate piling system and for estimating design capacities for different diameters and lengths of piles.

(v) For piles socketed into rocks, it is necessary to determine the uniaxial compressive strength of the rock and its quality.

(vi) The investigation shall also include location of ground water table and other parameters including results of chemical tests showing sulphate and chloride content and any other deleterious chemical content in soil and / or ground water, likely to affect durability.

2.7.2 Materials

The specifications for steel reinforcement, structural concrete, prestressed concrete and structural steel to be used in pile foundations shall be similar to provisions given in the relevant sections of the specifications.

2.7.2.1 Concrete in Piles

Grade of concrete to be used in cast-in-situ piles shall preferably be M 25 or as specified but never less than M 20 and the Cement content shall not be less than 400 kg per cubic metre of concrete. Grades of concrete for precast reinforced and prestressed concrete piles shall not be less than M 25 and M 35 respectively. Maximum water cement ratio shall be 0.5 for cast-in-situ piles and 0.45 for precast piles. The minimum slump of concrete for driven cast-in-situ piles shall be 100mm to 150mm and that of bored cast-in-situ piles 150mm to 200mm. The slump should not exceed 200mm in any case.

Suitable and approved admixtures may be used in concrete mix where necessary. The minimum clear cover for piles will be 40mm over all reinforcement including binding wire. Where piles are to be located in corrosive environment, the cover shall be 50mm. Where piles are exposed to action of harmful chemicals or severe conditions of exposure due to presence of sulphate, chloride etc., higher grades of concrete, restricting water cement ratio to 0.45 shall be used. Special types of cement, such as sulphate resistant cement may be used where considered appropriate by Engineer-in-Charge.

2.7.3 Test Piles

2.7.3.1 The piles shall be load tested in accordance with provisions laid down in IS 2911. Part 4.

2.7.3.2 Test piles which are shown on the drawings or specified in the contract or installed by the Contractor on his own to determine the lengths of piles to be furnished shall conform to the requirements for piling as indicated in these specifications, if they are to be incorporated in the completed structure.

2.7.3.3 Test piles which are to become a part of the completed structure shall be installed with the same type of equipment that is proposed to be used for piling in the actual structure. Test piles which are not to be incorporated in the completed structure shall be cut off at atleast 600mm below the proposed soffit level of pile cap and head finished properly with cover concrete and the remaining hole shall be back filled with earth or other suitable material. If any test pile in a cluster fails, an additional pile will be provided and incorporated in the Cluster at the position approved by the Engineer.

2.7.4 CAST-IN-SITU CONCRETE PILES

2.7.4.1 Cast-in-situ concrete piles may be either installed by making a bore into the ground by removal of material or by driving a metal casing with a shoe at the tip and displacing the material laterally. The two types of piles are termed as “bored piles” and “driven piles” respectively. Cast-in-situ concrete piles may be cast in metal shells which may remain permanently in place. However, other types of cast-in-situ concrete piles, plain or reinforced, cased or uncased, may be used if in the opinion of the Engineer the soil conditions permit their use and if their design and the methods of placing are satisfactory. The metal casing shall be of sufficient

thickness and strength to hold its original form and show no harmful distortion after it and adjacent casings have been driven and the driving core, if any, has been withdrawn.

2.7.4.2 Concreting and reinforcement work will be done in accordance with relevant clauses in Chapters of Concrete work & RCC of Specification supplemented by these specifications.

2.7.4.3 Cast-in-situ concrete driven piles shall be installed using a properly designed detachable shoe at the bottom of the casing.

2.7.4.4 Any liner or bore-hole which is improperly located or shows partial collapse that would affect the load carrying capacity of the pile, shall be rejected or repaired as directed by the Engineer at the cost of the Contractor.

2.7.4.5 Bored cast-in-situ piles in soils which are stable, may often be installed with only a small casing length at the top. A minimum of 2.0m length of top of bore shall invariably be provided with casing to prevent any loose soil falling into the bore. In cases in which the side soil lower down can fall into the hole, it is necessary to stabilise the side of the bore hole with drilling mud, or a suitable steel casing. The casing may be left in position permanently specially in cases where the aggressive action of the ground water is to be avoided, or in the cases of piles built in water or in cases where significant length of piles could be exposed due to scour.

2.7.4.6 For bored cast-in-situ piles, casing / liner shall be driven open ended with a pile driving hammer capable of achieving penetration of the liner to the length shown on the drawing or as approved by the Engineer. Materials inside the casing shall be removed progressively by air lift, grab or percussion equipment or other approved means. Boring shall be carried out using rotary or percussion type equipment. Unless otherwise approved by the Engineer, the diameter of the bore-holes shall be not more than the inside diameter of the liner.

2.7.4.7 Where bored cast-in-situ piles are used in soils liable to flow, the bottom of the casing shall be kept enough in advance of the boring tool to prevent the entry of soil into the casing, thus preventing the formation of cavities and settlements in the adjoining ground. The water level in the casing should generally be maintained at the natural ground water level for the same reasons. The joints of the casing shall be made as tight as possible to minimise inflow of water or leakage of slurry during concreting. Where mud flow conditions exist, the casing of cast-in-situ piles shall not be allowed to be withdrawn. Prior to the lowering of the reinforcement cage into the pile shaft, the shaft shall be cleaned of all loose materials. Cover to reinforcing steel shall be maintained by suitable spacers, tied in advance to the reinforcement.

2.7.4.8 Wherever practicable, concrete should be placed in a clean dry hole. Where concrete is placed in dry condition and there is casing present, the top 3m of the pile shall be compacted using internal vibrators.

2.7.4.9 Before concreting under water, the bottom of the hole shall be cleaned of drilling mud and all soft or loose material very carefully. In case a hole is bored with use of drilling mud, concreting should not be taken up when the specific gravity of

bottom slurry is more than 1.2. The drilling mud should be maintained at 1.5m above the ground water level.

2.7.4.10 Where the casing is withdrawn from cohesive soils for the formation of cast-in-situ pile, the concreting should be done with necessary precautions to minimise the softening of the soil by excess water. Care shall be taken during concreting to prevent as far as possible the segregation of the ingredients. The displacement or distortion of reinforcement during concreting and also while extracting the tube shall be avoided.

2.7.4.11 The concrete shall be properly graded, shall be self-compacting and shall not get mixed with soil, excess water, or other extraneous matter. Special care shall be taken in silty clays and other soils with the tendency to squeeze into the newly deposited concrete and cause necking. Sufficient head of green concrete shall be maintained to prevent inflow of soil or water into the concrete.

2.7.4.12 The placing of concrete shall be a continuous process from the toe level to the top of the pile. To prevent segregation, a tube or tremie pipe as appropriate shall be used to place concrete in all piles.

2.7.4.13 To ensure compaction by hydraulic static heads, rate of placing concrete in the pile shaft shall not be less than 6m (length of pile) per hour. Under water concreting should be done with tremie.

2.7.4.14 Concreting under water :-General requirements and precautions for concreting under water shall be as given in concreting chapter supplemented by following instructions:

a) The concreting of a pile must be completed in one continuous operation. Also, for bored holes, the finishing of the bore, cleaning of the bore, lowering of reinforcement cage and concreting of pile for full height must be accomplished in one continuous operation without any stoppage.

b) The concrete should be coherent, rich in cement with high slump and restricted water cement ratio.

c) The tremie pipe will have to be large enough with due regard to the size of aggregate. For 20mm aggregate the tremie pipe should be of diameter not less than 150mm and for larger aggregate, larger diameter tremie pipes may be necessary.

d) The first charge of concrete should be placed with a sliding plug pushed down the tube ahead of it to prevent mixing of water and concrete.

e) The tremie pipe should always penetrate well into the concrete with an adequate margin of safety against accidental withdrawal if the pipe is surged to discharge the concrete.

f) The pile should be concreted wholly by tremie and the method of deposition should not be changed part way up the pile to prevent the laitance from being entrapped within the pile.

g) All tremie tubes should be scrupulously cleaned after use.

h) In special circumstances, the Engineer may permit use of any other proved method of concrete placement designed for under water concrete. In such cases,

a detailed method statement should be prepared and got approved by the Engineer.

2.7.4.15 The diameter of the finished pile shall not be less than that specified and a continuous record shall be kept by the Engineer as to the volume of concrete placed in relation to the pile length cast.

2.7.5 Pile Cap

i) The minimum embedment of cast-in-situ concrete piles into pile cap shall be 150mm. Any defective concrete at the head of the completed pile shall be cut away and made good with new concrete. The clear cover between the bottom reinforcement in pile cap from the top of the pile shall be not less than 25mm. The reinforcement in the pile shall be exposed for full anchorage length to permit it to be adequately boned into the pile cap. Exposing such length shall be done carefully so as to avoid damaging the rest of the pile. In cases where the pile cap is to be laid on ground, a levelling course of M 15 or as stipulated nominal mix concrete 100mm thick shall be provided. Defective piles shall be removed or left in place as judged convenient without affecting the performance of adjacent piles or pile cap. Additional piles shall be provided to replace the defective piles.

ii) Pile caps shall be of reinforced concrete of minimum grade of M 25 unless otherwise stated in drawings or work specifications or directed by the Engineer. A minimum offset of 150mm shall be provided beyond the outer faces of the outer most piles in the group. If the pile cap is in contact with earth at the bottom, a levelling course of minimum 100mm thickness of M 15 or as specified nominal mix concrete shall be provided.

iii) The attachment of the pile head to the cap shall be adequate for loads and forces. The top of concrete in a pile shall be brought above cut-off level to permit removal of all laitance and weak concrete before pile cap is laid. This will ensure good concrete at the cut-off level.

iv) Concreting of the pile cap shall be carried out in dry conditions. The bottom of the pile cap shall be laid preferably as low as possible taking into account the water level prevalent at the time of casting. Suitable leak-proof floating form work shall be used for casting caps over piles in water.

2.7.5.1 Driving Equipment

Piles or their casings may be driven with any type of drop hammer, diesel hammer or single acting or double acting steam or compressed air hammer, provided they penetrate to the prescribed depth or attain the designed resistance without being damaged. The weight or power of the hammer should be sufficient to ensure a penetration of atleast 5mm per blow, unless rock has been reached. It is always preferable to employ the heaviest hammer practicable and to limit the stroke, so as not to damage the pile. The minimum weight of the hammer shall be 2.5t. In the case of precast concrete piles the mass of the hammer shall be not less than 30 times the mass of 300mm length of pile.

Steam or air hammers shall be operated with a boiler or air compressor of capacity not less than the capacity that is specified by the manufacturer of the hammer. The boiler or air compressor shall be equipped with an accurate pressure gauge and

safety valves at all times. The valve mechanism and other parts of steam, air or diesel hammers shall be maintained in first class condition so that the length of stroke and number of blows per minute for which the hammer is designed, will be obtained. The boiler shall be inspected by statutory authorities at prescribed intervals. Inefficient steam, air or diesel hammers shall be removed from the work.

2.7.6 Driving

2.7.6.1 General Procedure

Piles shall be installed from cranes or derricks standing on firm ground or from temporary supports or from fixed platform. Piles in water shall be installed from cranes erected on pontoons/ barges properly anchored and held in position. The arrangement shall provide sufficient rigidity to ensure accuracy of pile driving under all conditions of tide, stream flow or hammer drop. During driving, the top of pile shall be protected by a suitable helmet of substantial and well-fitting steel construction. The helmet shall provide uniform bearing across the top of the pile and shall hold the pile centrally under the hammer.

No pile shall be driven unless inspected and approved by the Engineer. Forces producing undue bending or torsional stresses in piles shall not be applied during driving. The force of the hammer shall be directed centrally and axially during driving. The stroke of a single acting or drop hammer shall be limited to 1.2m unless otherwise permitted by the Engineer. A shorter stroke may be specified when there is danger of damaging the pile.

Piles shall not be bent or sprung into position but shall be effectively guided and held on-line during the initial stages of driving. Attempts to correct any tendency for the pile to run off-line by the application of significant horizontal restraint will not be permitted. Shortly after the commencement of driving and at regular intervals throughout the driving operation, checks shall be made to ensure that the pile frame does not exert any undue lateral force on the pile due to restraint within the helmet.

To avoid the possibility of premature “set up” pile driving shall be continuous in the later stages, without any deliberate stops. Delays of an hour or less may lead to significant “set-up” in piles i.e. resistance to further driving increases after driving is stopped.

If any pile is damaged in any way during driving, it shall be repaired or replaced as directed by the Engineer, at no extra cost. If during driving, the head of a pile is damaged to the extent that further driving is not possible, the head shall be cut off and helmet replaced and driving continued. The cost of cutting of the head shall be borne by the Contractor and where, as a result of such cutting of the head, the pile is too short, the Contractor, shall, at his own cost, provide extension or splicing of sufficient length of pile to restore the pile to its correct length.

2.7.6.2 Piles should be driven to the minimum acceptable penetration shown on the drawings. This may require pre-boring and / or jetting as detailed in the relevant Clause of IS:2911 (Part I/ Section 3).

Piles shall be driven to nominal refusal or the required ultimate dynamic capacity specified on the drawings or until the top of the pile is at the level required and specified on the drawing whichever gives the lowest toe elevation. The Engineer’s decision in these matters shall be final. Nominal refusal shall be taken as equivalent

to 25mm total penetration for the final 20 blows using a hammer of driving energy as specified and shall be used as the criterion for acceptance for piles founded on rock. Severe driving which results in an average set per blow of less than 0.5mm will not be permitted.

2.7.6.3 Where hard drilling is encountered because of dense strata or obstructions located above the predetermined pile tip level, nominal refusal shall not be considered to have been achieved unless the Engineer is satisfied that the total number of blows, required for achieving the average driving resistance specified for nominal refusal, indicates that further driving will not advance the pile through the dense strata or obstructions.

2.7.6.4 The pile shall be driven as accurately as possible to the vertical or to specified batter. Straining the pile into position can damage it and the driving equipment should be adjusted as much as possible to follow the position of the pile. Any deviation from the proper alignment shall be noted and promptly reported to the Engineer. If the deviation is to such an extent that the resulting eccentricity cannot be taken care of by strengthening the pile cap or pile ties, such a pile shall, at the discretion of the Engineer, be replaced or supplemented by an additional pile. If the indications are that a pile will finish outside the specified tolerances, driving operations on that pile will cease. The pile shall be withdrawn, the hole filled and the pile re-driven at no extra cost.

2.7.6.5 When employing a tube which is subsequently withdrawn for the formation of cast-in-situ pile, consideration shall be given to the possibility of doing harm to a pile recently formed by driving the tube nearby before the concrete has sufficiently set. The danger of doing harm is greater in compact soils than loose soils. No pile shall be bored or driven within 3 m of a newly cast pile until atleast 24 hours after completion of its installation.

2.7.6.6 Driving piles in loose sand tends to compact the sand which in turn increases the skin friction. Therefore, driving a number of friction piles in a group shall proceed outward from the centre as otherwise it will be difficult to drive the inner piles to the same depth as the others. In the case of stiff clay also, the driving for a group of piles shall proceed outward from the centre. However, in case of very soft soil, the driving may proceed from outside to inside, so that the soil is restrained from flowing out during driving operations.

2.7.6.7 If there is a major variation between the depth at which adjacent foundation piles in a group meet refusal, a boring shall be made nearby to ascertain the cause of this difference. If the boring shows that the soil contains pockets of highly compressive material below the level of the shorter pile, it will be necessary to enforce penetration of all the piles to a level below the bottom of the zone which shows such pockets.

2.7.7 Pile Tests

a) The bearing capacity of a single pile may be determined from test loading a pile. The load test on a concrete pile may not be carried out earlier than 28 days from the time of casting of the pile. The methodology of carrying out load tests and of arriving at safe load on piles shall conform to IS 2911 (Part IV)

b) There shall be two categories of tests on piles, namely, initial tests and routine tests. Initial tests should be carried out on test piles which are not to be

incorporated in the work. Routine tests shall be carried out as a check on working piles. The number of initial and routine tests on piles shall be as determined by the Engineer depending upon the number of foundations span length, type of superstructure and uncertainties of founding strata. In any case, the initial load tests shall not be less than 2 in number, while the routine load tests shall not be less than 2 per cent of the total number of piles in the structure and nor less than 2 in number.

c) The above stipulations hold good for both vertical as well as lateral load tests on pile foundations. However, both initial and routine tests may be suitably increased for important structures or cases with large variation in the sub-surface strata.

d) In case of any doubt of workmanship or load carrying capacity of working piles not subjected to routine tests, or when ordered by the Engineer, or when provided in the Contract, load tests on working piles may be supplemented by non-destructive testing. Such tests may include “Integrity Testing” of concrete in the installed pile and utilisation of “Pile Driving Analyser” which gives an indication of pile capacity in end bearing and side friction.

2.7.8 IMPORTANT CONSIDERATIONS, INSPECTION / PRECAUTIONS Bored Cast-in-Situ Piles

i) While concreting uncased piles, voids in concrete shall be avoided and sufficient head of concrete shall be maintained to prevent inflow of soil or water into the concrete. It is also necessary to take precautions during concreting to minimise the softening of the soil by excess water. Uncased cast-in-situ piles shall not be permitted where mudflow conditions exist.

ii) The drilling mud such as bentonite suspension shall be maintained at a level sufficiently above the surrounding ground water level to ensure the stability of the strata which is being penetrated all through the boring operation and until the pile has been concreted.

iii) Where bentonite suspension is used to maintain the stability of the bore-hole, it is essential that the properties of the material be carefully controlled at stages of mixing, circulating through the bore-hole and immediately before concrete is placed. It is advisable to limit:

a) The density of bentonite suspension to 1.05 g/cc and maintain it.

b) The marsh cone viscosity between 30 and 40

c) The pH value between 9.5 and 12

d) The silt content less than 1 per cent

e) The liquid limit of bentonite not less than 400 per cent

These aspects shall act as controlling factors for preventing contamination of bentonite slurry by clay and silt.

iv) The bores shall be washed by bentonite flushing to ensure clean bottom at two stages viz. (a) after completion of boring and (b) prior to concreting after placing of reinforcement cage. Flushing of bentonite shall be done continuously with fresh bentonite slurry till the consistency of inflowing and outflowing slurry is similar.

v) Tremie of 150mm to 200mm diameter shall be used for concreting. The tremie should have uniform and smooth cross-section inside, and shall be withdrawn

slowly ensuring adequate height of concrete outside the tremie pipe at all stages of withdrawal. Other precautions to be taken while tremie concreting are:

a) The sides of the bore-hole have to be stable throughout

b) The tremie shall be water tight throughout its length and have a hopper attached at its head by a water tight connection.

c) The tremie pipe shall be large enough in relation to the size of aggregates. For 20mm aggregate the tremie pipe shall be of diameter not less than 150mm and for larger size aggregate tremie pipe of larger diameter is required.

d) The tremie pipe shall always be kept full of concrete and shall penetrate well into the concrete in the bore-hole with adequate margin of safety against accidental withdrawal if the pipe is surged to discharge the concrete.

e) For very long or large diameter piles, use of retarding plasticiser in concrete is desirable.

2.7.9 Tolerances for Installation of Piles

a) Permissible Tolerances for Pile

i) Bored Piles

1) Variation in cross-sectional dimensions : + 50mm, - 10mm
2) Variation from vertical or specified rake : 1 in 50
3) Variation in the final position of the head in plan: 50 mm
4) Variation of level of top of piles : $\pm$ 25 mm

ii) Permissible Tolerances for Pile Caps

a) Variation in dimensions : + 50mm – 10mm
b) Misplacement from specified position in plan : 15mm
c) Surface irregularities measured with 3m straight edge : 5mm
d) Variation of levels at the top : $\pm$ 25mm

2.7.10 Measurements for Payment

i) The Engineer shall decide on what depth of excavation is to be made and the level at which the top of pile is to be placed before driving or boring is started. Such excavation shall be paid for at rate specified for excavations for foundations. Rates applicable to driving / casting pile will be paid for the depth below that level only.

(For supply of precast concrete, timber or steel piles of specified cross section, the measurement shall be in metres of the length of piles ordered in writing by the Engineer measured from the head to the butt of the shoe or the tapered point.) Reinforcement in precast concrete piles shall be paid for separately unless otherwise specified in work contract.

ii) For driven cast-in-situ and bored concrete piles of specified cross-section, the measurement shall be the length in metres of the accepted pile that remains in the finished structure complete in place. Reinforcement in cast-in-situ driven and bored concrete piles shall be measured for payment as per RCC Chapter.

iii) Routine and Initial Pile Load Tests shall not be measured for payment, unless otherwise specified in the Contract schedule.

iv) For installation of the pile, i.e. by driving in the case of precast concrete, timber, steel and cast-in-situ driven piles, and by boring in the case of cast-in-situ bored piles the measurement shall be the length in metres that remains in the finished structure complete in place, limited to that shown on drawings or as ordered by the Engineer. No distinction shall be made for penetration through hard strata or rock and socketing into rock.

v) For steel liners / casing shown on the drawings to be permanently left in place, the measurement shall be by weight in ones (or in metre lengths of specified thickness as specified in the schedule) that remains in the finished structure complete in place, limited to that shown on drawings or ordered by the Engineer.

vi) For the pile cap, the quantity of concrete shall be measured in cubic metres while reinforcement in pile cap shall be measured in ones unless specified otherwise.

2.7.11 Rate

i) The contract unit rate for supplying precast concrete, timber or steel piles shall include cost of all labour, materials, tools and equipment, and other work involved in making or fabricating the pile complete as shown on the drawing, and where required its loading, transport, delivery to site, unloading and stacking it at the place indicated by the Engineer. The cost of reinforcement in precast concrete piles shall be deemed to be included in the quoted rate for supply of piles, unless otherwise specified.

ii) The contract unit rate for cast-in-situ driven and bored piles shall include the cost of concrete and all other items as per Concrete works & RCC. The contract unit rate shall also include costs of all labour, materials, equipments and all other incidentals involved in conducting routine and initial pile load tests including installation of piles for initial load tests.

iii) The contract unit rate for installation of piles shall include full compensation for furnishing all labour, materials, tools and equipment, and incidentals for doing all the works involved in driving timber, precast concrete and steel piles, driving or making bores for cast-in-situ driven and bored concrete piles, cutting off pile heads, all complete in place to the specified penetration of piles. Providing temporary liner / casing and its withdrawal and placing reinforcement in position shall also be deemed to be included in the rate for installation of piles and no additional payment shall be made for the same.

iv) The contract unit rate for permanent steel liners shall include cost of all labour, fabrication and placing the steel liner to the required depth as shown on the drawings and as ordered by the Engineer.

v) The contract unit rate for concrete in pile cap shall cover all costs of labour, materials, tools, plant and equipment, form work and staging including placing in position, sampling and testing and supervision, all as per provisions in Concrete work. Reinforcement in the pile cap shall be paid for separately in accordance with payment clause mentioned in chapter of RCC.

2.8 WELL FOUNDATIONS

2.8.1 General

2.8.1.1 In case of larger than 12m in diameter and for wells to be sunk by using special equipment, supplemental instructions / specifications will be

necessary. For basic items of work such as Concrete (Plain or RCC) brick work, stone masonry etc which are incidental relevant chapters may be referred to.

2.8.1.2 To facilitate sinking of well, steel cutting edge is fabricated and connected to a concrete well curb of required shape. Minimum grade of concrete for well curb shall be M 20 unless otherwise specified in Drawing or directed by Engineer. On top of the well curb, adequate height of wellsteining is cast and the process of sinking is carried out. After a portion of the well has been sunk, another height of well staining is cast on top of the previous section and further sinking carried out. This process is continued till the bottom level of the well reaches the founding level.

2.8.1.3 At the top of the well staining, an adequately designed “well cap” is laid which transmits the loads and forces from the sub-structure (piers or abutments) to the foundations.

2.8.1.4 The plan dimensions of sand islands, used for forming the well in water, shall be such as to have a working space of at least 2 metres all around the staining. The dimension of the sand islands shall however be not less than twice the dimension in plan of the well or caisson. Sand islands shall be maintained to perform their functions, until the well is sunk to a depth below the bed level at least equal to the depth of water. Sand island shall be protected against scour and the top level shall be sufficiently above the prevailing water level to be decided by the Engineer so that it is safe against waves and induced afflux Island should be adequately protected against force of water current and wave action.

2.8.1.5 Where depth of water is more than 5 to 6 metres and in fast flowing water, caissons shall be used. Floating caissons are generally fabricated or cast near the banks on dry land or in dry docks. Floating caissons are towed into position in floating condition.

Floating caissons maybe of steel, reinforced concrete or a combination of the two.

2.8.2 Equipment for sinking wells

Equipment shall be deployed for construction of well foundation as required and as directed by the Engineer in quality, performance and quantity. Generally, the following equipments may be required for the work:

a) Crane with grab buckets capacity 0.5 to 2.0 cum.
b) Submersible pumps
c) Air compressors, air locks and other accessories where pneumatic sinking of well is anticipated.
d) Chisels of appropriate sizes
e) Aqua header for cutting rocky strata
f) Driving helmets and accessories
g) Concrete Mixer or Batching Plant; Pumps or skips and hoists; vibrators etc.
h) Pre arrangements for blasting equipment in case of unforeseen circumstances.

2.8.3 Well Steining

2.8.3.1 The dimensions, shape, concrete strength and reinforcement of the well `steining shall strictly conform to those shown on the drawings. The form work shall preferably be of MS sheets shaped and stiffened suitably. In case timber forms are used, they shall be lined with plywood or M.S. sheets.

2.8.3.2 Steining built in the first lift above the well curb shall not be more than 2 metres high and in subsequent lifts it shall not exceed the diameter of the well or the depth of well sunk below the adjoining bed level at any time. For stability, the first lift of steining shall be cast only after sinking the curb at least partially for stability. Concreting of steining may be carried out in subsequent lifts of about 1.2, or 2 to 2.5 metres. Attempts should be made to minimise the number of construction joints. The concreting layers shall be limited to about 450 mm restricting the free fall of concrete to not more than 1.5m. Laitance formed at the top surface of a lift shall be removed to expose coarse aggregates before setting of concrete at the proposed construction joint. As far as possible, construction joints shall not be kept at the location of laps in the vertical steining bars.

2.8.3.3 The steining of the well shall be built in one straight line from bottom to top such that if the well is tilted, the next lift of steining will be aligned in the direction of the tilt. The work will be checked carefully with the aid of straight edges of lengths approved by the Engineer. Plumb bob or spirit level shall not be used for checking verticality alignment. After sinking of a stage is complete, damaged portions if any, of steining at top of the previous stage shall be properly repaired before constructing the next stage.

2.8.3.4 The height of steining shall be calibrated by making atleast 4 gauges (two in traffic direction and two in a direction normal to traffic direction) distributed equally on the outer periphery of the well. Each gauge should be in the form of a 100mm wide strip painted on the well, with every metre mark shown in black paint and sub-mark at 10 cm intervals. The gauges shall start with zero at the bottom of the cutting edge. It will be in black or a white background. Marking of the gauges shall be done carefully with a steel tape. Cost of providing the gauges will be presumed to be included in the rate for sinking.

2.8.3.5 After reaching the founding level, the well steining shall be inspected to check for any damage or cracks. The Contractor shall execute the remedial measures as directed by the Engineer before acceptance of the well steining. In case the well cannot be accepted even with any remedial measures, then the well shall stand rejected.

2.8.3.6 Blasting may have to be resorted to in order to facilitate sinking through difficult strata, such as boulders and rocks etc. In case blasting is anticipated, protective / strengthening measures specified in clause 710.6 (IV) of IRC: 78 shall be taken. The grade of concrete and / or Bridge Sub-structure in bottom 3 metres of steining shall not be leaner than M 20 or as shown on the drawings.

2.8.3.7 In case the bore hole data shows the presence of steeply dipping rock, chiselling may have to be resorted to so as to obtain proper seating of the foundation. For this purpose, the well may require to be dewatered completely

under high air pressure inside the well. This process is known as pneumatic sinking. Pneumatic sinking may also have to be resorted to in cases where obstacles such as tree trunks, large sized boulders or hard strata etc. cannot be removed by open dredging. The necessity of adopting pneumatic sinking shall be decided by the Engineer.

2.8.3.8 The curb and steining have to be specifically designed for special loadings when pneumatic sinking is adopted. Minimum grade of Concrete should, preferably be M 25.

2.8.3.9 The specifications given in this chapter deal only with such items of work as are peculiar to the construction of wells. For the basic items of work such as concrete (pain and reinforced), brickwork, stone masonry, earthwork, etc which are also incidental to the construction of wells, the relevant specifications as given in the respective chapters shall be followed.

2.8.4 Sinking Wells for Foundations

2.8.4.1 This specification pertains to the actual operation of sinking the well through various kinds of strata to the reduced level shown on the drawing, or to any other level as ordered by the Engineer, to enable it to be founded on a suitable foundation stratum.

2.8.4.2 Programme

The programme for sinking shall be so arranged that every well started during a working season is completed, plugged and sealed at top, and the pier or abutment over it built to a suitable height, within the same season, so as to be safe during the floods. In the event of the Contractor's failure to ensure this, any protective measure or other extra work involved in completing the unfinished portion in the next working season shall be done by the Contractor at his own cost.

2.8.4.3 Strata Variation

a) The Contractor may, at his own expense, make trial bores to ascertain the exact depth to which each well may have to be sunk. If any boring data are indicated by the Railway at the tender stage, these may be taken as a general guide only, and the Contractor shall not be entitled to any compensation on account of variations in the strata as actually met with during sinking.
b) The Contractor shall, during the course of the work, collect and hand over to the Engineer's representative samples of all the different strata passed through, including undisturbed samples, where so required by the Engineer. The cost of collection of these samples shall be included in the rate for sinking.
c) Unless otherwise stipulated, the sinking of wells through (a) Hard Rock, and (b) Soft rock & all soils shall be measured and paid for separately.

2.8.4.4 Level of commencement : Excavation and Island

(a) The sinking of the well shall start from a level not more than 30 cm. above the water level or the spring level (subsoil water level), as the case may be unless any higher level is specially approved by the Engineer, based on local conditions such as tidal or other anticipated variations in water level, stability of existing works

etc. The water level, for the purpose of this para, shall be taken as on the date of laying the cutting edge for the well curb.

(b) Where the existing ground level is higher than the level of commencement as specified above, open excavation shall be carried out to that level. Payment for such excavation shall be made as for ordinary cutting unless any special rate has been agreed upon. Notwithstanding the quantity of work actually done, the quantity payable shall be restricted to the actual area of the capping slab, multiplied by the average depth of excavation upto the level from which sinking starts as per sub-para (a) above.

(c) Where it is necessary to sink the well in water, an island shall be formed. The dimensions of the island shall be as approved by the Engineer, and its top finished to the level from which the sinking is to be commenced. The formation of the island shall be paid for separately at rates specially agreed upon, unless otherwise stipulated in the contract.

(d) If, for his own convenience, the Contractor commences sinking of a well from any level higher than that specified in sub-para (a) above, no payment shall be made to him for the extra depth of sinking resulting therefrom.

2.8.4.5 When the well curb is ready for sinking, it shall be "pitched" by careful removal of the blocking timbers on which the cutting edge was so long supported. The timbers shall be removed after loosening the sand around each, and the removal shall be so phased as to maintain equality of pressure and thereby avoid tilting of the curb.

2.8.4.6 After all the blocking timbers are removed, the soil from within the curb shall be excavated evenly over the whole internal area, excavating first in the centre and then working towards the circumference. In the case of double-D wells or twin octagonal wells, the excavation in both dredge holes shall progress simultaneously. The sinking shall be stopped when the top of the curb is about 15 cm above the ground, after which the building up of the initial lift (of say 1.5m height) of the steining shall be taken up.

2.8.4.7 Methods of Sinking:

a) All possible care shall be taken to ensure perfect verticality of sinking of the well curb and the first two lifts (or say 3m.) of the steining, since by doing so, the subsequent sinking to plumb becomes easier. The manner of sinking shall continue to be as followed for the well curb. The operation of sinking will, naturally, alternate with that of adding further lifts of steining, which may be done for two lifts in a sequence, except for the first two lifts which shall be done in two stages, with sinking done in between.

The maximum depth of excavation below the level of the bottom of cutting edge of the well at any stage shall not generally exceed the internal diameter of the well.

Where dewatering is resorted to and it gives rise, at any stage, to "blowing" of the surrounding soil into the bottom of the well, the dewatering shall be stopped forthwith and the water levels balanced to prevent further blowing, before attempting to remove the blown material from inside the well.

(b) In deep water, excavation shall be carried out with the use of grabs operated by winches, or preferably by cranes. Harder strata upto soft rock may be loosened by

the use of heavy chisels, slung at a suitable angle. Removal of obstructions such as boulders and logs shall be done by employing divers.

(c) Small charges of approved explosive may be used, with the written permission of the Engineer in the following circumstances: (1) To blast through rock or to break boulders, which cannot be done by any alternative method; and (2) To effect sinking, especially in the final stages, when the usual formation of a sump at the bottom of the dredge hole does not result in sinking. In the latter case, the charge of explosive shall be placed at the centre of the dredge hole and exploded to set up a tremor which will serve to help sinking of the well. Any damage caused to the well or to adjoining structure by the use of explosives shall be made good by the Contractor at his own expense.

(d) Where a considerable depth of rock is to be pierced through, and dry sinking i.e. without much water except what can be pumped out is not possible, it will be necessary to resort to pneumatic sinking. This requires the use of proper air locks and ancillary equipment, with special precaution observed for safety and certain modifications to the structure of the well to fit the air locks. Sinking of wells by such method shall be a matter of special agreement and covered by special specifications.

(e) Where two or more separate wells in a group are to be sunk, and the clear distance between any two wells is less than the diameter of the well, such wells shall be sunk alternately, each not having a lead of more than half the diameter over the other at any stage.

2.8.4.8 Use of Kentledge as Sinking Load

Kentledge shall be placed in an orderly and safe manner on the loading platform and in such a way that it does not interfere with the excavation of the material from inside the dredge hole and also does not in any way damage the steining of the well. Where tilts are present or there is a danger of well developing a tilt, the position of the kentledge load shall be regulated in such a manner as to provide greater sinking effort on the higher side of the well.

2.8.4.9 Use of Water Jetting

Water jetting, on the outside of the well may be employed for well sinking wherever necessary. Where stiff clayey strata is anticipated, small diameter water pipes are encased in the well with jet ends on periphery during casting of steining for this purpose.

2.8.4.10 Use of Explosives

Mild explosive charges may be used as an aid for sinking of the well only with prior permission of the Engineer. Blasting of any sort shall only be done in the presence of the Engineer and not before the concrete in the steining has hardened sufficiently and is more than 7 days old. When likelihood of blasting is predicted in advance, protection of the curb and the bottom portion of the well shall be done as per these specifications. After blasting operations are completed, the well curb and steining should be examined for any cracks and remedial measures taken.

a) The charges shall be exploded well below the cutting edge by making a sump so as to avoid chances of any damage to the curb or to the steining of the well. A

minimum sump of 1 metre depth should be made before resorting to blasting. Use of large charges, 0.7 kg or above, may not be allowed except under expert direction and with the permission from the Engineer. Suitable pattern of charges may be arranged with delay detonators to reduce the number of charges fired at a time. The burden of the charge may be limited to 1 metre and the spacing of holes may normally be kept as 0.5 to 0.6 metre.All prevalent laws concerning handling, storing and using of explosives as per “Indian Explosives Act” shall be strictly followed.

b) All safety precautions shall be taken as per IS:4081 “Safety Code for Blasting and related Drilling Operations”, to the extent applicable, whenever blasting is resorted to. There should be no equipment inside the well nor shall there be any labour in the close vicinity of the well at the time of exploding the charges.

c) If rock blasting is to be done for seating of the well, the damage caused by flying debris should be minimised by covering blasting holes by rubber mats before blasting.

If blasting has been used after the well has reached the design foundation level, normally 24 hours shall be allowed to lapse before the bottom plug is laid.

2.8.4.11 Daily records of tilt and shift, with reference to the principal axes of the well, shall be maintained at the site, separately for each well, on the Proforma prescribed by the Engineer. Tilts shall be measured along the two axis of the bridge and RL (Reduced Levels) of the marks painted on surface of steining shall be taken. For determination of shift, locations of the ends of the two diameters shall be precisely measured along the two axis, with respect to the fixed reference points. A pair of wells close to each other will have a tendency to come closer during sinking (Tilting towards each other). Timber struts may be introduced in between the steining of these walls to prevent tilting. Record shall also be kept of the daily water levels, commencing from the time of formation of islands or excavation of the site of the well, as the case may be. The Contractor shall further be responsible for maintaining a continuous record of the depth sunk in each working shift and of the types of strata passed through at the various depths, as well as any obstruction met with.

2.8.4.12 It shall be the Contractor’s responsibility to sink the wells to the correct alignment, spacing and levels, based on the reference pillars and bench mark provided by the Railway. Unless otherwise specified the completed well shall not have a tilt of more than 1 in 80 in any direction or a shift of more than 5 per cent of the overall diameter or width of the well, as measured in either of the principal directions or 150mm in resultant direction, whichever is less. Where these tolerances are exceeded, the orders of the Engineer shall be sought. These tolerances shall be further subject to the condition that the stability of the foundation is not affected and that any modification thereby necessitated in the design of the substructure or superstructure shall be done at the cost of the Contractor.

Such acceptance shall be subject to

i) Calculations for foundation pressures and steining stresses after accounting for the tilt and shift and consequent relocation of superstructure on top being safe

ii) Remedial measures required for bringing stresses within permissible limits such as increasing dimension of well cap, providing dummy weights on well cap as

well as redesign of structure above shall be carried out by the Contractor at no extra cost to Railway and

iii) The Contractor shall agree to any reduction in rate for such defective work.

2.8.4.13 Tilt observed may, during the sinking, be corrected by one or more of the following methods, as approved by the Engineer:-

1) Loading kentledge eccentrically

2) Carrying excavation at the bottom of the well deeper on the side which is higher.

3) Providing heavy inclined struts bearing against the face of the well steining on the side towards which it leans.

4) Jetting to reduce skin friction on the higher side, on the well periphery.

5) Pulling or pushing the well by approved methods.

If the well is rejected, the Contractor will dismantle the defective well to the extent desired by the Engineer, at his cost. Further, the Contractor, at his risk and cost, will complete the bridge with modified span arrangements.

2.8.4.14 Seating of Well

When the well approaches the final depth of sinking, the exact height to which the last lift of steining is to be made up shall be decided before it is completed and sunk. When the well has reached the required level and stratum, it shall be properly seated by levelling, the area under the cutting edge. In the case of rock also, every effort shall be made to ensure even seating of the cutting edge, with the use of divers for cutting or benching the rock, as required. No extra payment shall be admissible for the bedding of wells in this manner. Any portion of the rock stratum where the cutting edge cannot be bedded shall be got cleared of the overlying material and filled subsequently with the concrete of the bottom plug.

On completion of the bedding of the well, the bottom of the dredge hole shall be got cleared of all spoil and left in a fit condition for laying of the bottom plug.

2.8.5 ISLANDS FOR WELL SINKING

2.8.5.1 Islands shall be formed where it is necessary to sink wells in water of reasonable depth. The dimensions, method of construction, top level and side-slopes, if any, shall be as specified or got approved by the Engineer, depending on the local conditions.

2.8.5.2 Construction of Island

The island shall be made up of sand, earth or other approved material, deposited in uniform layers. The material shall be free from clods, stones or other hard materials which may obstruct the sinking of the well or deviate it from the correct location or plumb.

Where the water is shallow, the filling may be done within a ring of sand bags laid all round for protection. Alternatively, side-slopes may be formed and protected by pitching of stones or sand bags.

Where the depth of water is such that the above methods are rendered unsuitable, two rows of piling, with bamboos or casuarina piles or any other material as

approved by the Engineer, shall be driven all round. The piles shall be of such dimensions and driven to such spacing and depths as considered by the Engineer to be sufficient to withstand any possible scour and at the same time retain the earth fill of the island in a stable manner. Each row shall be lashed round with wire rope or bound together with horizontal bamboos or bullies at top. Two rows of bamboo matting shall be placed on the inside of the piling and the inter space filled up with earth. Alternatively, sand bags may be used for the filling. The inside space, i.e. within the inner row of piling, shall thereafter be filled up with the approved material for forming the island.

2.8.5.3 The island shall be maintained throughout the sinking operation and for any further period as may be necessary for completion of other items of the bridge work. If any of these works gets carried over to the next working season, the Contractor shall not be entitled for any compensation on account of repairs to damages caused to the island during the floods.

2.8.5.4 If so directed by the Engineer in writing, the Contractor shall remove the whole or part of the island when it is no longer required and / or when such removal is necessary to clear the obstruction to the water-way.

2.8.5.5 The rate for forming an island shall, unless otherwise stipulated, include the cost of its construction, its maintenance for the period of utility and its removal to the extent ordered in terms of sub para 4 above.

2.8.6 CUTTING EDGES FOR WELL CURBS

2.8.6.1 Unless otherwise specified, the cutting edges shall be fabricated out of new structural steel. The fabrication shall be done strictly in accordance with the detailed drawings and shall conform to the specifications.

2.8.6.2 Before being taken to the site, the cutting edge shall be assembled on level ground and verified for the accuracy of its shape and size. If in sections, the individual sections shall be match marked before being dismantled.

At the place for laying, necessary reference points to site the well accurately shall be fixed in advance, based on the permanent reference pillars on either bank or the base line provided on either or both banks. The ground shall be prepared by leveling to an even surface at the level from which sinking of the well is to be commenced.

2.8.6.3 On the prepared bed the cutting edge shall be placed and positioned accurately with respect to the reference points fixed. It shall be supported evenly and to true level on a series of blocking timbers, spaced sufficiently close together to withstand and distribute to the soil below the full weight of the cutting edge plus the weight of shuttering and concrete, without any unequal settlement. Where the cutting edge is in sections, any welding or riveting required shall be done after the cutting edge has thus been assembled to the correct lay out and level.

2.8.6.4 The rate for the cutting edge shall, unless otherwise specified, include the cost of supply, fabrication, transporting and placing the cutting edge as specified

above, to its correct lay out and level including site joining by welding or bolting / riveting with cover/ fish plates.

2.8.7 WELL CURBS AND STEINING

2.8.7.1 The basic items of work shall conform to one or more of the following and relevant specifications as applicable:-

- Cement Concrete
- RCC

Concrete steining shall generally be cast in "lifts" not exceeding 2.0m in height, for the convenience of placing and consolidation without segregation. Sinking shall not be started till the depth of masonry or concrete to be sunk has set properly. In the case of concrete steining and RCC well curbs, the minimum periods as specified below shall be observed, unless any different period is prescribed by the Engineer, taking into account the local conditions or in the Contract.

For well curbs	**Minimum period**
(a) Removal of outer shuttering	12 hours
(b) Removal of inside shuttering	6 days
(c) Commencement of sinking	7 days
For Steining	
(a) Removal of outer or inside shuttering	6 hours
(b) Resumption of sinking	48 Hours

In any case, the sinking shall not commence until the work that has been added on has been passed by the Engineer's representative and the commencement of sinking approved.

2.8.7.2 Bond Bars, bond flats, bottle nuts etc which are built into the steining will be paid for separately, but no extra payment will be made for keeping these in the concrete or masonry work nor will any deduction be made for their volume from the total volume of the concrete or masonry unless specified otherwise.

2.8.8 PLUGGING AND FINISHING OF WELLS

2.8.8.1 Bottom Plug

a) The concrete used for the bottom and top plugs of foundation wells shall be of the specified mix, conforming to Specification for Cement Concrete

Where the bottom plugging is to be done under water, the special provisions of "Under Water Concreting" shall be observed carefully; and it shall further be ensured that the water inside the well has first been brought to a steady level, and there is no flow of water into the well.

b) Before the concrete is placed, the bottom of the well shall be inspected carefully and cleaned of any debris etc. The concreting shall be done in such a manner as to ensure thorough and even filling to the desired level. In under-water work, divers shall be engaged for the purpose, as may be required.

2.8.8.2 After the concrete has set fully, water shall be pumped out completely or partially, as directed by the Engineer, to test whether the plugging has been satisfactory. If complete dewatering is done, any kentledge required to counteract

buoyancy shall be provided before pumping out. In case appreciable leakage of water into the well is observed, the Contractor shall, at his own cost, arrange for its rectification by grouting etc.

2.8.8.3 Sand Filing

Sand filling shall commence after a period of 3 days of laying of bottom plug. Also, the height of the bottom plug shall be verified before starting sand filling.

Sand shall be clean and free from earth, clay clods, roots, boulders, shingles etc and shall be compacted as directed. Sand filling shall be carried out upto the level shown on the drawing, or as directed by the Engineer.

2.8.8.4 Top Plug

After filling sand upto the required level a plug of concrete of specified mix shall be provided over it as shown on the drawing, or as directed by the Engineer.

2.8.8.5 Well Cap

1. A reinforced cement concrete well cap will be provided over the top of the steining in accordance with the drawing. Form work will be prepared conforming to the shape of well cap. Concreting shall be carried out in dry condition.

2. The bottom of the well cap shall be laid preferably as low as possible, taking into account the water level prevalent at the time of casting. Bond rods of steining shall be anchored into the well cap.

2.8.9 Tolerances

The permissible tilt and shift shall not exceed 1 (horizontal) in 80 (vertical) and the shift at the well base shall not be more than 150mm in any resultant direction or 5% of the overall diameter or width as measured in the principal directions, whichever is less.

For the well steining and well cap the permissible tolerances shall be as follows:

a) Variation in dimension : +50mm–10mm
b) Misplacement from specified position in plan : 15mm
c) Surface irregularities measured with 3m straight edge: 5mm
d) Variation of levels at the top : $\pm$ 25mm

2.8.10 Tests and Standards of Acceptance

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria.

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

2.8.11 Measurements for payment

All quantities shall be measured from the drawing, or as ordered by the Engineer, excepting those required to be provided by the Contractor at his cost.

a) The cutting edge shall be measured in tonnes based on the net weight of metal used in it, nearest to one kilogram. However no deduction for the holes drilled will be done.

b) The concrete in curb, well steining and well cap shall be measured in cubic metres separately for each item. The reinforcement shall be measured in tonnes and no deduction for the bottle nuts will be done.

c) The measurement for well sinking shall be made in running metres for different depths and in different types of strata (Hard rock/ other rock &soils) unless otherwise specified in the Contract. The depth of sinking shall be measured from the Reduced level specified in the Contract. If no level has been specified in the Contract, sinking shall be measured from the low water level or from the level at which the cutting edge was laid whichever is higher.

d) The quantity of concrete in bottom and top plug shall be measured in cubic metres.

e) The quantity of sand filling shall be measured in cubic metres.

f) Pneumatic sinking, where required shall be paid as a separate item and shall be measured in cubic metres of material to be excavated unless otherwise specified in Contract.

2.8.12 Rate

i) The Contract unit rates of cutting edge shall cover all costs of labour, material, tools, plant and equipment, including placing in position, sampling and testing, and supervision, all as per respective Section of Structural Steel Work and as described in this Section.

ii) The Contract unit rates for concrete in curb, steining, bottom plug, top plug and well cap, shall cover all costs of labour, material, tools, plant and equipment, form work and staging including placing in position, sampling and testing, and supervision all as per respective Section of Reinforced Concrete and as described in this section.

iii) The Contract unit rates for reinforcement in curb, steining, and well cap shall cover all costs of labour, material, tools, plant and equipment, including bending to shape, placing in position, sampling, testing and supervision.

iv) The Contract unit rates for sand filling shall cover all costs of labour, material, tools, plant and equipment, including placing in position, sampling, testing and supervision, all as described in this section.

v) The unit rates for sinking shall cover the costs of labour, tools, and equipment and plant and for all operations and other incidentals for sinking of well including seating excepting provisions of pneumatic sinking as described in this Section. The unit rates shall specify the strata such as types of soil, rock, etc. The rates shall cover all testing, correction of tilt and shift to be within the tolerances and supervision required for the work.

vi) The Contract unit rate of material to be excavated by pneumatic sinking shall cover all costs of labour, material, tools, plant and other equipment and other incidentals and safety provisions and supervision required for pneumatic sinking as per this Section.

vii) Reduction in contract unit rates for sinking as a penalty, in pursuance of Para 2.8.4.13 will be as stated below, unless otherwise specified in contract.

If any well with tilt and / or shift exceeding beyond permissible values is accepted by the Engineer, the Contractor shall give a reduction in the rates as follows:

SL	Amount of Tilt and / or shift	Per cent deduction on the rate (s) for sinking of whole well
1	Tilt exceeding the specified permissible value but equal to or within 1 in 60	10 per cent
2	Till exceeding 1 in 60 but equal to or within 1 in 50	15 per cent
3	Shift exceeding the specified permissible value but equal to or within 200mm	5 per cent
4	Shift exceeding 200mm but equal to or within 300 mm	10 per cent

Note: Penalties for excessive tilt and shift shall be deducted separately.

2.9 SUB STRUCTURE - The term substructure covers:

a) Piers

b) Abutments and

c) Wing walls

d) Bed Blocks

e) Ballast retainers or dirt walls

f) Arches which form integral part of the pier / abutment in Arch bridges and

g) Face walls or spandrels of Arches.

They can be made of :

i) Brick Masonry

ii) Stone Masonry

iii) Plain Concrete or Reinforced Concrete

Some special requirements as provision of temperature or nominal reinforcements with respect to form work are covered in this chapter. Brick work and stone work specification covered in relevant chapters are applicable.

2.10 FORM WORK

2.10.1 General

This section covers requirement of form work for bridge foundations, sub structure and superstructures. Form work as per **IS-3696, IS-4014** shall include all temporary or permanent forms required for forming the concrete of the shape, dimensions and surface finish as shown on the drawing or as directed by the Engineer, together with all props, staging, centering, scaffolding and temporary construction required for their support.

2.10.2 Material and Design

The Contractor shall furnish the design and drawing of complete form work (i.e. the forms as well as their supports) for approval of the Engineer before any erection is taken up. Materials used for form work will be steel or timber. All bolts shall be counter sunk. Approved internal steel ties, struts and plastic spacers may be used if approved. Steel plate shall be of adequate thickness and thickness of walls of steel tubes used for supporting shall be at least 4mm. If proprietary system of form work is used, the Contractor shall furnish detailed information to the Engineer for approval.

Notwithstanding any approval or review of drawing and design by the Engineer, the Contractor shall be entirely responsible for the adequacy and safety of form work.

The design of the form work shall be such that it shall ensure that the forms can be conveniently removed without disturbing the concrete. The design shall facilitate proper and safe access to all parts of form work for inspection. In the case of prestressed concrete superstructure, careful consideration shall be given to redistribution of loads on props due to prestressing.

2.10.3 Workmanship

i) The form work shall be robust and strong and the joints shall be leak-proof. Balli shall not be used as staging. Staging must have cross bracings and diagonal bracings in both directions. Staging shall be provided with an appropriately designed base plate resting on firm strata. Approved steel or trestles or cribs or standard pipe scaffolding shall be used.

ii) The number of joints in the form work shall be kept to a minimum by using large size panels. The design shall provide for proper “soldiers” to facilitate alignment. All joints shall be leak proof and must be properly sealed. Use of PVC Joint sealing tapes, foam rubber or PVC T-Section is essential to prevent leakage of grout.

As far as practicable, clamps shall be used to hold the forms together. Where use of nails is unavoidable, minimum number of nails shall be used and these shall be left projecting so that they can be withdrawn easily.

iii) Use of ties shall be restricted, as far as practicable. Wherever ties are used they shall be used with HDPE sheathing so that the ties can easily be removed. No parts prone to corrosion shall be left projecting or near the surface. The sheathing holes if permitted shall be grouted with cement mortar of the same strength as that of the structure.

Unless otherwise specified, or directed, chamfers or fillets of sizes 25mm x 25mm shall be provided at all angles of the form work to avoid sharp corners. The chamfers, bevelled edges and mouldings shall be made in the form work itself. Opening for fixtures and other fittings shall be provided in the shuttering as directed by the Engineer.

Shuttering for walls, sloping members and thin sections of considerable height shall be provided with temporary openings to permit inspection and cleaning out before placing of concrete.

iv) The form work shall be constructed with pre-camber to the soffit to allow for deflection of the form work. Pre-camber to allow for deflection of form work shall be in addition to that indicated for the permanent structure in the drawings.

Where metal forms are used, all bolts and rivets shall be countersunk and well ground to provide a smooth, plane surface. Where timber is used it shall be well seasoned, free from loose knots, projecting nails, splits or other defects that may mar the surface of concrete.

v) Forms shall be made sufficiently rigid by the use of ties and bracings to prevent any displacement or sagging between supports. They shall be strong enough to withstand all pressure, ramming and vibration during and after placing the concrete. Screw jacks or hard wood wedges where required shall be provided to make up any settlement in the form work either before or during the placing of concrete.

vi) Where centering trusses or launching trusses are adopted for casting of superstructure, the joints of the centering trusses, whether welded, riveted or bolted should be thoroughly checked periodically. Also, various members of the centering trusses should be periodically examined for proper alignment and unintended deformation before proceeding with the concreting. They shall also be periodically checked for any deterioration in quality due to steel corrosion.

vii) The formwork shall take due account of the calculated amount of positive or negative camber so as to ensure the correct final shape of the structures, having regard to the deformation of false work, scaffolding or propping and the instantaneous or deferred deformation due to various causes affecting prestressed structures. Suitable camber shall be provided to horizontal members of structure, especially in long spans to counteract the effects of deflection. The form work shall be so fixed as to provide for such camber.

viii) The form work shall be coated with an approved release agent that will effectively prevent sticking and will not stain the concrete surface. Lubricating (machine oils) shall be prohibited for use as coating. The inside surfaces of forms shall, except in the case of permanent form work or where otherwise agreed to by the Engineer be coated with a release agent supplied by approved manufacturer or of an approved material to prevent adhesion of concrete to the form work. Release agents shall be applied strictly in accordance with the manufacturer's instructions and shall not be allowed to come into contact with any reinforcement or prestressing tendons and anchorages. Different release agents shall not be used in form work for exposed concrete.

2.10.4 Formed Surface and Finish

The form work shall be lined with material approved by the Engineer so as to provide a smooth finish of uniform texture and appearance. This material shall leave no stain on the concrete and so fixed to its backing as not to impart any blemishes. It shall be of the same type and obtained from only one source throughout for the construction of any one structure. The contractor shall make good any imperfections in the resulting finish as required by the Engineer. Internal ties and embedded metal parts shall be carefully detailed and their use shall be subject to the approval of the Engineer.

2.10.4.1 Precautions in Bridge Works

i) Special measures in the design of form work shall be taken to ensure that it does not hinder the shrinkage of concrete. The soffit of the form work shall be so designed as to ensure that the formwork does not restrain the shortening and / or

hogging of beams during prestressing. The forms may be removed at the earliest opportunity subject to the minimum time for removal of forms with props retained in position.

ii) Where necessary, form work shall be so arranged that the soffit form, properly supported on props only can be retained in position for such period as may be required by maturing conditions of concrete.

iii) Any cut-outs or openings provided in any structural member to facilitate erection of form work shall be closed with the same grade of concrete as the adjoining structure immediately after removal of form work ensuring water tight joints.

iv) Provision shall be made for safe access on, to and about the form work at the levels as required.

v) Close watch shall be maintained to check for settlement of form work during concreting. Any settlement of form work during concreting shall be promptly rectified.

vi) Water used for curing should not be allowed to stagnate near the base plates supporting the staging and should be properly drained.

2.10.5 Removal of Form work for Reuse

i) The scheme for removal of form work (i.e. de-shuttering and decentering) shall be planned in advance and furnished to the Engineer for scrutiny and approval. The form work shall be so removed as not to cause any damage to concrete. Centering shall be gradually and uniformly lowered in such a manner as to permit the concrete to take stresses due to its own weight uniformly and gradually and any shock or vibration to structure is avoided.

ii) Where not specifically approved, the time of removal of form work (when ordinary Portland Cement is used without any admixtures at an ambient temperatures exceeding 10 degrees Celsius) shall be as under:

a. Walls, piers, abutments, columns and vertical faces of structural members	:	12 to 48 hours as may be decided by the Engineer
b. Soffits of Slabs (with props left under)	:	3 days
c. Props (left under slabs)	:	14 days
d. Soffit of Girders (with props left under)	:	7 days
e. Props (left under girders)	:	21 days

iii) Where there are re-entrant angles in the concrete sections, the form work should be removed at these sections as soon as possible after the concrete has set, in order to avoid cracking due to shrinkage of concrete.

iv) When form work is dismantled, its individual components shall be examined for damage and damaged pieces shall be removed for rectification. Such examination and rectification shall always be carried out before being used again. Before re-use all components shall be cleaned of deposits of soil, concrete or other unwanted materials. Threaded parts shall be oiled after cleaning. All bent steel props shall be straightened before re-use. The maximum deviation from straightness is 1/ 600 of the length. The maximum permissible axial loads in used props shall be suitably reduced depending upon their condition. The condition of the timber components, plywood and steel shuttering plates shall be examined closely for distortion and defects before re-use.

2.10.6 Re-use of Form work:

Before re-use of forms, the following actions shall be taken:

i) The contact surfaces of the forms shall be cleaned carefully thoroughly and dried before applying a release agent.

ii) It should be ensured that the release agent is appropriate to the surface to be coated. The same type and make of release agent shall be used throughout on similar form work materials and different types should not be mixed.

iii) The form surfaces shall be evenly and thinly coated with release agent. The vertical surface shall be treated before horizontal surface and any excess wiped out.

iv) The release agent shall not come in contact with reinforcement or the hardened concrete. All forms shall be thoroughly cleaned immediately before concreting.

2.10.6.1 Specialized Form work

a) Specialised form work may be required in the case of slip form work, underwater concreting, segmental construction etc. Such specialised form work shall be designed and detailed by competent agencies and a set of complete working drawings and installation instructions shall be supplied to the Engineer. The site personnel shall be trained in the erection and dismantling as well as operation of such specialised form work. In case proprietary equipment is used, the supplier shall supply drawings, details, installation instructions etc. in the form of manuals along with the form work. Where specialized form work is used, close coordination with the design of permanent structure is necessary.

2.11 SUB STRUCTURE

2.11.1 Piers and Abutments

a) Masonry, form work, concrete and reinforcement for piers and abutments shall conform to relevant sections of these specifications and drawings. In case of concrete piers, minimum grade will be M 20 unless otherwise specified / approved. The number of horizontal construction joints shall be kept to minimum. Construction joints shall be avoided in splash zones unless specifically permitted by the Engineer and provided they are treated in accordance with special provisions. No vertical construction joint shall be provided. Shear connectors in the form of vertical plumbs, dowels, bond bars or rail cut pieces shall be provided at all horizontal joints as directed by Engineer. The work shall conform strictly to the drawings or as directed by the Engineer.

b) In case of tall piers and abutments, use of slipform shall be preferred. The design, erection and raising of slip form shall be subject to special specifications which will be furnished by the Contractor. The concrete shall also be of higher grade and subject to additional specifications as necessary. All specifications and arrangements shall be subject to the approval of the Engineer.

c) The surface of foundation / well cap / pile cap shall be scraped with wire brush and all loose materials removed. In case reinforcing bars projecting from foundations are coated with cement slurry, the same shall be removed by tapping, hammering or wire brushing. Care shall be taken to remove all loose materials around reinforcements. Just before commencing masonry or concrete work, the surface shall be thoroughly wetted.

d) In case of solid (non-spill through type) abutments, weep holes as shown on the drawings or as directed by the Engineer, shall be provided.

e) The surface finish shall be smooth, except the earth face of abutments which shall be rough finished or left as form finished.

f) In case of abutments likely to experience considerable movement on account of backfill of approaches and settlement of foundations, the construction of the abutment shall be followed by filling up of embankment in layers simultaneously with filter backing behind to the full height to allow for the anticipated movement during construction period before casting of superstructure.

2.11.2 Pier Cap and Abutment Cap (Bed Blocks)

a) Form work, Concrete and reinforcement shall conform to relevant paras of Concrete work & RCC of these specifications and the Drawings. Unless otherwise specified, minimum grade of concrete mix shall be M 25.

b) The locations and levels of pier cap / abutment cap / pedestals and bolts for fixing bearings shall be checked carefully to ensure alignment in accordance with the drawings of the bridge.

c) The surface of cap shall be finished smooth and shall have a slope for draining of water as shown on the drawings or as directed by the Engineer. For short span slab bridges with continuous support on pier caps, the surface shall be cast horizontal. The top surface of the pedestal on which bearings are to be placed shall also be cast horizontal.

d) The surface on which elastomeric bearings are to be placed shall be wood float finished to a level plane which shall not vary more than 1.5mm from straight edge placed in any direction across the area. The surface on which other bearings (steel bearings, pot bearings) are to be placed shall be cast about 25mm below the bottom level of bearings and as indicated on the drawings. Specified rich levelling mortar shall be provided over this at the time of placing of bearing.

2.11.3 Dirt / Ballast Wall, Return Wall and Wing wall

Dirt and ballast walls shall be in RCC. Minimum grade of concrete will be M25 unless otherwise specified. Return walls and wing walls can be of masonry (brick or stone), concrete or in RCC, as specified in drawings. Minimum grade of concrete for them will be M20 unless otherwise specified.

i) Brick Work Stone:- Masonry, concrete and reinforcement shall conform to relevant chapters of these specifications and Drawings.

ii) In case of cantilever return walls, no construction joint shall generally be permitted. Wherever feasible, the concreting in cantilever return walls shall be carried out in continuation of the ballast wall.

iii) For gravity type masonry and concrete return and wing wall, the surface of foundation shall be prepared in the same manner as prescribed for construction of abutment. No horizontal construction joint shall be provided. If shown on drawing or directed by the Engineer, vertical construction joint may be provided. Vertical expansion gap of 20mm shall be provided in return wall / wing wall at every 10 metre intervals or as directed by the Engineer. Weep holes shall be provided as prescribed for abutments or as shown on the drawings.

iv) Form work, reinforcement and concrete in dirt / ballast wall shall conform to relevant sections of these specifications.

v) The finish of the surface on the earth side shall be rough/form finish while the front face shall be smooth finished.

vi) Architectural coping for wing wall / return wall in brick masonry shall conform to Drawings.

2.11.4 Tests and Standards of Acceptance

The materials shall be tested in accordance with these specifications and shall meet the prescribed criteria.

The work shall conform to these specifications and shall meet the prescribed standards of acceptance.

2.11.5 Tolerances in Concrete elements

a) Variation in cross-sectional dimensions : + 10mm, -5mm
b) Misplacement from specified position in plan : 10mm
c) Variation of levels at the top : $\pm$ 10mm
d) Variations of reduced levels of bearing areas : $\pm$ 5mm
e) Variations from plumb over full height : $\pm$ 10mm
f) Surface irregularities measured with 3m straight edge
    - All surfaces except bearing areas : 5mm
    - Bearing areas: 3 mm

2.11.6 Measurements

Reference is drawn to Para 2.6.10

2.11.7 Rates

Reference is drawn to Para 2.6.11.

Chapter 3
Bridge Work : Superstructure-RCC

3.1 GENERAL

3.1.1 Coverage

This chapter covers specifications for Reinforced Concrete and Prestressed Concrete superstructure of bridges. Bridge superstructure work in form of

i) Slabs –both RCC and PSC

ii) RCC Beams and Slabs

iii) Prestressed concrete girders and slabs

3.1.2 The girders and slabs may be cast-in-situ or precast in units, transported and erected. The precast elements may be in complete units; individual girders or of girders-in segments. Deck slab will be cast in situ in case of I or T section girders.

3.1.3 Codes and Specifications to cover

3.1.3.1 The provisions in codes listed in these specifications and specifications accompanying the contract documents so far as they are applicable to superstructure shall be strictly followed.

3.1.3.2 Contractor shall study the general arrangement drawings (GADs) and other detailed drawings accompanying contract documents and point out any discrepancies, short comings and contradictions and shall have them clarified and reconciled before start of the work. Any delay caused due to contractor seeking such clarification during progress of work will be considered to contractor's account.

3.1.3.3 Contractor will be responsible for preparation of further detailing and preparation of bar bending schedules.

3.1.4 Methodology Statement

3.1.4.1 Contractor will submit a 'methodology statement' if not already included in the bid offer at tendering stage itself and have it approved by the Engineer at start of work. This statement shall include:

i) Sequencing of work, vis-à-vis the substructure work

ii) PERT chart to fit in with overall duration within targeted completion date

iii) Requirement and arrangements proposed in base depot / precasting yard including form work designs and details.

iv) Scheme for transport of precast elements.

v) Girder erection scheme including prestressing, grouting, alignment etc.

vi) Scheme for providing accessories / appurtenances.

3.1.4.2 Before commencement of work, Contractors will discuss with Engineer and finalise the details listed above. If any changes in the scheme are called for, the Contractor will promptly bring such necessity to notice of Engineers and give his proposals in writing. They will be discussed and finalised in a workmanlike manner. Any delay and cost involved will be to contractor's account

unless such change has been called for due to any major change in design or scope of the work or change of policy of Government.

3.1.4.3 Nothing extra is payable for preparation and finalisation of the Methodology / Methods Statement.

3.2 FORM WORK

3.2.1 General Requirement

Form work shall include all temporary or permanent forms required for forming the concrete of the shape, dimensions and surface finish as shown on the drawing or as directed by the Engineer, together with all props, staging, centering, scaffolding and temporary construction required for their support. Unless otherwise specified in contract documents or by the Engineer, the design, erection and removal of form work shall conform to IRC 87 “Guidelines for Design and Erection of False work for Road Bridges” and these specifications.

3.2.2 Materials

Forms shall be constructed with metal or timber. The metal used for forms shall be of such thickness that the forms remain true to shape. All bolts should be countersunk. The use of approved internal steel ties or steel or plastic spacers shall be permitted. Structural steel tubes used as support for forms shall have a minimum wall thickness of 4mm. Other materials conforming to the requirements of IRC 87, or other proven standard products may also be used if approved by the Engineer.

3.2.3 Pre-camber and Rigidity

3.2.3.1 The form work shall be constructed with pre-camber to the soffit to allow for settlement / deflection of the form work. Pre-camber to allow for deflection of form work shall be in addition to that indicated for the permanent structure in the drawings.

3.2.3.2 Where centering trusses or launching trusses are adopted for casting of superstructure, the joints of the centering trusses, whether welded, riveted or bolted should be thoroughly checked periodically. Also, various members of the centering trusses should be periodically examined for proper alignment and levels and unintended deformation before proceeding with the concreting, They shall also be periodically checked for any deterioration in quality due to steel corrosion, loose joints, damaged individual members etc.

3.2.3.3 The form work shall be so made as to produce a finished concrete true to shape, line and levels and dimensions as shown on the drawings, subject to the tolerances specified in respective sections of these specifications, or as directed by the Engineer.

3.2.3.4 Forms shall be made sufficiently rigid by the use of ties and bracings to prevent any displacement or sagging between supports. They shall be strong enough to withstand all pressure, ramming and vibration during and after placing the concrete. Screw jacks or hard wood wedges where required shall be provided to make up for any settlement in the form work either before or during the placing of concrete

3.2.3.5 Unless otherwise specified fillets of size 25m x 25m shall be provided at sharp corners. Where ties are used, they shall be used with HDPE sheathing,

for ease of removal after concreting. Sheathing shall be grouted with cement mortar of same strength as precast concrete.

3.2.4 Preparation of Form work before Concreting

3.2.4.1 The inside surfaces of forms shall, except in the case of permanent form work or where otherwise agreed to by the Engineer be coated with a release agent supplied by approved manufacturer or of an approved material to prevent adhesion of concrete to the form work. Release agents shall be applied strictly in accordance with the manufacturer's instructions and shall not be allowed to come into contact with any reinforcement or prestressing tendons and anchorages. Different release agents shall not be used in form work for exposed concrete.

3.2.4.2 All forms shall be thoroughly cleaned immediately before concreting.

3.2.4.3 The Contractor shall give the Engineer due notice before placing any concrete in the forms to permit him to inspect and approve the form work, but such inspection shall not relieve the contractor of his responsibility for safety of form work, men, machinery, materials and finish or tolerances of concrete.

3.2.4.4 Where not specifically mentioned otherwise, the time of removal of form work (when ordinary Portland Cement is used without any admixtures at an ambient temperatures exceeding 10 degrees Celsius) shall be as given in Para 2.10.5.

3.2.4.5 In order to verify the time and sequence of striking / removal of specialised form work, routine field tests for the consistency of concrete and strength development are mandatory and shall be carried out before adoption.

3.2.5 Measurements and Rate

(a) Measurements

i) The rate for concrete in Plain Concrete or Reinforced Concrete or Prestressed Concrete shall exclude all form work required in accordance with this section and formwork shall be measured and paid separately.

ii) Measurement of form work shall be taken in square metres of the surface area of concrete which is in contact with form work. For this, linear measurement shall be made covered to nearest cm and area computed to 0.01 sqm.

b) Rate

i) The unit rate of the Plain Concrete or Reinforced Concrete or Prestressed Concrete as defined in respective sections shall be deemed to cover the costs of all materials, labour, tools and plant required for design, construction and supervision as described in this section including properly supporting the members until the concrete is cured, set and hardened as required except form work.

ii) Unit rate for form work shall include the cost of all materials, labour, tools and plant required for design, construction and removal of form work and supervision as described in this Section including properly supporting the members until the concrete is cured, set and hardened as required.

3.3 CONCRETE FOR SUPERSTRUCTURE

3.3.1 General: Concrete used in any of the bridge structures will conform to the provisions made in Concrete work & RCC, supplemented and / or modified to the extent the following clauses cover.

3.3.2 Basic Requirements: (i) Unless otherwise specified, minimum grades of concrete to be used for superstructure are as given in Table 3.1(a) below or as shown in the drawings.

Table 3.1 (a) Minimum Grade of Concrete

Type of Work	Moderate Exposure	Severe Exposure
RCC Boxes and RCC cast in situ slabs	M 20	M 25
RCC precast slabs	M 25	M 30
RCC T-beam and slab	M 35	M 40
PSC slabs / girders	M 40	M 45

Minimum Cement content and maximum Water -Cement ratio will be as given in Tables 3.1(b) and 3.1(c) below.

Table 3.1 (b) Minimum Cement Concrete and Water Cement Ratio

Type of Work	Minimum Cement kg/cum	Exposure Condition W/c Ratio	
		Normal	Severe
Major Works			
PCC members	360	0.45	0.45
RCC members	400	0.45	0.40
PSC members	400	0.45	0.40

Table 3.1 (c) For minor works upto 30m span girders given

Type of work	Minimum Cement kg/cum Severe	Exposure Condition W/c Ratio	
		Normal	Severe
PCC members	250 to 310	0.50	0.45
RCC members	310 to 400	0.45	0.40

For concrete in very severe and extreme exposure conditions, provisions in Concrete work chapter may be referred to. For underwater concreting 10% extra cement will be added.

ii) **Requirements of Consistency**

The mix shall have the consistency which will allow proper placement and consolidation in the required position. Every attempt shall be made to obtain uniform consistency.

The optimum consistency for various types of structures shall be as indicated in Table 3.2 or as directed by the Engineer. The slump of concrete shall be checked as per IS:516.

Table 3.2 Slump Required for Workability

	Type	**Slump (mm)**
1	(a) Structures with exposed inclined surface requiring low slump concrete to allow proper compaction	25
	(b) Plain Cement Concrete	25
2	RCC structures with widely spaced reinforcements; e.g. solid columns, piers, abutments, footings, well steining	40-50
3	RCC structures with fair degree of congestion of reinforcement; e.g. pier and abutment caps, box culverts well curb, well cap, walls with thickness greater than 300mm	50-75
4	RCC and PSC structures with highly congested reinforcements e.g. deck slab girders, box girders, walls with thickness less than 300mm	75-125
5	Underwater concreting through tremie e.g. bottom plug, cast-in-situ piling	100-200

iii) **Additional Requirements**

Concrete shall meet with any other requirements as specified on the drawing or as directed by the Engineer. Additional requirements shall also consist of the following overall limits of deleterious substances in concrete:

a) The total chloride content of all constituents of concrete as a percentage of mass of cement in mix shall be limited to values given below:

- Prestressed Concrete : 0.1 per cent
- Reinforced concrete exposed to chloride in service : 0.2 per cent
  (e.g. structures located near sea coast)
- Other reinforced concrete construction : 0.3 per cent

b) The total sulphuric anhydride (SO_2) content of all the constituents of concrete as a percentage of mass of cement in the mix shall be limited to 4 per cent.

3.3.3 Admixtures

Use of admixtures such as superplasticisers for concrete may be made with the approval of the Engineer. As the selection of an appropriate concrete admixture is an integral part of the mix design, the manufacturers shall recommend the use of any one of his products only after obtaining complete knowledge of all the actual constituents of concrete as well as methodologies of manufacture, transportation and compaction of concrete proposed to be used in the project.

Manufacturer should provide satisfactory evidence that such admixtures do not have adverse effect the properties of concrete or mortar particularly with respect to

strength, volume change, durability and has no deleterious effect on the reinforcement. Admixtures used should conform to provisions of IS: 9103.

Calcium chloride or admixtures containing calcium chloride shall not be used in structural concrete containing reinforcement, prestressing tendon or other embedded metal. Also admixtures containing Cl and SO_3 ions or nitrates shall not be used. Admixtures based on thiocyanate can promote corrosion and hence are prohibited.

3.3.4 Size of Coarse Aggregate

The size (maximum nominal) of coarse aggregates for concrete to be used in various components of bridges shall be given as Table 3.3.

TABLE 3.3 Coarse Aggregate Size

	Components	Maximum Nominal Size of Coarse Aggregate (mm)
i)	RCC well curb	20
ii)	RCC/ PCC well steining	40
iii)	Well cap or Pile Cap Solid type piers and abutments	40
iv)	RCC work in girders, slabs, wearing coat, kerb, approach slab, hollow piers and abutments, pier / abutment caps, piles	20
v)	PSC work	20
vi)	Any other item	As specified by Engineer

Maximum nominal size of aggregates shall also be restricted to the smaller of the following values:

a) 10mm less than the minimum lateral clear distance between main reinforcements

b) 10mm less than the minimum clear cover to the reinforcements

The proportions of the various individual size of aggregates shall be so adjusted that the grading produces densest mix and the grading curve corresponds to the maximum nominal size adopted for the concrete mix.

3.3.5 Equipment

Unless specified otherwise, equipment for production, transportation and compaction of concrete shall be as under:

a) For Production of Concrete:

   i. For overall bridge length of less than 200 metres – batch type concrete mixer diesel or electric operated, with a minimum size of 200 litres, automatic water measuring system and integral weigher (hydraulic / pneumatic type)

ii. For overall bridge length of 200 metres or more – concrete batching and mixing plant fully automatic with minimum capacity of 15 cum. per hour.

All measuring devices of the equipment shall be maintained in a clean and serviceable condition. Its accuracy shall be checked over the range in use, when set up at each site and thereafter periodically as directed by the Engineer.

The accuracy of the measuring devices shall fall within the following limits:

Measurement of Cement ± 3 per cent of the quantity of cement in each batch

Measurement of Water ± 3 per cent of the quantity of water in each batch

Measurement of Aggregate ± 3 per cent of the quantity of aggregate in each batch

Measurement of Admixture ± 3 per cent of the quantity of admixture in each batch

b) For Concrete Transportation : depending upon actual requirement

- i) Concrete dumpers — minimum 2 tonnes capacity
- ii) Powered hoists — minimum 0.5 tonne capacity
- iii) Chutes
- iv) Buckets handled by cranes
- v) Transit truck mixer
- vi) Concrete pump
- vii) Concrete distributor booms
- viii) Belt conveyor
- ix) Cranes with skips
- x) Tremies

c) For Compaction of Concrete:

- i) Internal vibrators — size 25mm to 70mm
- ii) Form vibrators — minimum 500 watts
- iii) Screed vibrators — full width of carriage way (upto two lanes)

3.3.6 Transporting, Placing and Compaction

i) The method of transporting and placing concrete shall be approved by the Engineer. Concrete shall be transported and placed as near as practicable to its final position, so that no contamination, segregation or loss of its constituent materials takes place. Concrete shall not be freely dropped into place from a height exceeding 1.5 metres.

ii) When concrete is conveyed by chute, the plant shall be of such size and design as to ensure practically continuous flow. Slope of the chute shall be so adjusted that the concrete flows without the use of excessive quantity of water and without any segregation of its ingredients. The delivery end of the chute shall be as close as possible to the point of deposit. The chute shall be thoroughly flushed with water before and after each working period and the water used for this purpose shall be discharged outside the form work.

iii) All form work and reinforcement contained in it shall be cleaned and made free from standing water, dust, snow or ice immediately before placing of concrete.

iv) No concrete shall be placed in any part of the structure until the approval of the Engineer has been obtained.

v) If concreting is not started within 24 hours of the approval being given, it shall have to be obtained again from the Engineer. Concreting then shall proceed continuously over the area between the construction joints. Fresh concrete shall not be placed against concrete which has been in position for more than 30 minutes unless a proper construction joint is formed.

vi) Except where otherwise agreed to by the Engineer, concrete shall be deposited in horizontal layers to a compacted depth of not more than 450mm when internal vibrators are used and not exceeding 300mm in all other cases.

vii) Concrete when deposited shall have a temperature of not less than 5 degrees Celsius, and not more than 40 degrees Celsius. It shall be compacted in its final position within 30 minutes of its discharge from the mixer, unless carried in properly designed agitators, operating continuously. It may be necessary to add retarding admixtures to concrete if trials show that the periods indicated above are unacceptable. In all such matters, the Engineer's decision shall be final.

viii) Concrete shall be thoroughly compacted by vibration, or other means approved by Engineer, during placing and worked around the reinforcement, tendons or duct formers, embedded fixtures and into corners of the form work to produce a dense homogeneous void-free mass having the required surface finish. When vibrators are used, vibration shall be done continuously during the placing of each batch of concrete until the expulsion of air has practically ceased and in a manner that does not promote segregation. Over vibration shall be avoided to minimise the risk of forming a weak surface layer. When external vibrators are used, the design of form work and disposition of vibrator shall be such as to ensure efficient compaction and to avoid surface blemishes. Vibrators shall not be applied through reinforcement and where vibrators of immersion type are used, contact with reinforcement and all inserts like ducts etc., shall be avoided. The internal vibrators shall be inserted in an orderly manner and the distance between insertions should be about one and a half times the radius of the area visibly affected by vibration. Additional vibrators in serviceable condition shall be kept at site so that they can be used in the event of breakdowns.

ix) Mechanical vibrators used shall comply with requirement of IS: 2502, IS:2505, IS 2514 and IS:4656.

3.3.7 Construction Joints

Construction Joints shall be avoided as far as possible and in no case the locations of such joints shall be changed or increased from those shown on the drawings, except with express approval of the Engineer. The joints shall be provided in a direction perpendicular to the member axis.

Location, preparation of surface and concreting of construction joints shall conform to the additional specifications given in **Annexure 3.1**and concreting work chapter.

3.3.8 Concreting in Adverse Weather Conditions

3.3.8.1 Cold Weather Concreting

Where concrete is to be deposited at or near freezing temperature, precautions shall be taken to ensure that at the time of placing, it has a temperature of not less than 5 degrees Celsius and that the temperature of the concrete shall be maintained above 4 degrees Celsius until it has thoroughly hardened. When necessary, concrete ingredients shall be heated before mixing but cement shall not

be heated artificially other than by the heat transmitted to it from other ingredients of the concrete. Stock piled aggregate may be heated by the use of dry heat or steam. Aggregates shall not be heated directly by gas or on sheet metal over fire. In general, the temperature of aggregates or water shall not exceed 65 degrees Celsius. Salt or other chemicals shall not be used for the prevention of freezing. No frozen material or materials containing ice shall be used. All concrete damaged by frost shall be removed. It is recommended that concrete exposed to freezing weather shall have entrained air and the water content of the mix shall not exceed 30 litres per 50 kg of cement.

3.3.8.2 Hot Weather Conditions

When depositing concrete in very hot weather, precautions shall be taken so that the temperature of wet concrete does not exceed 40 degrees Celsius while placing. This shall be achieved by stacking aggregate under the shade and keeping them moist, using cold water, reducing the time between mixing and placing to the minimum, cooling form work by sprinkling water, starting curing before concrete dries out and restricting concreting as far as possible to early mornings and late evenings. When ice is used to cool mixing water, it will be considered a part of the water in design mix. Under no circumstances shall the mixing operation be considered complete until all ice in the mixing drum has melted.

The Contractor will be required to state his methodology for the Engineer's approval when temperatures of concrete are likely to exceed 40 degrees Celsius during the work.

3.3.9 Protection and Curing

3.3.9.1 Concreting operations shall not commence until adequate arrangements for concrete curing have been made by the Contractor. Curing and protection of concrete shall start immediately after compaction of the concrete to protect it from:

a) Premature drying out particularly by solar radiation and wind

b) High internal thermal gradients

c) Leaching out by rain and flowing water

d) Rapid cooling during the first few days after placing

e) Low temperature or frost

f) Vibration and impact which may disrupt the concrete and interfere with its bond to the reinforcement.

3.3.9.2 Where members are of considerable size and length, with high cement content, accelerated curing methods may be applied, as approved by the Engineer.

3.3.9.3 Water Curing

Water for curing shall be as specified in Concrete work chapter specification and approved by the Engineer. Sea water shall not be used for curing. Sea water shall not come into contact with concrete members unless it has attained adequate strength.

Exposed surfaces of concrete shall be kept continuously in a damp or wet condition by ponding or by covering with a layer of sacks, canvas, Hessian or similar materials

and shall be kept constantly wet for a period of not less than 14 days from the date of placing of concrete.

3.3.9.4 Steam curing

i) Where steam curing is adopted, it shall be ensured that it is done in a suitable enclosure to contain the live steam in order to minimise moisture and heat losses. The initial application of the steam shall be after about four hours of placement of concrete to allow the initial set of the concrete to take place.

ii) Where retarders are used, the waiting period before application of the steam shall be increased to about six hours.

iii) The steam shall be at 100 per cent relative humidity to prevent loss of moisture and to provide excess moisture for proper hydration of the cement. The application of steam shall not be directly on the concrete and the ambient air temperature shall increase at a rate not exceeding 5 degrees Celsius per hour until a maximum temperature of 6 degrees Celsius to 70 degrees Celsius is reached. The maximum temperature shall be maintained until the Concrete has reached the desired strength.

iv) When steam curing is discontinued, the ambient air temperature shall not drop at a rate exceeding 5 degrees Celsius per hour until a temperature of about 10 degrees Celsius above the temperature of the air to which the concrete will be exposed, has been reached. The concrete shall not be exposed to temperatures below freezing for at least six days after curing.

3.3.9.5 Curing Compounds

a) Curing compounds shall only be permitted in special circumstances and will require specific approval of the Engineer. Curing compounds shall not be used on any surface which requires further finishing to be applied. All construction joints shall be moist, cured and no curing compound will be permitted in locations where concrete surfaces are required to be bonded together.

b) Curing compounds shall be continuously agitated during use. All concrete cured by this method shall receive two applications of the curing compound. The first coat shall be applied immediately after acceptance of concrete finish. If the surface is dry, the concrete shall be saturated with water and curing compound applied as soon as the surface film of water disappears. The second application shall be made after the first application has set. Placement in more than two coats may be required to prevent streaking.

3.3.10 Finishing

i) Immediately after the removal of forms, exposed bars or bolts, if any, shall be cut inside the concrete member to a depth of at least 50mm below the surface of the concrete and the resulting holes filled with cement mortar. All fins caused by form joints, all cavities produced by the removal of form ties and all other holes and depressions, honeycomb spots, broken edges or corners, and other defects, shall be thoroughly cleaned, saturated with water, and carefully pointed and rendered true with mortar of cement and fine aggregate mixed in the proportions used in the grade of concrete that is being finished and of as dry a consistency as is possible to use. Adequate pressure shall be applied in filling and pointing to ensure thorough filling in all voids. Surfaces which have been pointed shall be kept moist for a period

of twenty four hours. Special pre-packaged proprietary mortars shall be used where appropriate or where specified in the drawing or by the Engineer.

ii) All construction and expansion joints in the completed work shall be left carefully tooled and free from any mortar and concrete. Expansion joint filler shall be left exposed for its full length with clean and true edges.

iii) Immediately on removal of forms, the concrete work shall be examined by the Engineer before any defects are made good.

a) The work that has sagged or contains honeycombing to an extent detrimental to structural safety or architectural appearance shall be rejected.

b) Surface defect of a minor nature may be accepted. On acceptance of such work by the Engineer, the same shall be rectified as directed by the Engineer.

3.3.11 Tests and Standards of Acceptance

3.3.11.1 Dividing into Lots

a) Concrete shall conform to the surface finish and tolerance as prescribed in these specifications for respective components.

b) Random sampling and lot by lot of acceptance inspection shall be made for the 28 days cube strength of concrete.

c) Concrete under acceptance shall be notionally divided into lots for the purpose of sampling, before commencement of work. The delimitation of lots shall be determined by the following:

i) No individual lot shall be more than 30 cum. in volume.

ii) At least one cube forming an item of the sample representing the lot shall be taken from concrete of the same grade and mix proportions cast on any day.

iii) Different grades of mixes of concrete shall be divided into separate lots.

iv) Concrete of a lot shall be used in the same identifiable component of the bridge.

Procedure for collection of samples and testing are given in relevant clause of RCC work chapter.

3.3.11.2 Sampling and Testing

a) Concrete for making 3 test cubes shall be taken from a batch of concrete at point of delivery into construction, according to procedure laid down in IS:1199.

b) A random sampling procedure to ensure that each of the concrete batches forming the lot under acceptance inspection has equal chance of being chosen for taking cubes shall be adopted.

c) 150mm cubes shall be made, cured and tested at the age of 28 days for compressive strength in accordance with IS:516. The 28 day test strength result for each cube shall form an item of the sample.

3.3.11.3 Test Specimen and sample strength:

Three test specimens shall be made from each sample for testing at 28 days. Additional cubes may be required for various purposes such as to determine the strength of concrete at 7 days or for any other purpose. The test strength of the sample shall be the as per IS 456.

3.3.11.4 Frequency of Sampling:

The minimum frequency of sampling of concrete of each grade shall be in accordance with **Table 3.4**.

TABLE 3.4 Frequency of Sampling

Quantity of Concrete in work, m^3	No. of samples
1- 5	1
6-15	2
16-30	3
31-50	4
51 and above	4 plus one additional sample for each additional 50 m^3 or part thereof.

At least one sample shall be taken from each shift of work.

3.3.11.5 Acceptance Criteria

Compressive strength

The quantity of concrete represented by the test results include the batches from which the first and last samples were taken, together with all intervening batches.

Chloride and Sulphate content

The total chloride and sulphuric anhydride (SO_3) content of all the constituents of concrete as a percentage of mass of cement in the mix shall not exceed the values given in this section of the specifications.

3.3.11.6 Density of Fresh concrete

Where minimum density of fresh concrete is specified, the mean of any four consecutive samples shall not be less than the specified value and any individual sample result shall not be less than 97.5 per cent of the specified value.

3.3.11.7 Density of Hardened Concrete

Where minimum density of hardened concrete is specified, the mean of any four consecutive samples shall not be less than the specified value and any individual sample result shall not be less than 97.5 per cent of the specified value.

3.3.11.8 Permeability Test

The concrete should pass the following test if it is properly compacted and is not considered permeable.

i) Prepare a cylindrical test specimen 150mm dia and 160mm high

ii) After 28 days of curing, the test specimen is fitted in a machine such that the specimen can be placed in water under pressure upto 7 bars.

iii) At first a pressure of one bar is applied for 48 hours, followed by 3 bars for 24 hours and 7 bars for next 24 hours.

iv) After the passage of the above period, the specimen is taken out and split in the middle by compression applied on two round bars on opposite sides above and below.

v) The water penetration in the broken core is to be measured with a scale and the depth of penetration assessed in mm (max. permissible limit 25mm).

If the concrete is not able to meet any of the standards of acceptance as prescribed, the effect of such deficiency on the structure shall be investigated by the Contractor as directed by the Engineer. The Engineer may accept the concrete as sub-standard work. Any additional work required by the Engineer for such acceptance shall be carried out by the Contractor at his cost. In case the concrete is not found to be acceptable after investigation, the Contractor shall remove the rejected concrete forthwith.

3.4 PRESTRESSING

3.4.1 General

Concrete and HTS steel for the construction of prestressed concrete members shall conform to the requirements of Concrete work&RCC chapter of specificationfor Structural Concrete and Steel Reinforcement respectively and provisions contained in Clause 3.3 in so far as the requirements of these Sections apply and are not specifically modified by requirements set forth herein.

3.4.2 Sheathing

i) The sheathing ducts shall be of the spiral corrugated type. Unless otherwise specified, the material shall be Cold Rolled Cold Annealed (CRCA) Mild Steel conforming to IS: 513 intended for mechanical treatment and surface refining but not for quench hardening or tempering.

ii) The material shall normally be bright finished. However where specified, as in case of use in aggressive environment, galvanized or lead-coated mild steel strips shall be used. The thickness of sheathing shall be as shown on the drawing, but shall nevertheless not be less than 0.3mm, 0.4mm and 0.5mm for sheathing ducts having internal diameter of 50mm, 75mm and 90 mm respectively. For larger diameter of ducts, thickness of sheathing shall be based on recommendations of prestressing system supplier or as directed by the Engineer.

iii) For major projects, the sheathing ducts should preferably be manufactured at the project site utilising appropriate machines. With such an arrangement, long lengths of sheathing ducts may be used with consequent reduction in the number of joints and couplers. Where sheathing duct joints are unavoidable, such joints shall be made slurry tight by the use of corrugated threaded sleeve couplers which may be tightly screwed onto the outer side of the sheathing ducts.

iv) The length of the coupler should not be less than 150mm but should be increased upto 200mm wherever practicable. The joints between the ends of the coupler and the duct shall be sealed with adhesive sealing tape to prevent penetration of cement slurry during concreting. The couplers of adjacent ducts should be staggered wherever practicable. As far as possible, couplers should not

be located in curved zones. The corrugated sleeve couplers are being conveniently manufactured using the sheath making machine with the next higher size of die set.

v) The internal diameter of the sheathing duct shall be in accordance with the recommendations of the system manufacturer and shall be about three times the area of the tendons. In case of 6T13, 12T13 and 19T13 sizes of tendons comprising 12/13mm dia strands, the inner diameter of the sheathing shall not be less than 50mm, 75mm and 90mm respectively or those shown in the drawing, whichever is greater.

3.4.3 Anchorages

i) Anchorages shall be procured from authorized manufacturers only. Anchorages shall conform to BS 4447. Test certificates from a laboratory fully equipped to carry out the tests shall be furnished to the Engineer. Such test certificates shall not be more than 12 months old at the time of making the proposal for adoption of a particular system for the project.

No damaged anchorages shall be used. Steel parts shall be protected from corrosion at all times. Threaded parts shall be protected by greased wrappings and tapped holes shall be protected by suitable plugs until used. The anchorage components shall be kept free from mortar and loose rust and any other deleterious coating.

ii) Swages of prestressing strand and button heads of prestressing wire, where provided shall develop a strength of atleast 95 per cent of the specified breaking load of the strand or wire as the case may be. Where swaging / button-heading is envisaged, the Contractor shall furnish details of his methodology and obtain approval of the Engineer, prior to his taking up the work.

3.4.4 Testing of Prestressing steel and Anchorages

All materials specified for testing shall be furnished free of cost and shall be delivered in time for tests to be made well in advance of anticipated time of use.

All wire, strand or bars to be shipped to the site shall be assigned a lot number and tagged for identification purposes. Anchorage assemblies to be shipped shall be like-wise identified.

All samples submitted shall be representative of the lot to be furnished and in the case of wire or strand, shall be taken from the same master roll. The Contractor shall furnish samples of atleast 5.0m length selected from each lot for testing. Also, two anchorage assemblies, complete with distribution plates of each size or types to be used, shall be furnished along with short lengths of strands as required.

3.4.5 Workmanship

3.4.5.1 Cleaning

Tendons shall be free from loose rust, oil, grease, tar, paint, mud or any other deleterious substance.

Cleaning of the steel may be carried out by immersion in suitable solvent solutions, wire brushing or passing through a pressure box containing carborandum powder. However, the tendons shall not be brought to a polished condition.

3.4.5.2 Straightening

High tensile steel wire and strand shall be supplied in coils of sufficiently large diameter such that tendons shall retain their physical properties and shall be straight as it unwinds from the coil. Tendons of any type that are damaged, kinked or bent shall not be used.

The packing of prestressing wire / strand shall be removed only just prior to making of cable for placement. Suitable stands shall be provided to facilitate uncoiling of wires / strands without damage to steel. Care shall be taken to avoid the possibility of steel coming into contact with the ground.

3.4.5.3 Positioning

a) For Post-Tensioning

Prestressing tendons shall be accurately located and maintained in position, both vertically and horizontally, as per drawings. Tendons shall be so arranged that they have a smooth profile without sudden bends or kinks.

The positioning of prestressed cables shall be such as to facilitate easy placement and vibration of concrete in between the tendons. High capacity tendon shall be used to reduce the number of cables thereby eliminating the necessity of grouping. The selected profiles of the tendons shall be such that their anchorages are not located in the top deck surface. Where two or more rows of cables have to be used, the cables shall be vertically in line to enable easy flow of concrete. The clear vertical and horizontal distances between any two cables shall in no case be less than 100mm anywhere along the length of the superstructure. Where precast segments are used, the clear distance shall be atleast 150mm.

Sheathing shall be placed in correct position and profile by providing suitable ladders and spacers. Such ladders may be provided at intervals of approximately 1.0m. Sheathing shall be tied rigidly with such ladders / space bars so that they do not get disturbed during concreting.

Sheathing in which the permanent tendon will not be in place during concreting shall have a temporary tendon inserted or shall be stiffened by some other method to be approved by the Engineer. The temporary tendon shall be pulled out before threading the permanent tendon into place by a special threading machine or other contrivance.

Where possible, tendons shall not be placed until immediately prior to stressing. Tendons shall be handled with care to avoid damage or contamination, to either the tendon or the sheathing. Any tendon damaged or contaminated shall be cleaned or replaced.

b) For Pre-Tensioning:

Prestressing steel shall be accurately located and maintained in position, both vertically and horizontally as per drawings.

c) Each anchorage device shall be set square to the line of action of the corresponding prestressing tendon and shall be positioned securely to prevent movement during concreting.

d) The anchorage devices shall be cleaned to the satisfaction of the Engineer prior to the placing of concrete. After concreting, any mortar or concrete which adheres to bearing or wedging surfaces shall be removed immediately.

3.4.5.4 Cutting

Cutting and trimming of wires or strands shall be done by suitable mechanical or flame cutters. When a flame cutter is used, care shall be taken to ensure that the flame does not come in contract with other stressed steel. The location of flame cutting of wire or strand shall be kept beyond 75mm of where the tendon will be gripped by the anchorage or jacks.

In post-tensioning the ends of prestressing steel projecting beyond the anchorages, shall be cut after the grout has set.

3.4.5.5 Protection of Prestressing Steel

Prestressing steel shall be continuously protected against corrosion, until grouted. The corrosion protector shall have no deleterious effect on the steel or concrete or on the bond strength of steel to concrete. Grouting shall conform to these specifications or as directed by the Engineer or specified in Contract Specifications.

In the case of external prestressing, steel shall be encased in suitable polyethylene pipes before grouting.

3.4.5.6 Sheathing Joints and Couplings

Joints in sheathing shall, if so instructed be sealed with a heat shrink tape.

Special attention should be paid to its junction at the anchorage. It should tightly fit on the trumpet end of anchorage and the junction should be sealed, preferably, with heat shrink tape.

The heat shrink tape is supplied in the form of bandage rolls which can be used for all diameters of sheathing ducts. The bandage is coated on the underside with a heat sensitive adhesive so that after heating the bandage material shrinks on the sheathing duct and ensures formation of a leak-proof joint. The heating is effected by means of a soft gas flame.

The sheathing and all joints shall be water tight. Any temporary opening in the sheathing shall be satisfactorily plugged and all joints between sheathing and any other part of the prestressing system shall be effectively sealed to prevent entry of mortar, dust, water or other deleterious matter. Sheathing shall be neatly fitted at joints without internal projection or reduction of diameter.

Enlarged portions of the sheathing at couplings or anchorages shall be of sufficient length to provide for the extension of the tendons.

3.4.5.7 Grout Vents

Grout vents of atleast 20mm diameter shall be provided at both ends of the sheathing and at all valleys and crests along its length. Additional vents with plugs shall also be provided along the length of sheathing such that the spacings of consecutive vents do not exceed 20m. Each of the grout vents shall be provided with a plug or similar device capable of withstanding a pressure of 1.0MPa without the loss of water, air pressure or grout.

3.4.5.8 Anchorages

All bearing surface of the anchorages shall be cleaned prior to concreting and tensioning. Anchor cones, blocks and plates shall be securely positioned and maintained during concreting such that the centre line of the duct passes axially through the anchorage assembly. The anchorages shall be recessed from the concrete surface by a minimum cover of 100mm. After the prestressing operations are completed and prestressing wire / strands are cut, the surface shall be painted with two coats of epoxy of suitable formulation having a dry film thickness of 80 microns per coat and entire recess shall be filled with concrete or non-shrink / pre-packaged mortar or epoxy concrete.

3.4.6 Tensioning Equipment

3.4.6.1 All tensioning equipment shall be procured from authorized manufacturers only and be approved by the Engineer prior to use. Where hydraulic jacks are used, they shall be power driven unless otherwise approved by the Engineer. The tensioning equipment shall satisfy the following requirements:

i) The means of attachments of the prestressing steel to the jack or any other tensioning apparatus shall be safe and secure.

ii) Where two or more wires / strands constitute a tendon, a single multipull stressing jack shall be used which is capable of tensioning simultaneously all the wires / strands of the tendon. Suitable facilities for handling and attaching the multi-pull jack to the tendons shall be provided.

iii) The tensioning equipment shall be such that it can apply controlled total force gradually on the concrete without inducing dangerous secondary stresses in steel, anchorage or concrete; and

iv) Means shall be provided for direct measurement of the force by use of dynamometers or pressure gauges fitted in the hydraulic system itself to determine the pressure in the jacks. Facilities shall also be provided for the linear measurement of the extension of prestressing steel to the nearest mm and of any slip of the gripping devices at transfer.

3.4.6.2 All dynamo meters and pressure gauges including a master gauge shall be calibrated by an approved laboratory immediately prior to use and then at intervals not exceeding 3 months and the true force determined from the calibration curve.

3.4.6.3 Pressure gauges shall be concentric scale type gauges accurate to within two per cent of their full capacity. The minimum nominal size of gauge shall be 100 mm. The gauge shall be so selected that when the tendon is stressed to 75 per cent of its breaking load, the gauge is reading between 50 per cent and 80 per cent of its full capacity.

Suitable safety devices shall be fitted to protect pressure gauges against sudden release of pressure.

3.4.6.4 Provision shall be made for the attachment of the master gauge to be used as a check whenever requested for by the Engineer.

3.4.7 Post Tensioning Procedure

3.4.7.1 Tensioning force shall be applied in gradual and steady steps and carried out in such a manner that the applied tensions and elongations can be measured at all times. The sequence of stressing, applied tensions and elongations shall be in accordance with the approved drawing or as directed by the Engineer.

3.4.7.2 It shall be ensured that in no case, the load is applied to the concrete before it attains the strength specified on the drawing or as stipulated by the prestressing system supplier, whichever is more.

3.4.7.3 After prestressing steel has been anchored, the force exerted by the tensioning equipment shall be decreased gradually and steadily so as to avoid shock to the prestressing steel or anchorage.
The tensioning force applied to any tendon shall be determined by direct reading of the pressure gauges or dynamo meters and by comparison of the measured elongation with the calculated elongation. The calculated elongation shall be invariably adjusted with respect to the modulus of elasticity of steel for the particular lot as given by the manufacturer.

3.4.7.4 The difference between calculated and observed tension and elongation during prestressing operations shall be regulated as follows:

a) If the calculated elongation is reached before the specified gauge pressure is obtained, continue tensioning till attaining the specified gauge pressure, provided the elongation does not exceed 1.05 times the calculated elongation. If 1.05 times the calculated elongation is reached before the specified gauge pressure is attained, stop stressing and inform the Engineer.

b) If the calculated elongation has not been reached at the specified gauge pressure, continue tensioning by intervals of 5 kg/sqcm until the calculated elongation is reached provided the gauge pressure does not exceed 1.05 times the specified gauge pressure.

c) If the elongation at 1.05 times the specified gauge pressure is less than 0.95 times the calculated elongation, the following measure must be taken, in succession, to determine the cause of this lack of discrepancy:

i) Check the correct functioning of the jack, pump and leads.

ii) De-tension the cable. Slide it in its duct to check that it is not blocked by mortar which has entered through holes in the sheath. Re tension the cable if free.

iii) Re-establish the modulus of elasticity of steel for the particular lot from an approved laboratory.

d) If the required elongation is still not obtained, further finishing operations such as cutting or sealing, should not be undertaken without the approval of the Engineer.

e) When stressing from one end only, the slip at the end remote from the jack shall be accurately measured and an appropriate allowance made in the measured extension at the jacking end.

f) A complete record of prestressing operations along with elongation and jack pressure data shall be maintained in the prescribed format. The number of stages of prestressing and grouting shall be reduced to a minimum, preferably 2 in the case of simply supported girders.

3.4.7.5 Groutingof Prestressed Tendons

Grouting shall conform to provisions in **Annexure 3.2.**A record of grouting operations shall be maintained in a format given by Engineer.

3.4.8 Pre-tensioning Process

a) General

The planning and construction aspects of the tensioning bed, tensioning bench, abutments at location of anchorage, steam curing system, form work of the concrete elements and arrangements for demoulding, lifting, stacking and transportation of the pre-tensioned concrete elements are all specified items and shall be entrusted to engineers specifically experienced in this type of work.

The Contractor shall submit method of tensioning the tendons including the arrangement and layout of prestressing cables and all tensile deflection points to the Engineer for approval before manufacture commences.

b) Stressing Bed for pre-tensioning

i) The abutments and bed for pre-tensioning of tendons shall be designed to withstand the total tensioning force.

ii) A notice shall be displayed adjacent to the stressing bed showing the maximum tensioning force permitted.

iii) Where concrete elements are cast and prestressed individually, the stressing bench or moulds shall be rigid enough to sustain the reaction of the prestressing force without distortion.

iv) In the long line method of prestressing, sufficient locator plates should be distributed throughout the length of the bed to ensure that the wires are maintained in their proper position during concreting. The moulds shall be free to slide in the direction of their length and thus permit the transfer of the prestressing force to all the concrete elements along the whole line.

v) Sufficient space shall be left in between the ends of concrete elements to permit access for cutting the strands / wires after transfer. Hold downs or deflectors shall be used for holding or deflecting the tendons in required position firmly. Deflectors which are in contact with the tendon shall have a diameter not less than the tendon or 15mm, whichever is greater.

vi) The tensioning force required to be applied as specified on the drawings shall be the force remaining in the strands / wires after all strands / wires have been anchored to the abutments of the stressing bed and after the anchorage slip has already taken place. The tensioning force shall be determined by direct reading of the pressure gauges or dynamo meters and by the measured elongation after slip.

vii) The Contractor shall carry out trial stressing operations to establish the frictional resistance offered by the hold downs and the slip during anchoring.

viii) Where sheathing of pre-tensioned tendons is required to prevent bond over a specified length, it shall consist of plastic tubing or other material approved by the Engineer and shall be of a quality, diameter and thickness such that bond shall be effectively prevented. The tubing shall be fastened to the tendon in such a manner that cement mortar cannot enter. The Engineer may order that the pull-in of the tendon be measured during the transfer of prestress.

ix) The Contractor shall also submit calculations showing that the hold downs and deflectors have been designed and constructed to withstand concentrated loads resulting from the application of the tensioning force.

c) Tensioning procedure

i) The tensioning of the wires and strands shall be done not too much in advance of concreting.

ii) The tensioning force shall be applied gradually and uniformly.

In order to remove slack and to lift tendons off the bed floor, an initial force approved by the Engineer shall be applied to the tendons. Allowance shall be made for this force in calculating the required elongation.

iii) Tendons shall be marked for measurement of elongation after the initial force has been applied. When required by the Engineer, tendons shall be marked at both the jacking end and dead end of the stressing bed and at couplers if used so that slip and draw-in may be measured.

iv) Where deflected strands have been specified, the Engineer may direct the elongation or strain gauge measurements be taken at various positions along the tendon to determine the force in the tendon at those positions.

d) Transfer of Prestress

While the process of tensioning can be accomplished by means of hydraulic jacks, some positive mechanical means shall be provided to maintain the tension during the entire period between the tensioning of the wires / strands and transfer of the prestressing force to the concrete element.

Transfer of prestress shall not proceed until the Engineer has approved the proposed method. Tendons and deflection devices shall be released in such a pre-determined order that unacceptable tensile stresses are not induced in the concrete.

Prior to transfer of the force to the units, all wire tendons shall be tested for tightness and any loose tendon shall be reported to the Engineer who will decide whether the units affected shall be rejected.

The Engineer may require that tendons be marked at each end of any unit to allow measurement of the pull in of the concrete.

Tendons shall be released gradually and preferably simultaneously.

e) Cutting of wires Precautions to be taken

Under no circumstances shall tendons / wire be cut while under tension.

On completion of the transfer of prestress, the projecting lengths of tendon shall be cut off flush with the end surface of the unit, unless otherwise shown, by a method approved by the Engineer.

In no case shall the transfer of prestressing force to the concrete elements take place before concrete attains the strength specified in the drawings. To determine the specified strength, additional cube testing shall be undertaken at the Contractor's cost. In case steam curing is employed, the cubes shall be placed in the same environment as the concrete elements to obtain an accurate assessment of concrete strength at the time of transfer.

The sequence of transfer of prestressing force shall be done strictly as indicated in the drawings and ensuring that eccentricities of the prestressing force in the vertical and horizontal directions of the concrete elements is a minimum during the entire sequence.

The maximum slip of any tendon during transfer shall not exceed 3mm at any end of the concrete element. In case this slip is exceeded, the concrete element in question shall be rejected.

f) Protection of Ends

The exposed ends of the tendons and the concrete surfaces of the ends of the units shall be wire brushed clean of all rust, loose mortar, grease and dirt.

The exposed ends of the tendons and concrete surface within 50mm of tendons shall be then abraded to provide a clean sound surface. An epoxy tar paint suitably formulated to give a dry film thickness of 80 microns per coat shall then be immediately applied over the ends of the tendons unless otherwise directed.

A second coat of paint shall be applied prior to the drying out of the first coat.

3.4.9 Safety Precautions during Tensioning

These are applicable for both pre-tensioning and post tensioning operations.

i) Care shall be taken during tensioning to ensure the safety of all persons in the vicinity.

ii) Jacks shall be secured in such a manner that they will be held in position, should they lose their grip on the tendons.

iii) No person shall be allowed to stand behind the jacks or close to the line of the tendons while tensioning is in progress.

iv) The operations of the jacks and the measurement of the elongation and associated operations shall be carried out in such a manner and from such a position that the safety of all concerned is ensured.

v) A safety barrier shall be provided at both ends to prevent any tendon, which might become loose from recoiling unchecked.

vi) During actual tensioning operation, warning sign shall be displayed at both ends of the tendon. No person will stand behind in line with jacks while tendon / wire are being stressed.

vii) After prestressing, concrete shall neither be drilled nor any portion cut nor chipped away nor disturbed, without express approval of the Engineer.

viii) No welding shall be permitted on or near tendons nor shall any heat be applied to tendons. Any tendon which has been affected by welding, weld spatter or heat shall be rejected.

3.4.10 Transportation and Storage of Units

Precast girders or elements shall be transported in an upright position. Points of support and the direction of reactions with respect to the girder shall approximately be the same during transportation, and storage as when the girder is placed in final position.

When members are to be stacked, they shall be firmly supported at such bearing positions as will ensure that the stresses induced in them are always less than the permissible design stresses. Further, inclined side supports shall be provided at the ends and along the length of a precast girder to prevent lateral movements or instability.

Care shall be taken during storage, hoisting and handling of the precast units to prevent their cracking or being otherwise damaged. Units worked or damaged by improper storing or handling or transport shall be replaced by the Contractor at his expense.

3.4.11 Tolerances

Permissible tolerances for positional deviation of prestressing tendons shall be limited to the following:

a)	Variation from the specified horizontal profile	:	5 mm
b)	Variation from the specified vertical profile	:	5 mm
c)	Variation from the specified position in member	:	5 mm

3.4.12 Measurements for Payment

a) Prestressed Concrete shall be measured in cubic metres unless otherwise specified. The volume occupied by mild steel reinforcement / HYSD bars, high tensile steel, sheathing and anchorages shall not be deducted.

b) High tensile (prestressing) steel shall be paid for separately and its length shall be measured as actually incorporated in the finished work. From the length so measured its weight shall be calculated in tonnes on theoretical basis and paid for.

c) Anchorage devices, additional length of cables for attaching jack, ducts or sheathing, grout, non-prestressed steel reinforcement fixed to the anchorage devices, making of recesses and filling the same protection by painting with epoxy and furnishing samples for testing shall all be deemed to be included in the item of high tensile steel and shall not be measured separately.

3.4.13 Rate

a) The contract unit rate for cast in place pre-stressed concrete shall cover the cost of all materials, labour, tools and plant required for mixing, placing in position, vibrating and compacting, finishing as per directions of the Engineer, curing and other incidental expenses for producing concrete of specified strength to complete the structure or its components as shown on the drawings and according to specifications. The contract unit rate shall exclude the cost of making, fixing and removing of all formwork required for the work.

b) For precast prestressed concrete members, the rate in addition to above shall also include the cost of all materials, labour, tools and plant required to transport and places these members in their final position as shown on the drawings and as directed by the Engineer unless otherwise specified.

c) The contract unit rate for high tensile steel shall cover the cost of material, labour, tools and plant required for manufacturing, placing, tensioning, anchoring and grouting the high tensile steel in the prestressed concrete as shown on the drawings and as per specifications herein above or as directed by the Engineer.

d) The cost of anchorage devices, additional length of cables for attaching jack, ducts or sheathing, grout, non-prestressed steel reinforcement fixed to the anchorage devices, making of recesses and filling the same, protection by painting with epoxy and furnishing samples for testing shall all be included in the unit rate of HTS. Rate shall also include payments if any to be made to the supplier of the prestressing system who has to monitor, ensure and certify the correctness of all operations.

e) Unit rate for form work shall include the cost of all materials, labour, tools and plant required for design, construction and removal of form work and supervision as described in this Section including properly supporting the members until the concrete is cured, set and hardened as required.

Annexure 3.1

SPECIFICATION FOR CONSTRUCTION JOINTS

(Based on Appendix 1700/1 of MORTH Specifications for Roads and Bridges)

Location

The construction joints shall be located as shown in the drawings and/ or as specified by the engineer. When not shown in drawing, the following guidelines shall be followed for locating them:-

i) Construction joist shall be provided in non-aggressive zones and on non-splash zones. If not feasible, joints shall be sealed.

ii) Location of joints should be easily accessible for preparation and concreting. e.g., where the cross section is relatively small and where there is no congestion of reinforcement.

iii) Joints should not be near support in beams and slabs. Construction joints between ribs and slabs should be avoided in composite construction.

iv) Soffit and webs of box girders should preferably cast without any construction joint between.

v) Locations of construction should be such as to minimize the effects of discontinuity on durability of structure and on appearance of structure are minimized.

Preparation of Surface of the Joint

All laitance shall be removed. The surface shall be roughened without dislodging the coarse aggregates of the set concrete. If the concrete has partially hardened, it shall be brushed with a stiff wire brush or stiff air jet followed by air jet immediately. Fully hardened concrete shall be roughened with mechanical hand tools or grit blasting, taking care not to split or crack the aggregate particles.

Surface shall be thoroughly cleaned, preferably with air jet to remove all accumulated particles and dust before further concrete is cast. If any delay is expected before placing next layer of concrete, all protruding reinforcement shall be protected (preferably with a cement wash). Before next concreting is done, all rust, loose mortar/ particles and any other contamination of the reinforcement shall be removed thoroughly. In aggressive environment, the concrete shall be cut back so as to expose the rods for about 50mmlength and all contaminated concrete around is removed.

Concreting of Joints

Old surface after cleaning shall be soaked with water as directed by Engineer. Any standing water shall be removed just before laying fresh concreting. Further concreting shall be well compacted and carried out continuously upto next construction joint.

Stopping boards shall be fixed in advance for vertical construction joints at predetermined positions and properly stayed. Concreting shall be done continuously upto the board.

Surface retarders can be used for improving quality of joint, if so desired with approval of Engineer, but at no extra cost.

Annexure 3.2

GROUTING POST TENSIONED CABLES IN PRESTRESSED CONCRETE

Extracts from Appendix 1800 Specifications for Roads and Bridges of MORTH

1. Materials

Cement - Ordinary Portland cement shall be used for preparing the grout. It shall be as fresh as possible and be free from any lumps.

Water- Only clean potable water free from any impurities and conforming to clause 4.3 of IS 456 and with chloride content not exceeding 500mg per litre shall be used.

2. Equipment

Equipments as detailed below will be used or be available at site.

Grout Agitator- A grout agitator shall be used for preparation of the mortar in order to ensure its homogeneity. The grout shall be continuously agitated in a suitable mixer with a minimum speed of 1000 RPM and travel of discharge not exceeding 15 m per second.

Grout Pump - The pump used for grouting should be a positive displacement type and capable of injecting the grout in a continuous operation (and not by way of pulses). The grout pump shall be fitted with a pressure gauge for enabling pressure of grouting to be controlled. Minimum pressure of grouting shall be 0.3 MPA. The pump shall have a relief arrangement for bypassing when the grout pressure builds up to 1 MPA. Capacity of the grout pump shall be such as to forward speed of 5 to 10 metres per second. Slower rate is preferable for avoiding occurrence of voids.

If the capacity of grout pump is large, it is usual to grout two or more cables simultaneously using a common manifold.

Use of hand pump for grouting or use of compressed air operated equipment for grouting is strictly prohibited. They are likely to result in some air entrapment in the duct.

Water pump- Before commencement of grouting, a direct feed high pressure water pump should available at site as a standby. Adequate storage of clean potable water also should be available for use in the pump. In case of any problem in or during grouting operations, this pump shall be directly connected to the duct and all grout shall be flushed out by use of high pressure water flushing.

Grout Screens- The grouting equipment should include a screen having mesh size of IS -105. The grout shall be passed through this screen before being introduced into the grout pump. The screen should be easily accessible for inspection and cleaning.

3. Properties of Grout

i) Water cement ratio of the grout should be as low as possible consistent with the workability required. It should not exceed 0.45

ii) Before grouting the strength of the grout should be ascertained through laboratory tests ant it should be done for each job separately.

Cubes cast shall be moist cured for 24 hrs. and subsequently in water. The compressive strength on 100 mm cubes should not be less than specified.

4. Mixing of Grout

i) Mixing shall be done by measurement of materials by eight. Proportion of materials shall be based on field trials, but within limits specified above.

ii) Water shall be poured into the mixer, followed by cement, keeping the mix stirred. Approved admixture may be added with the Engineer's approval.

iii) Mixing shall be done for 2 to 3 minutes, depending on type of mixer. It should, however, be such as to obtain a uniform and thoroughly blended grout and not subjected to excessive rise of temperature or loss of expansive properties of the admixtures. Grout should be continuously kept agitated till it is injected.

iv) No water shall be added to the grout after it is mixed, for purpose of increasing fluidity.

v) Hand mixing is **not** permitted

5. Grouting Operation

i) Grouting should be carried out preferably within four hours of stressing the tendon /cables. Whenever this condition cannot be complied with due to unavoidable circumstances, adequate temporary protection of the cable against corrosion by methods or products, which will not impair the adherence properties of the injected grout, with the approval of the Engineer.

ii) The ends of anchorage shall be sealed in order to prevent ingress of moisture/ water and is desirable in all cases. Such sealing is mandatory in structures cast in regressive environment.

iii) Ducts shall be flushed with water before grouting, in order to clean the duct as well as keeping it wet for receiving the grout. Water should be of same quality as used for grouting. It may. However, contain upto about 1 % of slake lime or quick lime.

iv) The water should be blown out with use of oil free compressed air.

v) The connection between the nozzle of the injection pipe should be tight and such that no air can be sucked in. All vent openings should be kept open prior to commencement of injection of grout, unless some other sequence is specified by designers.

vi) All air in the pump and hose should be expelled before commencement of grouting. The junction circuit of the pump should be air tight.

6. Injection of Grout

i) After mixing, the grout should be kept in continuous motion/ movement.

ii) Injection of grout should be continuous and should not be interrupted.

iii) The method of injection used should ensure complete filling of the voids with no voids or air entrained. Volume of the annular space to be filled should be compared with the actual quantity of grout injected actually.

iv) Grouting will be started initially with a low pressure of injection of 0.3 Mpa and increased until the grout comes out at the other end. Grout should be allowed to flow freely at the other end till the consistency of the exiting grout is the same as that at injecting end. When such grout flows at the end, should be closed off and

buildup of pressure commenced. Full injection pressure of about 0.5 Mpa shall be maintained for at least one minute before closing the injection pipe. If the buildup pressure exceeds 1 Mpa and still the grout is not flowing at the other end, the grouting operation shall be stopped and the entire duct flushed with high pressure water. The duct should be examined for any blockage and seizure of cable by moving the cable up and down, and defect remedied before recommencing.

v) Grout should be used up within 30 minutes of mixing and any grout not used within 30 minutes shall be rejected.

Chapter 4
Bridge Works: Superstructure-Steel

4.1 GENERAL

4.1.1 Coverage

All steel work, whether in fabrication or in erection, shall be done in accordance with the relevant Codes of Practice and Standard Specifications, subject to any further provisions contained in this chapter. These specifications are equally applicable to steel structures in buildings and sheds except where specified otherwise. In the event of any of these provisions being at variance with the standard IRS specifications, the latter shall prevail unless otherwise specified by the Engineer or in Drawings.

4.1.2 Weight for Payment

(a) Unless otherwise stipulated, payment for steel work shall be based on the calculated weight of the finished work. In calculating the weight, the overall lengths of the members used in the fabrication (i.e. as measured Length/square) will be taken into account and no deduction will be made for rivet or bolt holes, skew cuts, notches etc. Gussets will be measured as per the dimensions of the smallest enveloping rectangles. Over the total weight of the main components and gussets thus calculated, an addition in weight for welds, rivet heads, bolts etc used will be made as follows :-

i) 3 Percent in case of riveted or composite (riveted and welded) work;

ii) 1 percent in the case of purely welded work.

iii) In case of composite work (welding and HSFG bolts), addition in weight shall be 1% for welding and HSFG bolts shall be paid in addition.

(Para iii above does not exist in IRS B1-2001 specification included now in Unified specifications as HSFG Bolts item introduced in USSOR as new item.)

(b) Holding down bolts, nuts and washers as well as anchor channels or plates, will be measured separately.

The scope of the work covered by any particular rate shall be as defined in the individual cases, depending on the extent to which materials etc are to be supplied free by the Railway.

4.2 MATERIALS

4.2.1 General requirements

General requirements relating to the supply of material shall conform to the IS Code IS: 1387, for the purpose of which the supplier shall be the Contractor and the purchaser shall be the Engineer.

Mild steel shall be to IS:226 and /or IS 2062 and HTS to IS 561 unless otherwise specified. In case of imported material, Steel work Specifications of the country of origin or equivalent IS Specifications will be as indicated in the Contract or by the Engineer.

Finished rolled material shall be free from cracks, flaws, injurious seams, laps, blisters, ragged and imperfect edges and other defects. It shall have a smooth and

uniform finish, and shall be straightened in the mill before shipment. They shall also be free from loose mill scale, rust, pitting or other defects affecting its strength and durability.

The acceptance of any material on inspection at the mill i.e. rolling mills, foundry or fabricating plant where material for the work is manufactured, shall not be a bar to its subsequent rejection, if found defective. Unless specified otherwise, high tensile steel rivet conforming to IS:1149 shall be used for members of high tensile steel conforming to IS:961 and shall not be used for mild steel members. Unless specified otherwise, bolted connection of structural joints using high tensile friction grip bolts shall comply with requirements of IS:4000. Cast iron shall not be used in any portion of the bridge structure, except where it is subject to direct compression and as shown in the drawings.

4.2.2 Standards Applicable

4.2.2.1 All materials shall conform to requirements of respective IS Codes and IRS Specifications listed below. Special requirements are given below:

Mild steel for bolts and nuts shall conform to IS:226 and IS: 1148 but have a minimum tensile strength of 44 kg/sq.mm and minimum percentage elongation of 14. High tensile steel for bolts and nuts shall conform to IS:961 and IS:1149 but with a minimum tensile strength of 58 kg/sq.mm. High strength friction grip bolts shall be permitted for use only on satisfactory evidence of performance to the requirements (not covered by these specifications) specified by the Engineer or included in the special provisions of the Contract.

4.2.2.2 For cast steel, the yield stress shall be determined and shall not be less **than 50 per cent of the minimum tensile strength.**

4.2.2.3 Plain washers shall be of steel. Tapered or other specially shaped washers shall be of steel or malleable cast iron.

4.2.2.4 Parallel barrel drifts shall have a tensile strength not less than 55 kg/ sq.mm. With elongation of not less than 20 per cent measured on a gauge length of 4 So (So = cross sectional area in sq.mm).

4.2.2.5 Materials for castings and forgings, fasteners and welding consumables shall be as per relevant IS code.

4.2.3 Use of Corrosion Resistant steel

In aggressive environment, corrosion resistant steel can be used. These are low-alloy steels containing a total of 1 per cent to 2 per cent alloys, in particular, copper, chromium, nickel and phosphorous.

4.2.4 Paints

All materials for paints and enamels shall conform to the requirements specified on the drawings or other special provisions laid down by the Engineer. Relevant Chapter of Specification on painting deals with Painting including of steel work and may also be referred to.

4.3 FABRICATION OF STEEL WORK

4.3.1 Codes of Specifications:-The work shall be done in accordance with the following codes and specifications and any other requirements that may be prescribed in special cases.

(a) Bridge Work

1. IRS Steel Bridge Code
2. IRS Specification No.B-1-2001 for Steel Girder Bridges
3. IRS Specification No. M 3-Class I, II, III and IV Steel forgings, blooms for forgings and billets for re-rolling
4. IRS Specification No. M-28 Classification, testing and approval of metal arc welding electrodes for use – Indian Railways.
5. IRS Specification No M-29 Classification, testing and approval of submerged arc welding with flame combination.
6. IRS Specification No M-41 Corrosion resistance steel
7. IRS Specification No M-42 High strength low alloy structural steel with enhanced corrosion resistance.
8. IRS Specification No M-49 High strength excavating structural steel rivet bars with enhanced corrosion resistance.
9. IRS Specification No P-31 Zinc Chromate red oxide primer.

The fabrication and erection of the steel work shall be in accordance with IRS: B1-2001 supplemented by relevant provisions of this Specifications.

(b) Iron and steel tanks and stagings:- IRS Specification No.B-3-61 Part 4

4.3.2 Quality of Steel:-The steel used for fabrication work shall conform to the appropriate quality as specified below, unless the use of any other quality of steel is specially approved.

i) IS 226:1962 (Standard quality): For non-welded structures subjected to dynamic loading and for welded non-dynamically loaded structures, if the thickness of material welded does not exceed 20mm.

ii) IS:2062-1962 (Fusion welding quality) - For all welded structures for which IS:226 is not suitable.

iii) IS:1977-1962 (Ordinary quality):-

(a) Grade ST 44-0: For non-welded structures not subjected to dynamic loading other than wind (e.g. sheds, buildings, foot over bridges) except structures designed according to plastic theory.

(b) Grade ST-32-0: For general purposes where the load carried is not the main consideration (e.g. grills, railings)

4.3.3 Straightening of members:-All members used shall be straight except those meant to be curved and any straightening necessary shall be carried out before the material is worked upon. The straightening shall be done by pressure and no heating resorted to except with the prior approval of the Engineer and with such safeguards as considered by him to be necessary.

4.3.4 Cutting of Steel

Cutting of steel for fabrication may be done by shearing, sawing or by gas. For less important works the Engineer may permit the use of chisels and jim crows also. Gas cutting for important works shall preferably be done by mechanically controlled torches. Cut edges shall be machined where so specified. If machining is not specified, hand flame cut, chisel cut and jim crowed edges shall be ground smooth where so directed by the Engineer. Para 17 of B1-2001 may also be referred to in this connection.

4.3.5 Making of Holes

(a) In all important works and in splices, the holes for rivets or bolts shall either be drilled to the correct sizes or sub-punched initially to a diameter 6mm less than the finished diameter and reamered subsequently to the correct sizes as indicated in Para 18 of B1-2001. Sub-punching is, however, not permissible in the main truss members of open-web bridge girders.

(b) Forming of holes by gas-cutting is strictly forbidden.

(c) Holes for rivets and black- bolts shall be 1.5mm (1/16 inch) larger in diameter than the rivet bar or the bolt, and care shall be taken not to exceed this limit. In the case of turned bolts the holes shall be drilled to such tolerances as laid down in **para 18.5** of I.R.S. B.I.-2001 Specification for Steel girder Bridges and Locomotive turn-tables.

(d) Marking and drilling of holes in members, especially for the end connections, shall preferably be done with the use of templates. Holes in rolled sections shall follow the standard gauge lines unless otherwise indicated in the drawings.

4.3.6 Rivetting

(a) Unless otherwise specified, the size of the rivet shall be designated by the diameter of the rivet bar and not that of the hole or the finished rivet. Rivets and Rivetting shall be in accordance with para **23** of IRS-B1-2001 supplemented by following specifications.

(b) The rivet shank shall be of length just sufficient to fill the hole thoroughly and to form a full head of the standard proportions as shown below. Generally the sizes in the Table at **Annexure 4.1** will be found sufficient.

(c) Rivets shall completely fill the holes and shall be machine driven, unless otherwise permitted by the Engineer under special circumstances. Riveting will be done by means of pressure or percussion riveters of approved design. Hand riveting shall not be resorted to except with the prior approval of the Engineer. The rivets shall be at the proper heat and in no case shall the tip be hotter than the head. Rivets less than 10mm (or 3/8 in.) in diameter may be driven cold.

(d) Before riveting is commenced, the work shall be kept tightly bolted together. Special care shall be taken to retighten the bolts frequently as the riveting proceeds.

(e) Driven rivets, when struck sharply on the head with a 110 g (1/4 lb) rivet testing hammer, shall be free from movement and vibration. All loose and burnt rivets and those with cracked badly formed, eccentric or deficient heads shall be cut out and replaced. While cutting out rivets care shall be taken not to damage the surrounding metal and not to disturb adjoining rivets. Recouping and caulking shall in no circumstance be resorted to.

4.3.7 Welding

(a) In the case of welded fabrication, the following directions shall be observed in addition to the provisions of the IRS welded Bridge Code.

i) Shop welding shall be adopted wherever possible in fabricating components and sub members for welding shall be done by submerged and welding.

ii) Suitable jigs and fixtures shall be used, both in the field and in the shop, to avoid distortion during welding, and in the case of plated construction, to control distortions within the same limits as applicable to corresponding rolled sections.

iii) Components which are mass fabricated in the shops should be proved in master templates.

(b) Unless specified otherwise, the lowest classes of electrodes to be used for different types of welding work shall be as given in **Table 4.1 (a**) under, based on IRS Specification No.M.28-66 for the classification.

Table 4.1 (a) Testing and Approval of Metal Arc Welding Electrodes

Class of Electrode as per IRS Specification No.M.28.66	Type of work to be welded	I.S. Specification No.	Code (as per IS:815-66)
Class A	Mild steel work where the strength of weld is of no importance e.g. filling of holes, dents etc	814-63	M.100 to M.999
Class B (Normal ductility)	For general welding work on steel – M.S. to IS:226-1962 and cast steel to IS:1030 Grade 3 and IRS M3 Grade 2, for service conditions where the weld is subjected to static or moderate dynamic loading	814-63	M 110 to M 997-H, J, K or P.
Class B2 (Moderately high ductility)	For welding of mild steel to IS:2062-1962 (Fusion welding quality) or equivalent, for service conditions where the weldment is rigid and subjected to relatively high dynamic stresses	814-63	M 110 to M 997-H, J, K or P.

The classification of the various makes and brands of electrodes in the market, as assessed from time to time will have to be referred to before its use on the work. Lists shall be made out by the M&C Wing of RDSO and maintained in the Headquarters Works Branch and CAO's Offices. Any electrode to be used shall be verified from these lists to see if it is of the appropriate class.

(c) The maximum size of electrodes for welding any work and the size of run to be obtained from each shall be based on the following **Tables 4.1 (b) and 4.1 (c)** except for close butt welds or other cases where any special technique is approved.

Table 4.1 (b) Size of Electrodes

Average thickness of plate or section	Maximum size of electrode to be used
Less than 5mm	10 S.W.G. (or 3.2mm)
5mm and above but less than 8mm	8 S.W.G. (or 4mm)
8mm and above, but less than 10mm	6 S.W.G. (or 5mm)
10mm and above, but less than 16mm	4 S.W.G. (or 6mm)
16 mm and above, but less than 25mm	5/16” (or 8mm)
25 mm and above	3/8” (or 9mm dia)

Table 4.1 (c) Size of Weld runs

Gauge of Electrode	Sectional area of separate run(mm^2)		Approximate size of run in cm per electrode 42.5 cm long	
	Maximum	Minimum	Maximum	Minimum
12 S.W.G. …	18.00	12.30	10.0	15.0
10 S.W.G.	22.60	12.30	12.7	22.8
8 S.W.G.	25.20	14.20	17.7	30.5
6 S.W.G.	27.10	16.80	22.8	38.0
4 S.W.G.	32.90	19.35	27.9	48.2
2 S.W.G.	36.80	23.25	35.5	55.9
0 S.W.G. (or 5/16”)	41.30	27.0	43.2	66.9

Note: In any strength weld, the first run shall not ordinarily be deposited with an electrode of gauge larger than 8 S.W.G. For subsequent runs the electrode shall not be increased by more than two sizes between consecutive runs.

4.3.8 Shop Painting

(a) Fabricated steel work shall not be painted over except to the extent specified in sub para (b) until it has been inspected and passed by the Engineer or his representative and any defect, pointed out by him has been rectified. Till then, all rivet heads and weld metal shall be protected by coating with clean boiled linseed oil.

(b) All surfaces which shall be in permanent contact and any others which will not be accessible for painting later on shall be cleaned thoroughly and given one coat of Zinc Chrome Red Oxide Priming to IS 2074 or other approved composition in the

prescribed number of coats immediately prior to assembly, and for this no extra payment shall be admissible.

(c) After the steel work has been inspected and passed, painting shall be done as stipulated in Para 39 of IRS Specification B-1-2001 for the prescribed number of coats, uniformly over the work. Payment for this painting shall be made separately unless it is specifically included in the rate for the fabrication.

(d) Further reference is drawn to general provisions detailed in relevant chapter on painting.

4.4 WORKMANSHIP IN STEEL WORK

4.4.1 General

Fabrication - Such work shall be performed only within the plants and by fabricators who have at the tendering stage established, to the satisfaction of the Engineer / Railway, that they have the experience, knowledge, trained man power, quality controls, equipment and other facilities required to produce the steel work to desired quality. Prequalification of the plant and fabricator will be established either by the submission of detailed written proof or through in plant inspection by the Engineer.

The contractor shall advise the Engineer in writing, at least 20 calendar days in advance of the actual start of fabrication.

4.4.2 Rolling Margin

The rolling margin in plates, sections and bars shall be in accordance with the relevant Indian Standard and all materials outside these limits shall be liable to rejection.

4.4.3 Interchangeability of Parts

The Contractor shall arrange for corresponding parts of each unit manufactured from the same drawing to be interchangeable as far as economic manufacturing conditions permit and shall advise the Engineer of the precise arrangements made in this respect. There should be level, finished concrete floor of sufficient dimensions in the fabrication yard, on which the fabricator will precisely set out the outline of the structure (to full scale) as per drawings for the purpose of preparing templates. Only steel tapes shall be used for all measurements and they will be held tight and level on the floor while measuring or marking.

4.4.4 Templates

The templates for the work shall be steel bushed in cases where the Engineer may consider necessary. Where actual materials from the work have been used as templates for drilling similar pieces, the Engineer will decide whether they are fit for use as part of the finished structure.

4.4.5 Steel Tapes

Steel tapes used for marking out the work shall be calibrated at a temperature of 20^{o} C.

4.4.6 Universal Plates and Flats

Where universal plates or flats are used as part of a built up section and with their edges exposed, such edges shall be true or planed true.

4.4.7 Drilling

a) Rivet and Bolt Holes

No holes shall be punched full size without the permission of Engineer. See also Para 4.3.5.

b) Reamered Holes

All holes for turned bolts shall be reamered in the manufacturer's works.

c) Holes in welded Members

All bolt and rivet holes in members built up by welding shall be drilled after welding has been completed.

d) Removal of Burrs

Holes which are drilled through two or more separable parts shall have all burrs removed after separating the parts.

e) Holes for Countersunk H.S.F.G. Bolts

Holes for countersunk H.S.F.G. bolts shall conform to the proportions for flat countersunk heads with 80^{o} included angle and head diameter approximately twice the diameter of the bolt. The counter sunk shall be truly concentric with the shank holes. Bolt heads shall be dressed flush where necessary for proper construction.

4.4.8 Close Butted Joints

i) Where close butted joints are required they will be indicated on the Drawings and the butting ends of the parts shall be machined to ensure close contact when the joint is made.

ii) Close contact shall be deemed to have been achieved when atleast 90% of the area is in close contact and the remaining 10% or so also has clearance not exceeding 0.2mm.

4.4.9 Shearing of Plates

Shearing and grinding of steel plates shall not be carried out without the permission of the Engineer.

4.4.10 Notches

The roots of all notches shall be smoothened.

4.4.11 Procedure Trials for Welding and Cutting

Where required by the Engineer, welding and flame cutting trials shall be carried out and completed before fabrication on representative samples of materials to be used in the work, as follows:-

a) The samples of materials shall be selected and marked by the Engineer when the materials for the work are inspected at the mills.

b) Trials on material 19mm thick may be taken to include all material under 19mm thick and on material 38mm thick to include material between 19mm and 38mm

thick. Over 38mm thickness material shall be tested for every thickness increment of 6mm. The trials of flame cutting shall be carried out on material representative of all thicknesses to be used in the work.

c) The welding and flame cutting trials shall demonstrate workmanship / quality to the satisfaction of the Engineer. The procedures to be adopted shall include:

i) Welding procedure in accordance with IRS welded Bridge Code supplemented by IS:813 and IS:1980.

ii) The heat control techniques required to ensure that the flame cut surfaces of any imported steel like steel to B.S. 4360 Grade WR 50, 50B, WR 50B, 50C and WR 50C are suitable for inclusion in welds.

(d) The trials shall include specimen weld details from the actual construction which shall be welded in a manner simulating the most un-favourable instances of fit up and preparation which it is expected will occur in the particular fabrication. After welding, the specimens shall be held as long as possible at room temperature, but in any case not less than 72 hours, and shall then be sectioned and examined for cracking.

(e) Procedure Trials: Testing shall be to relevant IS Code or if approved to B.S. 709. The following groups of tests, shall be carried out in accordance with the type of welds.

(i) Butt welds:- Transverse tensile test. Transverse and longitudinal bend test with the root of the weld in tension and compression respectively and Charpy V notch impact test.

(ii) Fillet welds: Fillet weld fracture test

(iii) Tack welds: Inspection for cracking

(iv) All welds: Macro examination specimen for each type of weld. Additional tests not included in (i) and (ii) above will be specified by the Engineer as required. Shop welded joints will be radiographically examined for 100%

4.4.12 Welding Requirements

a) Qualification and Testing of Welders

Only qualified welders will be engaged in the work and they also will be tested for their skill in welding to full satisfaction of the Engineer as directed below.

(i) No welding operator shall be employed on the work until he has, in the presence of the Engineer, passed the appropriate tests laid down in relevant codes.

(ii) Where plates of 12mm thick and over are to be butt welded the tests. Engineer may specify other tests to be conducted.

(iii) Routine re-testing of welding operators may be required every six months if considered necessary by Engineer.

(iv) The Engineer can also require any welding operator to be retested at any time during the Contract.

b) Supervision of Welding

i) The Contractor shall appoint welding supervisors whose competence and qualifications shall be subject to approval of the Engineer and all welds shall be carried out under their direction.

ii) Except where agreed by the Engineer, a record shall be kept to enable butt welds to be identified with the welders responsible for the work but material shall not be marked by hard stamping for this purpose.

c) Welding Plant

The welding plant shall be capable of maintaining at the weld, the voltage and current specified by the manufacturer of the electrodes used. The Contractor shall supply instruments for verifying voltage and current as and when required by the Engineer.

d) Welding

Metal Arc welding shall be carried out in accordance with IRS Welded Bridge Code (and if so required with B.S. 5135) and the following additional requirements.

i) The general welding programme for shop and site welds, including particulars of the preparation of fusion faces, pre-heating where required and methods of making welds shall be submitted in writing to the Engineer for approval before the work is put in hand. No departure from the welding programme or from the details shown on the Drawings shall be made without the prior approval of the Engineer.

ii) Approval of the welding procedure shall not relieve the Contractor of his responsibility for correct welding and for minimising of distortion in the finished structure.

iii) The procedures for welding and flame cutting established by the procedure trials under Para 4.4.11 shall be strictly followed.

iv) All main butt welds shall have complete penetration and shall comply with the requirements of IRS Welded Bridge Code. They shall be made between prepared fusion faces. Where possible they shall be welded from both sides. The ends of the welds shall have full throat thickness. This shall be obtained on all main welds by the use of extension pieces adequately secured on either side of the main plates. Additional metal remaining after the removal of the extension pieces shall be removed by machining, or by other approved means and the ends and surfaces of the welds shall be smoothly finished.

v) In the fabrication of built-up assemblies all butt welds in the component parts shall be complete before the final assembly.

vi) Pre-heating and temperature conditions, electrodes, and size of single runs shall be as follows:

a)Grades 43A and 43C steel – no welding of these and similar mild steels shall be undertaken where the ambient or plate temperature is 0^{o} C or below.

b) Grades WR 50B and WR 50C Steel - for all welding of steel to Grades 50B and 50 C and similar carbon manganese steels the temperature shall be not less than 10^{o}C when welding is commenced.

vii) Controlled hydrogen electrodes shall be dried out and used in strict accordance with the manufacturer's instructions.

viii) Loose flux used for automatic and semi-automatic welding shall be kept free from contamination and used in accordance with the manufacturer’s instruction.

ix) All tack welds shall be of the same quality and size as the first run of the main weld. The main weld shall fuse completely with the ends of the tack welds to form a regular profile. Where preheat is required for the main welds the tack welds shall be made under the same heat conditions. The length of the tack welds shall

not be less than four times the thickness of the thicker part or 50mm whichever is the smaller.

x) The position of welds required for temporary attachments shall be approved by the Engineer before the work starts.

xi) Temporary attachments shall be removed without damage to the parent metal, which shall be finished smooth by grinding in the direction of the applied stress in the finished structure.

xii) All cracked welds shall be cut out to the satisfaction of the Engineer before re-welding.

xiii) Where automatic or semi-automatic welding processes are used, back gouging will not be required when it is demonstrated to the Engineer that satisfactory welds are produced.

xiv) Where butt welds are to be ground flush, there shall be no loss of parent metal. The final grinding shall be in the direction of the applied stress.

xv) Run – off plates and run-on plates.

a) One pair of “run-on” plates and one pair of “run-off” plates all prepared to the same thickness and profile as the parent metal shall be attached by clamps to the start and finish respectively of all butt welds so that the direction of rolling of the added plates is parallel to that of the parent metal.

b) Except as directed by the Engineer the plates in approximately 1 in 5 pairs of run-off plates shall each be 150mm wide by 200mm long, the length being measured in the rolling direction of the metal and at right angles to the weld.

c) The welds shall run the full length of the joint and extend at full section for a minimum distance of 25mm into the run-off plates.

d) On completion of the welds the 150mm x 200mm run-off plates shall not be removed until they have been marked by the Engineer to identify them with the joints to which they are attached.

e) When removing the run-off and run-on plates by flame cutting the cuts shall not be nearer than 6mm to the sides of the parent metal and remaining metal shall be removed by grinding in the direction of the applied stress or by other method approved by the Engineer.

f) Specimens for test shall be selected from the run-off plates as required by the Engineer.

4.4.13 Welding Inspection

The Engineer will require radiographic or other non-destructive examinations to be carried out on all main welds carrying tension and on other welds to his satisfaction. If required, samples of the welds in permanent or temporary works shall be cut out for examination by the Engineer.

4.4.14 Stress Relieving

If required by the Engineer or specified elsewhere herein or specified on the Drawings, welds shall be stress relieved and special units may require to be normalised.

4.4.15 Flame Cutting

Where the flame cut surface is not subsequently incorporated in a weld, machine flame cutting may be used subject to the following requirements.

i) Grades 43A and 43C steel. All irregularities in the cut face, edges and corners shall be removed by grinding in the direction of the main stress to be carried by the material.

ii) Grades WR 50, 50B, WR 50B, 50C and WR 50C steel:- The heat input and cooling condition shall be in accordance with the procedures specified in Clause 13 of B.S. 5135, unless otherwise specified.

4.4.16

4.4.17 Welding of stud shear connectors

The stud shear connectors shall be welded in accordance with the manufacturer's instructions including preheating. The stud and the surface to which studs are welded shall be free from scale, moisture, rust and other foreign material. The stud base shall not be painted, galvanised or cadmium plated prior to welding. Welding shall not be carried out when temperature is below 10 degrees Celsius or surface is wet or during periods of strong winds unless the work and the welder are adequately protected. The welds shall be visually free from cracks and shall be capable of developing at least the nominal ultimate strength of studs. The procedural trial for welding the stud shall be carried out when specified by the Engineer.

4.4.18 Tolerances

Tolerances in dimensions of components of fabricated structural steel work shall be specified on the drawings and shall be subject to the approval of the Engineer before fabrication. Unless otherwise specified, all parts of an assembly shall fit together accurately within tolerances specified in **Table 4.2**.

A machined bearing surface, where specified by the Engineer, shall be machined within a deviation of 0.25 mm for surfaces that can be inscribed within a square of side 0.5m.

TABLE 4.2 FABRICATION TOLERANCES

A.INDIVIDUAL COMPONENTS		
1.	Length	
	a) Member with both ends finished for contact bearing	± 1mm
	b) Individual components of members with end plate connection	+ 0 mm - 2 mm
	c) Other members i) Upto and including 12M ii) Over 12M	 ± 2mm ± 3.5mm
2.	Width	

	a) Width of built-up girders	± 3mm
	b) Deviation in the width of members required to be inserted in other members	+ 0mm - 3mm
3.	Depth	
	Deviation in the depths of solid web and open web girders	+ 3mm -2 mm
4.	Straightness	
	a) Deviation from straightness of columns	L/3000 subject to a maximum of 15mm where L is length of member
	i) In elevation	+ 5mm - 0 mm
	ii) In plan	L/1000 subject to a maximum of 10mm
5.	Deviation of centre line of web from centre line of flanges in built-up members at contact surfaces	3mm
6.	Deviation from flatness of plate of webs of built-up members in a length equal to the depth of the member	0.005 d to a maximum of 2mm where d is depth of the member
7.	Tilt of flange of plate girders a) At splices and stiffeners, at supports, at the top flanges of plate girders and at bearings	0.005 b to a maximum of 2mm where b is width of the member
	b) at other places	0.015b to a maximum of 4 mm where b is width of the member
8.	Deviation from squareness of flange to web of columns and box girders	L/1000, where L is nominal length of the diagonal
9.	Deviation from squareness of fixed base plate (not machined) to axis of column. This dimensions shall be measured parallel to the longitudinal axis of the column at points where the outer surfaces of the column sections make contact with the base plate.	D/500 where D is the distance from the column axis to the point under consideration on the base plate
10.	Deviation from squareness of machined ends to axes of columns	D/1000, where D is as defined in 9 above
11	Deviation from squareness of machined ends to axes of beams or girder	D/1000, where D is as defined in 9 above

12	Ends of members abutting at joints through cleats or end plates, permissible deviation from squareness of ends	1/600 of depth of member subject to a maximum of 1.5mm

4.5 ERECTION OF STEEL WORK

4.5.1 Reference Specifications

The erection of steel work for different types of structures shall be done in accordance with the respective Indian Railway standard specifications as listed below.

(a) Bridge work: IRS Specification No. B1-2001 for Erection and Riveting of Bridge Girders.

(b) General Structural Work: IRS Specification No.B2 for Steel Structures (other than Girder Bridges)- Part 3.

(c) Iron and Steel tanks and staging – IRS Specification No.B3- Part 4.

The important provisions of IRS Specification No.B1-2001 (Part 3) which is commonly required to be followed in the field for all steel girders are extracted and given below for ready reference, duly amplified where necessary.

4.5.2 Material Handling

(a) The materials, on receipt, shall be carefully unloaded, examined for defects, checked, sorted and stacked securely on a level bed, out of danger from flood or tide and out of contact with water or ground moisture. They will be supported on timber or concrete plinths so that they do not touch the ground.

(b) The materials shall be verified with the marking shown on the marking plan, if any, or with the detailed drawings issued for the work.

(c) Any material found damaged or defective shall be stacked separately. The materials should, as far as possible, be inspected before unloading from trucks to ascertain if any damage has occurred in transit. The portions found damaged or defective shall be marked with paint of distinctive colour. Such materials shall be dealt with under orders of the Engineer and without delay. Slightly distorted parts may be straightened by gradual pressure without heating, whereas badly damaged portions may require to be replaced. In exceptional cases, where rectification of badly distorted or broken parts is allowed by the Engineer, it shall be done in such manner and with such safeguards as directed by him. Connection plates, if slightly bent or twisted shall be straightened cold. If bent so sharply as to require heating, the whole plate thus treated shall be annealed before use on work. Engineer at his discretion may have such rectified component tested for its load carrying capacity before use on work.

4.5.3 Preliminary Requirements

i) Before starting the work, the method of erection and the details of the erection equipment proposed to be used shall be got approved by the Engineer, but such approval shall not be considered as relieving the Contractor of his responsibility for safety or for carrying out the work in full accord with the drawings and specifications. All temporary works shall be properly designed and substantially constructed for

the loads they would be called upon to sustain, including wind and lateral forces, etc. according to the local conditions.

ii) A careful inspection of plant and tackle shall be made to ensure that they are in good order and well upto the capacity required. When chains or ropes are used for lashing, care must be taken to protect them as well as the members lashed, to avoid damage to either.

iii) Frame and steel skeleton structures shall be carried up true and plumb. Temporary bracings shall be provided, if required, to take care of stresses from erection equipment or other loads carried during erection and also to ensure lateral stability of structures during the process of erection.

iv) All surfaces which shall be in permanent contact after assembly shall be thoroughly cleaned to remove all paint and mill scale and shall receive, immediately before being assembled one coat of approved primer like Zinc Chrome Red Oxide to IS 2074 or in accordance with relevant Para in Painting Iron Work, with the prescribed number of coats. Care shall be taken to see that any burr or other surface defects are removed before the parts are assembled. Field rivets, welds and bolted connections shall be protected by a coat of clean boiled linseed oil till the work is inspected and passed by the Engineer's representative. After passing, these shall be cleaned and painted with a coat of red lead paint or other approved primer, irrespective of whether the final painting of the finished structure is to be done by the Contractor or not.

4.5.4 Assembling Steel

4.5.4.1 The parts shall be accurately assembled as shown on the drawings and match marks shall be followed. The material shall be carefully handled so that no parts will be bent, broken or otherwise damaged.

4.5.4.2 Hammering which will injure or distort the members shall not be done. Bearing surface or surfaces to be in permanent contact shall be cleaned, before the members are assembled. The truss spans shall be erected on blocking, so placed as to give the proper camber. The blocking shall be left in place until the tension chord splices are fully riveted and all other truss connections pinned and bolted. Rivets in splices of butt joints of compression members and rivets in railings shall not be driven until the span has been swung.

4.5.4.3 All joint surfaces for bolted connections including bolts, nuts, washers shall be free from scale, dirt, burrs, other foreign materials and defects that would prevent solid seatings of parts. The slope of surface of bolted parts in contact with bolt head and nut shall not exceed 1 in 20, to the plane normal to bolt axis, otherwise suitable tapered washer shall be used.

4.5.4.4 All fasteners shall have a washer under nut or bolt head whichever is turned in tightening. Any connection to be riveted or bolted shall be secured in close contact with service bolts or with a sufficient number of permanent bolts before the rivets are driven or before the connections are finally bolted. Joints shall normally be made by filling not less than 50 per cent of holes with service bolts and barrel drifts in the ratio 4:1. The service bolts are to be fully tightened up as soon as the joint is assembled. Connections to be made by close tolerance or barrel bolts shall be completed as soon as practicable after assembly.

4.5.4.5 Any connection to be site welded shall be securely held in position by approved methods to ensure accurate alignment, camber and elevation before welding is commenced.

4.5.4.6 The field riveting, and bolted and pin connection shall conform to the requirements of Para 4.5.5 as appropriate.

4.5.4.7 The correction of minor misfits involving harmless amounts of reaming, cutting and chipping will be considered a legitimate part of erection. However, any error in the shop fabrication or deformation resulting from handling and transportation which prevents proper assembling and fitting up of parts by moderate use of drifts or by a moderate amount of reaming and slight chipping or cutting shall be reported immediately to the Engineer and his approval of the method of correction obtained. The correction shall be made in the presence of the Engineer.

4.5.5 Rivetting

(a) Riveted connections shall be securely bolted up before the rivets are driven.

(b) Parallel barrel drifts, with their greatest diameter not exceeding that of the rivet hole, may be used for drawing members into position; but no drifting to match up unfair holes shall be allowed. Any apparent error in fabrication work which prevents assembling and fitting up of the parts by the proper use of these drifts shall be investigated immediately. No reamering shall be undertaken without the written authority of the Engineer, and if it be approved, any special rivets that may be required shall be used to fill such holes, and for this no extra payment shall be admissible to the Contractor. All correspondence relating to the recourse to reamering and the use of special rivets shall invariably be recorded by the Engineer for information.

(c) In cases where the joint has to withstand stresses arising from special methods of erection before being rivetted up, parallel barrel drifts and turned bolts shall be used to withstand the whole of such stresses, the number of drifts being subject to a maximum of 40 per cent of the total.

(d) In the event of any emergency arising, such as staging being in danger of being carried away by floods before the riveting can be completed, the joints shall be made secure by filling 40 per cent of the holes with drifts and an equal number with service bolts fully tightened up.

(e) Riveting shall not be started until such time as the Engineer or his representative has personally satisfied himself that the alignment and levels of the members are correct, the verticals plumb, all joints and cover plates well in order, service bolts tight and the field rivet holes properly matching.

(f) Joints shall normally be made by filling not less than 50 per cent of the holes with service bolts and parallel drifts in the ratio of 4 to 1. The service bolts shall be fully tightened up.

4.5.6 Bolted Connection:-Permanent bolted connections shall be used only where shown on the drawings or where specially approved by the Engineer. In all such cases, washers not less than 6mm thick shall be used under the heads and nuts, and the nuts drawn tight and “checked” by burring over the threads with a chisel.

4.5.7

4.5.7 Rates: Unless stipulated to the contrary, the rates for erection of steel work shall cover the cost of all labour, tools and plant, tackle and consumable stores and temporary staging, etc. as required for the work. Unless otherwise specified and in other than supply and erection contract the supply of fabricated steel work and the fittings required for making the field connections will be arranged by the Railway. Unless otherwise specified if ordered to be done, painting of the finished structure, will be paid for separately. But no extra payment will be made for cleaning and painting the surfaces of contact or the field connections, as specified in Paras 4.5.5 and 4.5.6. Field rivets, welds and bolted connections shall be protected by a coat of clean boiled linseed oil till the work is inspected and passed by the Engineer's representative. After passing, these shall be cleaned and painted with a coat of red lead paint or other approved primer, irrespective of whether the final painting of the finished structure is to be done by the Contractor or not.

4.6 PAINTING STEEL WORK

4.6.1 General:-Unless otherwise specified all painting and protection coating work shall be done in accordance with Para 39 of IRS B1-2001 and IS:1477 (Part 1) supplemented by the specifications given below. In locations where girders are subjected to satisfy such as close vicinity of sea and or over creeks, metalising with sprayed aluminium as given is Appendix VII to IRS B1-2001 will be done, followed by painting with one coat of etch primer to IS: 5666 (ii) or the coat of zinc chrome primer to IS:104 the zinc chrome to be used in the manufacturer conforming to type 2 of IS 51 and (iii) two coats of aluminium paint to IS 2339 by brushing or spraying as specified. One coat is to be applied in shop before dispatch and second after erection after touching up the earlier coats if damaged in transit or during erection.

4.6.2 Surface Preparation

Steel surface to be painted either at the fabricating shop or at the site of work shall be prepared in a thorough manner with a view to ensuring complete removal of mill scale by one of the following processes as agreed to between the fabricator and the Engineer.

a) Dry or wet grit / sand blasting

b) Pickling which should be restricted to single plates, bars and sections

c) Flame cleaning

Primary coat shall be applied as soon as practicable after cleaning and in case of flame cleaning, primary coat shall be applied while the metal is still warm.

All slag from welds shall be removed before painting. Surfaces shall be maintained dry and free from dirt and oil. Work out of doors in frosty or humid weather shall be avoided.

4.6.3 Coatings

Prime coat to be used shall conform to the specification of primers specified hereinafter or in Drawings / Contract and should be approved by the Engineer. Metal coatings shall be regarded as priming coatings. Primer shall be applied to the blast cleaned surface before any deterioration of the surface is visible. In any case,

the surface shall receive one coat of primer within 4 hours of abrasive blast cleaning.

All coats shall be compatible with each other. When metal coatings are used, the undercoat shall be compatible with the metal concerned. The undercoat and finishing coat shall preferably be from the same manufacturer. Successive coats of paints shall be of different shades or colours and each shall be allowed to dry thoroughly before the next is applied. Particular care shall be taken with the priming and painting of edges, corners, welds and rivets. Typical guidelines for epoxy based paints and the conventional painting system for bridge girders as given below may be complied with:

a) Epoxy Based Painting

i) Surface preparation: Remove oil / grease by use of petroleum hydrocarbon solution (IS:745) and Grit blasting to near white metal surface.

ii) Paint system: 2 coats of epoxy zinc phosphate primer = (60 micron; Total 5 coats = 300 micron) to RDSO Specn. No. IC/PCN/103/86. Finished coats approved by --- air less spray of coats of Epoxy zinc phosphate to RDSO Specifications No. M&C /PCN/102/86.

b) Conventional Painting System for areas where corrosion is not severe

Priming Coat:

One coat of ready mixed zinc chrome priming conforming to IS:104 followed by one coat of ready mixed red oxide zinc chrome primer conforming to IS:2074.

Or

Two coats of zinc chromate red oxide primer conforming to IRS P-31.

Finishing Coats

Two cover coats of red oxide paint conforming to IS:123 or any other approved paint shall be applied over the primer coat. One coat shall be applied before the fabricated steel work leaves the shop. After the steel work is erected at site, the second coat shall be given after touching up the primer and the cover coats if damaged in transit.

c) Conventional Painting System for areas where corrosion is severe

Priming Coat:

One coat of ready mixed zinc chrome primer conforming to IS:104 followed by one coat of red oxide zinc chrome conforming to IS:2074.

Finishing Coats:

Two coats of aluminium paint conforming to IS:2339 shall be applied over the primer coat. One coat shall be applied before the fabricated steel work leaves the shop. After the steel work is erected at site, the second coat shall be given after touching up the primer and the cover coats if damaged in transit.

4.6.4 Painting in the Shop

i) All fabricated steel shall be painted in the shops after inspection and acceptance with at least one priming coat unless the exposed surfaces are

subsequently to be cleaned at site or are metal coated. No primer shall be applied to galvanised surfaces.

ii) Shop contact surfaces, if specifically required to be painted, shall be brought together while the paint is still wet.

iii) Field contact surfaces and surfaces to be in contact with cement shall be painted with primer only. Paint shall be completely dried before loading and transporting to site.

iv) Surface not in contact but inaccessible after shop assembly shall receive the fully specified protective treatment before assembly.

v) Where surfaces are to be welded, the steel shall not be painted or metal coated within a suitable distance from any edges to be welded if the specified paint or metal coating would be harmful to welders or is expected to impair the quality of site welds.

vi) Exposed machined surfaces shall be adequately protected.

4.6.5 Painting at Site

i) Surfaces which will be inaccessible after site assembly shall receive the full specified protective treatment before assembly.

ii) Surfaces which will be in contact after site assembly shall receive a coat of paint (in addition to any shop priming) and shall be brought together while the paint is still wet.

iii) Damaged or deteriorated paint surfaces shall be first made good with the same type of coat as the shop coat.

iv) Where steel has received a metal coating in the shop, this coating shall be completed on site so as to be continuous over any welds, bolts and site rivets.

v) Specified protective treatment shall be completed after erection.

4.6.6 Methods of application

The methods of application of all paint coatings shall be in accordance with the manufacturer's written recommendation and approved by the Engineer or as indicated in painting chapter to the extent they are applicable to major steel structures. Spray painting may be permitted provided it will not cause inconvenience to the public and is appropriate to the type of structure being coated. Areas hard to gain access for painting and areas shaded for spray application shall be coated first by brushing.

Oil based red lead primers must be applied by brush only, taking care to work into all corners and crevices.

The primer, intermediate and finishing coats shall all be applied so as to provide smooth coatings of uniform thickness. Wrinkled or blistered coatings or coatings with pinholes, sags, lumps or other blemishes, shall not be accepted. Where the Engineer so directs, the coating shall be removed by abrasive blast cleaning and replaced at the Contractor's expense.

4.6.7 Guideline of Specifications for Protective Coating System in Different Environments

a) Since the seriousness of the problem of corrosion depends upon atmospheric conditions and these vary enormously, there is no single protective system or method of application that is suitable for every situation.

b) However, as a guide to specifying authorities, broad recommendations in this respect are given in **Table 4.3** for various types of coatings in various environmental conditions, extracted from MOST Specifications for Roads and Bridges. Approximate life to first maintenance is also indicated and can be used as a guide.

TABLE 4.3 RECOMMENDATIONS FOR TYPES OF PROTECTIVE COATINGS

System	Environment
i) Wire brush to remove all loose rust and scale: 2 coats drying oil type primer; 1 under coat alkyd type paint; 1 finishing coat alkyd type. Total dry film thickness = 150 um	Suitable for mild conditions where appearance is of some importance and where regular maintenance is intended. This system may deteriorate to a marked extent if it is exposed to moderate aggressive atmospheric conditions for lengthy period.
ii) Wire brush to remove all loose rust and scale; 2 coats drying oil type primer; 2 under coats micaceous iron oxide (MXO) pigmented phenolic modified drying oil. Total dry film thickness = 170 μm.	Similar to (i) but where appearance is not very important provides longer life in mild condition. Will provide upto 5 years life to first maintenance in polluted inland environment
iii) Blast clean the surface: 2 coats of quick drying primer; undercoat alkyd type paint; 1 finishing coat alkyd type. Total dry film thickness: 130-150μm.	Compared to (i) this would provide a longer life in mild conditions and could be used in less mild situation e.g. inland polluted, where maintenance could easily be carried out at regular intervals
iv) Blast clean the surface; 2 coats of drying type oil primer; 1 undercoat micaceous iron oxide pigmented drying oil type paint. Total dry film thickness: 165-190μm	Suitable for general structural steel work exposed to ordinary polluted inland environments where appearance is not of primary importance.
v) Blast clean the surface; 2 coats of metallic lead pigmented chlorinated rubber primer. 1 undercoat of high build chlorinated rubber, 1 finishing coat of chlorinated rubber. Total dry film thickness: 200 um	Suitable for structures in reasonably aggressive conditions e.g. near the coast. Will provide, long term protection than (iv) in non-coastal situations. Also suitable for aggressive interior situations such as industrial areas.
vi) Blast clean the surface: 350-450 μm thickness. Coal tar epoxy.	Suitable for sea water splash zones or for conditions of occurrence of frequent salt sprays
vii) Pickle: hot dip galvanised (Zinc) Total thickness: 85 μm	Suitable for steel work in reasonably mild conditions. Life of 15-20 years

	before first maintenance could be expected in many situation
viii) Grit blast, hot dip galvanised. (Zinc). Total thickness = 140 μm	Provides a longer life than (vii) because of thicker zinc coating
ix) Grit blast; 1 coat of sprayed zinc/ aluminium followed by suitable sealer Total Thickness = 150 μm	Expected to provide long term protection approx 15-20 years in aggressive atmosphere

4.7 Tests and Standards of Acceptance

The materials shall be tested in accordance with relevant IS specifications and necessary test certificates shall be furnished. Additional tests, if required, shall be got carried out by the Contractor at his own cost.

The fabrication, furnishing, erecting, painting of structural steel work shall be in accordance with these specifications and shall be checked and accepted by the Engineer.

4.8 Measurements for Payment

a) The measurements of steel work shall be in tonnes based on the net weight of metal in the fabricated structure computed on the basis of nominal weight of materials, unless otherwise specified. See also Para 4.1.2 (a).

b) The weight of rolled and cast steel and cast iron shall be determined from the dimensions shown on the drawings on the following basis:

Rolled or cast steel : 7.85 x $\mathbf{10^3}$ kg/cum.

Cast Iron : 7.21 x $\mathbf{10^3}$ kg/cum

This will be applicable in areas not covered by condition (e) below:

c) Weight of structural sections shall be nominal weight.

Weight of castings shall be computed from the dimensions shown on the drawings with an addition of 5 per cent for fillets and over runs.

d) No additions shall be made for the weight of protective coating or weld fillets.

Where computed weight forms the basis for payment, the weight shall be calculated for exact cut sizes of members used in the structure, deductions being made for all cuts, except for rivet holes. Additions shall be made for the rivet heads as mentioned above.

When specially agreed upon, the basis for payment may be the bridge weight complete, according to specifications included in special provisions of the Contract.

e) Any steel work, the weight of which differs by more than 2.5% from the calculated weight determined from the nominal weight of the sections shall be liable to rejection.

f) Payment shall be made on the tendered weight to be calculated in accordance with the nominal weight of the sections as specified in the contract drawings. In addition for welds and rivet heads will either be specified in the schedule and if not so will be

i) 3 percent in the case of riveted or composite (riveted & welded) work

ii) 1 percent in the case of purely welded work.

iii) In case of composite work (welding and HSFG bolts), addition in weight shall be 1% for welding and HSFG bolts shall be paid separately under relevant item.

(Para iii) above does not exist in IRS B1-2001 specification, included now in Unified specifications as HSFG Bolts item introduced in USSOR as new item.)

g) Should the actual weight fall short of the calculated weight by more than 2.5% the material if accepted will be paid for the actual weight.

h) No separate payment shall be made for supply of bolts and nuts and drifts required for erection purposes and any wastages thereof.

i) In the event of a dispute arising as to the weight of a portion of steel work, a weighment shall be made in the presence of Inspecting Officer.

4.9 Rate

The contract unit rate for the completed structural steel work shall include the cost of all materials, labour, tools, plant and equipment, handling and transport required for fabrication, connections, oiling, painting, temporary erection, inspection, tests and complete final erection as shown on the drawings and as specified in these Specifications and specifications given on the drawings and accompanying bid documents. In such cases, latter will prevail unless otherwise directed.

Annexure 4.1

(Refer Para 4.3.6)

Lengths (L) Required for Different Diameters of Rivets

(All dimensions in mm).

Grip Length	**(i) Cuphead Rivets**						**(ii) Countersunk Head Rivets**					
	10	12	16	18	20	22	10	12	16	18	20	22
12	31 32	33 32	38 40	41 40	..	..	23	..	..	..	..	..
14	33 32	36	41 40	43	46	..	25 26	..	..	..	..	..
16	36	38 40	43	46	48 49	51 52	28 29	..	..	..	..	..
18	38 40	41 40	45 46	48 49	51 52	53 52	30 29	31 32	32	..	..	..
20	41 40	43	48 49	50 49	53 52	56 55	33 32	33 32	35 36	..	..	..
22	44 43	46	50 49	53 52	55	58	36	36	37 36	..	..	..
24	46	48 49	53 52	55	58	60 61	38 40	38 40	40	40	..	..
26	49	51 52	55	57 58	60 61	63 64	41 40	41 40	42 43	42 43	43	..
28	51 52	53 52	57 58	60 61	62 61	65 64	43	43	44 43	45 46	45 46	..
30	54 55	56 55	60 61	62 61	65 64	67	46	46	47 46	47 46	48 49	49
34	..	61	64	67	69 70	72 73	51 52	51 52	51 52	52	52	54 55
38	..	66 67	69 70	71 70	74 73	76	..	56 55	56 55	56 55	57 58	58
42	..	71 70	74 73	76	78 80	81 80	..	61	61	61	61	63 64
46	..	76	79 80	81 80	83	85 86	..	66 67	66 67	66 67	66 67	67

50	..	81 80	83	85 86	88 89	90 89	..	71 70	70	70	71 70	72 73
55	..	87 86	89	91 92	93 92	96 95	..	77 76	76	76	76	78 80
60	..	..	95	97 99	99	101 102	..	83	82 83	82 83	82 83	83
65	..	..	101 102	103 102	105 108	107 108	..	..	88 89	88 89	88 89	89
70	..	..	107 108	109 108	111 114	113 114	..	..	94 95	94 95	94 95	95
75	..	..	113 114	115 114	116 118	118	..	..	100 99	100 99	99	100 99
80	..	..	..	120 118	122 125	124 125	..	..	106 108	105 108	105 108	106 108
85	..	..	..	..	128 125	130 132	..	..	112 114	111 114	111 114	112 114
90	..	..	..	..	..	135	..	..	..	117 118	117 118	117 118
95	..	..	..	..	..	141 140	..	..	..	..	122 125	123 125
100	..	..	..	..	..	..	..	..	..	..	..	129 132

Note :(1) The lengths given above are those required theoretically, except that where two lengths are indicated, the figure in the denominator represents the length to which rivets are generally produced by standard manufacturers.

(2) Interpolate between the theoretical lengths for intermediate grip lengths.

Chapter- 5
Bridge Works – Miscellaneous

5. BRIDGE BEARINGS

5.1 Types and General Requirements

a) Types of Bearing scan be:-

i) Steel Plate Bearings

ii) Pin Bearings

iii) Rocker and Roller Bearings

iv) Neoprene Bearings and Elastomeric Pads

v) PTFE/ POT Bearings

b) **Common requirements of different types of bearings are:-**

i) Bearing plates, bars, rockers, assemblies and other expansion or fixed devices shall be constructed in accordance with the details shown on the drawings.

ii) The bearings may either be procured directly by the Engineer from the manufacturers, and supplied to be installed by the Contractor or the Contractor may be required to supply and install the bearings as part of the contract. In the former case, the manufacturer shall be associated with the installation of the bearings to the full satisfaction of the Engineer, whereas in the latter case, the Contractor shall be solely responsible for the satisfactory supply and installation of the bearing. In the detailed description of the specification, a general reference shall be made to the Contractor or manufacturer and the interpretation shall be as per terms of contract.

iii) The Contractor shall exercise the utmost care in transporting, setting and fixing all bearings in their correct positions and ensuring that uniformity is obtained on all bearing surfaces.

iv) Bearings shall be handled with care and stored under cover.

v) When bearing assemblies or plates are shown on the drawings to be placed (not embedded) directly on concrete, the concrete bearing area shall be constructed slightly above grade (not exceeding 12mm) and shall be finished by grinding.

vi) It shall be ensured that the bearings are set truly level and in exact position as indicated on the drawings so as to have full and even bearing on the seats. Thin mortar pads (not exceeding 12mm) may even be made to meet with this requirement.

vii) It shall be ensured that the bottoms of girders to be received on the bearings are plane at the locations of these bearings and care shall be taken that the bearings are not displaced while placing the girders.

viii) Unless otherwise specified for sliding plate bearings, stainless steel surface sliding on stainless steel plate with mild steel matrix shall be used. The other option shall be to provide PTFE surface sliding on stainless steel.

ix) These specifications cover the types of bearings which have been successfully used in various bridges in India. For other types of structures (like cable stayed bridges or similar and in special cases, special types of bearings to

suit the requirements may have to be provided, for which special specifications may be laid down by designers and approved by the Engineer.

5.2 STEEL BEARINGS

5.2.1 Materials

The material for steel bearings shall conform to the requirements of Chapter 4. Some additional requirements for materials for steel bearings are indicated below:

a) For the purpose of checking the soundness of cast steel components, castings shall be ultrasonically examined following procedures as per IS:7666 with acceptance standard as per IS:9565. The castings may also be checked by any other accepted method of non-destructive testing as specified in IS:1030. Quality level of castings shall be level 3 as per IS:9565.

The grease for bearings shall conform to the requirements of IS:503 (Grade 4).

5.2.2 Fabrication

i. All work shall conform strictly to the drawings and shall be in accordance with the provisions of this section. Care shall be taken to ensure that all parts of an assembly fit accurately together. The workmanship shall satisfy all relevant provisions laid down in Chapter 4.

ii. Knuckle pins, rolling surfaces of the rollers and bearing surface of the bearing plates shall be machined and all bolt holes shall be drilled. The whole bearings shall be fitted and finished as required for good quality machined work to the satisfaction of the Engineer. However, in case of bearings which are to be grouted or bedded on a suitable yielding material on any surface which is to be in permanent contact with the grout or the yielding material may be left un-machined.

iii. Fabrication shall be carried out by an organization experienced and qualified to undertake precision engineering of this type and be approved by the Engineer.

iv. Workmanship shall be of good quality, neatly finished and of good appearance.

v. Castings shall be true to the forms and dimensions shown on the drawings and shall be free from pouring faults, sponginess, cracks, blow holes and other defects on position, affecting their appearance or strength. Warped or distorted castings will not be accepted. Exposed surfaces shall be smooth and dense.

vi. All castings shall be cleaned by sand or shot blasting to remove sand or scale and to present a clean uniform surface.

vii. All irregularities, fins or risers shall be ground off flush with the adjacent surface. Castings with visible cracks, blow holes or similar blemishes shall be rejected if the imperfections are located in bearing surfaces or cannot be remedied to the satisfaction of the Engineer.

viii. Imperfections which are not located in bearing surfaces shall be cleaned out and filled with weld metal of the appropriate composition and ground flush.

ix. All surfaces of major components like top plates, saddle plates, base plates and rollers of the bearings shall be machined all over for correct alignment, interchangeability, proper fitting etc.

5.2.3 Tolerances

Tolerances for its individual components or of the assembled bearings shall be as shown on the drawings or subject to the approval of the Engineer. In all other cases, unless otherwise directed, the following tolerances shall be maintained:

a) Diameter of Rollers, Knuckle Pins and Bores

Tolerances on diameter of rollers and all convex surfaces shall conform to K7 of IS:919.

Tolerances on diameter of all concave surfaces shall conform to D8 of IS : 919.

b) Height of Bearings

Tolerances on height of any component casting shall not exceed + 0.5mm. No minus tolerance shall be allowed. The edges of all ribs shall be parallel throughout their length.

c) Base Plate

Tolerance on length and width of the base plate shall not exceed + 1.0mm, tolerance on the thickness of the plate shall not exceed + 0.5mm. No minus tolerance shall be allowed. All rocking, rolling and sliding surfaces shall have a machine smooth finish to 20 micron maximum mean deviation as per IS:3073.

d) Castings

No minus tolerance shall be allowed in the thickness of any part of the castings. The edges of all ribs shall be parallel throughout their length.

5.2.4 Installation of Steel Bearings

i) General

a) Bearings shall be placed in the positions as shown on the drawings with all bearing surfaces in full contact and to the tolerances as specified.

b) Roller and rocker bearings shall be placed so that their axes of rotations are horizontal and normal to the direction of movement of the members they support. Upper and lower bearing plates shall be set horizontal in both directions.

c) During installation the bearings shall be pre-set with respect to the bearing axis to account for the movement due to the following:

i) Temperature variation between the average temperature prevailing at the time of installation and the mean design temperature.

ii) Shrinkage, creep and elastic shortening.

d) For bridges in gradient, the bearing plates shall be placed in a horizontal plane.

e) In pre-stressed concrete construction where launching of girders is employed, in order to avoid slipping or jumping of rollers due to vibration or jolts, adequate measures may be taken to ensure that the roller assembly is not disturbed. It is normal practice to provide rocker bearings on the launching end and place the beam on the rocker end slightly in advance of placing on the roller.

f) During concreting of girders, the bearings shall be held in position securely by providing temporary connection between the top and bottom plates in case of fixed bearings and between top plate, base plate and saddle plate in case of roller cum rocker bearing or by any other suitable approved arrangement which prevents the relative displacement of the components.

g) In pre-stressed precast girders, where recesses are left on the underside of girders to receive the anchor bolts, grout holes extending to the beam sides or to the deck level shall be provided. The cement sand grout shall have a mix of 1:1.

ii) Checking, Cleaning and Lubrication

Before erection, each bearing shall be uncrated, disassembled and checked. Any damaged part shall be made good for approval by the Engineer.

All bearings with sliding surfaces shall be cleaned and lightly lubricated with an approved lubricant immediately before erection.

iii) Testing

Testing of steel Roller and Rocker bearings will be done in accordance with provisions of IRS Specifications B-1-2001.

A) If required, a suitable number of complete bearings as specified by an accepting authority shall be tested to 1.25 times the design load. Recovery should be 100 per cent. Contact surfaces shall be examined by illumination source for any defects, cracks, etc. Segmental roller shall be tested for design movements.

B) For large lots (consisting of 12 sets or more), a quality control report shall be submitted as detailed below:

a) Unless otherwise agreed upon by the Engineer and the manufacturer, the latter shall furnish a complete report on the process of quality control. The Engineer may appoint an authorized inspection agency for inspection purpose on his behalf. Such an inspection agency shall also submit reports to the Engineer regarding various tests performed on the bearing or certify the acceptance of the bearings.

b) Test Certificates of all raw materials shall be submitted. If manufacturer's test certificates are not available for the raw materials, the bearings manufacturer shall perform the necessary confirmatory tests as per relevant codes of practice and shall furnish the test results.

c) A detailed quality control system including stage by stage inspection, starting from raw materials upto the finished bearing shall be submitted by the bearing manufacturer.

d) The Engineer shall reserve the right to witness such inspection at manufacturer's works with or without prior permission of the manufacturer. For this, the bearing manufacturer shall have in plant testing facilities as far as possible and practicable.

e) The bearing manufacturer shall maintain a list of consumption of raw materials for a period of at least previous one year.

f) Test certificates of bearings manufactured during preceding one year shall be made available at the manufacturer's works.

g) In case the lot size of similar bearings exceeds 12 sets as per the direction of the Engineer, one extra set of bearings for each 24 sets of bearings or part thereof shall be manufactured and the cost of such extra bearings shall be borne by the user.

h) The Engineer shall select the extra bearing (s) at random and shall perform various tests including destructive testing on it at his discretion, either at the

manufacturer's works or at any other approved test laboratory, notwithstanding the test reports submitted.

i) In case there is a major discrepancy regarding material, the Engineer shall declare the whole lot of bearings as unacceptable.

j) In case minor defects in fabrication, like welding or machining is found in the test bearing before destructive testing and if the test bearing is found to be acceptable after destructive testing, the minor defects in the test bearings shall not be a bar to the acceptance of the entire lot.

k) The opinion of the Engineer in cases (i) and (j) above shall be binding on the manufacturer.

iv) Placing

a) On supporting structures, pockets shall be provided to receive anchor bolts; one side of the pocket shall project beyond the bearing plate. The pocket shall be filled with mortar of mix 1:1 and the concrete bearing area also shall be finished level by a thin and stiff mortar pad of mix 1:1 (the thickness not exceeding 12mm) just before placing of bearing assemblies or bottom plate on the concrete seat.

b) In case of precast girders a recess of 6mm shall be provided on the underside with a level finish for housing the bearing plate. A thin and stiff mortar pad of mix 1:1 with thickness not exceeding 3mm shall be provided over the top plate before lowering the precast beam in position in order to ensure full and even pressure on the plate surface.

c) It shall be ensured that while placing the girders, the bearings are in their exact positions as indicated on the approved drawing and not displaced therefrom.

d) All concrete surfaces to be in contact with the mortar shall be thoroughly cleaned and kept saturated with water for a period not less than 24 hours before placing mortar and operations are to be carried out when the surface temperatures of the exposed bearings are the minimum practical.

e) No mortar that is more than 30 minutes old after completion of mixing, shall be used.

f) After placing and finishing the mortar, the bearing shall be checked for position and shims or other temporary supports removed and the mortar made good. If the bearing has moved, the bearing or the plate shall be lifted, the mortar removed and the whole procedure repeated.

g) Exposed faces of the mortar shall be cured under damp Hessian for 7 days.

h) Placing of the bearing and mortar shall only be carried out in the presence of the Engineer.

5.3 ELASTOMERIC BEARINGS

Note:- The term "bearing" in this case refers to an elastomeric bearing consisting of one or more internal layers of elastomer bonded to internal steel laminates by the process of vulcanization. The bearing shall cater for translation and / or rotation of the superstructure by elastic deformation.

5.3.1 Raw Material

a) Chloroprene (CR) only shall be used in the manufacture of bearing.

Grades of raw elastomer of proven use in elastomeric bearings, with low crystalization rates and adequate shelf life (e.g. Neoprene WRT, Bayprene 110, Skyprene B-5 and Denka S-40V) shall be used.

b) No reclaimed rubber or vulcanized wastes or natural rubber shall be used.

The raw elastomer content of the compound shall not be lower than 60 per cent by its weight. The ash content shall not exceed 5 per cent (as per tests conducted in accordance with ASTM D-297, sub-section 10)

c) EPDM and other similar elastomers for bridge bearing use shall not be permitted.

d) Properties and Tests

The elastomer shall conform to the properties specified in **Table 5.1**

Table 5.1 Properties of Elastomer for Bearings

	Property	**Unit**	**Test Method, IS Specification reference**	**Value of the characteristic specified**
1	**Physical properties**			
1.1	Hardness	IRHD	IS:3400 (Part II)	60+5
1.2	Minimum Tensile Strength	Mpa	IS:3400 (Part I)	17
1.3	Minimum Elongation at break	Per cent	IS:3400 (Part I)	400
2	**Maximum Compression Set**	Per cent	IS:3400 (Part X) duration (h)	Temperature (deg C)
	CR		+0 to 24.2	100±1
3	**Accelerated Ageing**		IS:3400 (Part IV) duration (h)	Temperature (deg C)
	CR		70	100±1
3.1	Max. change in Hardness	IRHD		+15
3.2	Max. change in Tensile Strength	Per cent		-15
3.3	Max. change in Elongation	Per cent		-40

Shear modulus of the elastomer bearing shall neither be less than 0.80 MPa nor greater than 1.20 MPa.

e) The adhesion strength of elastomer to steel plates determined according to IS:3400 (Part XIV) method A shall not be less than 7 kN/m.

For elastomeric bearings (CR) used in adverse climatic conditions the following ozone resistance test shall be satisfied:

f) The ozone resistance of elastomer shall be proved satisfactory when assessed by test according to IS:3400 (Part XX). The strain, temperature, duration and ozone concentration of the test shall be 20 per cent, 40 ± 1 degree Celsius, 96h and 50 pphm by volume respectively.

g) No cracking detected by visual observation at the end of the test shall be considered satisfactory. No specific tests for assessment of low temperature resistance may be deemed necessary.

NOTE: For use of elastomer in extreme cold climates, the Engineer may specify special grade of low temperature resistant elastomer in conformity with operating ambient temperature conditions. The specifications of such special grade elastomer including the tests for low temperature resistance shall be mutually agreed to by the Engineer and the producer supplier and are outside the purview of these specifications.

h) Laminates of mild steel conforming to IS:226 shall only be permitted to be used. Use of any other material like fibre glass or similar fabric as laminates shall not be permitted.

i) The manufacturers of elastomeric bearings shall satisfy the Engineer that they have in-house facilities for testing the elastomer for carrying out the following tests in accordance with the relevant provisions of ASTM D-297 as given below:-

i) Identification of polymers	:	to confirm the usage of Chloroprene (Appendix X-2)
ii) Ash content test	:	to determine the percentage (sub-section 34)
iii) Specific gravity test	:	(sub-section 15)
iv) Polymer content test	:	(sub-section 10)

j) The Engineer shall invariably get the test (a) performed in his presence or in the presence of his authorized representative to satisfy the requirement. In case of any disputes regarding interpretation of results the Engineer may carry out test as per ASTM S-3452-78 (Chromatography test) at the manufacturer's cost in a recognized test house.

k) The elastomer specimen to conduct the test shall be obtained from the bearings selected at random for destructive test. Remaining part of the test bearing shall be preserved by the Engineer for any test to be done in future, if required.

5.3.2 Fabrication

a) Steel plates for laminates shall be sand blasted, clean of all mill scales and shall be free from all contaminants, prior to bonding by vulcanization. Rusted plates with pitting shall not be used. All edges of plates shall be rounded.

b) Each bearing with steel laminates shall be cast as a single unit in a mould and vulcanised under heat and pressure. Casting of elements in separate units and subsequent bonding shall not be permitted, nor shall cutting from large size cast be permitted.

Bearings of similar size to be used in particular bridge project shall be produced by identical process and in one lot as far as practicable. Phased production may only be resorted to when the total number of bearings is large enough.

The moulds used shall have standard surface finish adequate to produce bearings free from any surface blemishes.

c) Spacers used in mould to ensure cover and location of laminates shall be of maximum size and number practicable. Any hole at surface or in edge cover shall be filled in subsequently.

Care shall be taken to ensure uniform vulcanising conditions and homogeneity of elastomer through the surface and body of bearings.

d) The bearings shall be fabricated to comply with the tolerances specified in **Table 5.2**.

TABLE 5.2 TOLERANCES

	ITEMS	**TOLERANCES**
1.	Overall plan dimensions	-0, + 6mm
2.	Total bearing thickness	-0, + 5mm
3.	Parallelism	
a)	Of top surface of bearing with respect to the bottom surface as datum	in 200
b)	Of one side surface with respect to the other as datum	1 in 100
4a)	Thickness of individual internal layer of elastomer	$\pm$ 20 per cent (max. of 2mm)
b)	Thickness of individual outer layer	-0, +1mm
5a)	Plan dimensions of laminates	-3mm, +0
b)	Thickness of laminates	$\pm$ 10 per cent
c)	Parallelism of laminate with respect to bearing base as datum	1 in 100

e) The vulcanising equipment / press shall be such that between the platters of press the pressure and temperature are uniform and capable of being maintained at constant values as required for effecting a uniform vulcanization of the bearing.

f) The moulding dies utilised for manufacturing the bearings shall be so set inside the platen of the press so that the pressure developed during vulcanizations of the product is evenly distributed and the thickness maintained at all places within acceptable tolerance limits taking into consideration the shrinkage allowance of vulcanizate.

g) The raw compound which has been introduced inside the metal dies for vulcanization shall be accurately weighed each time and it must be ensured that sufficient quantity has been put inside the die for proper flow of material at every place so that a homogeneous and compact bearing is produced without any sign of sponginess or deficiency of material at any place.

h) Before any vulcanizate of any batch of production is used for producing vulcanised bearings, test pieces in the form of standard slab and buttons shall be prepared in accordance with prescribed standards and salient properties tested and

recorded regularly against each batch of production to monitor the quality of the products.

5.3.3 Acceptance Specifications

a) All acceptance and process control tests shall be conducted at the manufacturer's plant. Cost of all materials, equipment and labour shall be borne by the manufacturer unless otherwise specified or specially agreed to between the manufacturer and the Engineer.

The manufacturer shall have all the test facilities required for the process and acceptance control tests installed at his plant to the complete satisfaction of the Engineer. The test facilities and their operation shall be open to inspection by the Engineer on demand.

b) Acceptance testing shall be commenced with the prior submittal of testing programme by the manufacturer to the Engineer and after obtaining his. Any acceptance testing delayed beyond 180 days of production shall require special approval of the Engineer and modified acceptance specification, if deemed necessary by him.

All acceptance testing shall be conducted by the Engineer with aid of the personnel having adequate expertise and experience in rubber testing provided by the manufacturer, working under the supervision of the Engineer and to his complete satisfaction.

c) The size and composition of acceptance lot shall be got approved by the Engineer. Acceptance lot shall comprise all bearings including pair of extra bearings, where applicable, of equal or near equal size produced under identical conditions of manufacture to be supplied for the particular project.

d) Testing lots shall be classified as follows:

i) a lot of size 24 or larger number of bearings shall be defined as a large lot

ii) a lot of less than 24 bearings shall be defined as a small lot

When production of a number of bearings of equal or near equal size for a large (single) bridge project is permitted to be manufactured in phases, the numberof bearings supplied from each phase shall be treated as a lot and each such lot shall be considered a large lot.

e) Lot by lot inspection and acceptance shall be made.

5.3.4 Levels of Acceptance Inspection and Testing

a) The level of acceptance testing shall generally be graded into the following two levels depending on lot size:

Level 1 acceptance testing

Level 2 acceptance testing

b) Acceptance testing Level 1 is a higher level inspection and shall be applicable to large lots only, unless otherwise specified. This shall involve manufacture of two extra bearings for each lot to be used as test bearing and eventually consumed in destructive testing.

c) Acceptance testing Level 2 shall be applicable to small lots only, (i.e. less than 24 sets) for which one extra bearing shall be manufactured. Out of the lot, one

bearing shall be selected at random for carrying out material tests. This bearing shall be excluded from the lot accepted.

d) Acceptance inspection level 1 may be specified at the sole discretion of the Engineer taking into account the special importance of bridge project for small lots also under the purview of special acceptance inspection. The cost of extra bearings, in such cases shall be borne by the user, while the cost of all other materials, equipment and testing shall be borne by the manufacturer.

e) Testing: Acceptance testing shall comprise general inspection, test on specially moulded test pieces and test on complete bearings or sections for measurement of various quality characteristics as detailed in 2005.3.3 to 2005.3.7 of MOST Specifications for Roads and Bridges and IRC 83 Part II – 1996 Appendices 2 and 3, which may be referred to for details.

5.3.5 Certification and Marking

a) Bearings shall be transported to bridge site after final acceptance by the Engineer and shall be accompanied by an authenticated copy of the certificate to that effect.

b) An information card giving the following details for the bearings, duly certified by the manufacturer shall also be appended:

- Name of manufacturer
- Date of manufacture
- Elastomer grade used
- Bearing dimensions
- Production batch no.
- Acceptance lot no.
- Date of testing
- Specific bridge location, if any

c) Explanation of markings used on the bearing

d) All bearings shall have suitable index markings for identifying the information. The markings shall be made in indelible ink or flexible paint and if practicable should be visible after installation. The top of the bearing and direction of installation shall be indicated.

5.3.6 Storage and Handling

Each elastomeric bearing shall be clearly labeled or marked. The bearing shall be wrapped in a cover. They shall be packed in timber crates with suitable arrangement to prevent movement and to protect corners and edges. Care shall be taken to avoid mechanical damage, contamination with oil, grease and dirt, undue exposure to sunlight and weather to the bearings during transport and handling prior to and during installation.

5.3.7 Installation of Elastomeric Bearings

i) Multiple bearings to be installed one behind the other on a single line of support shall be of identical dimensions.

ii) Bearings must be placed between true horizontal surfaces (maximum tolerance 0.2 per cent perpendicular to the load) and at true plan position of their control lines marked on receiving surfaces (maximum tolerance + 3mm.)

iii) Concrete surfaces shall be free from local irregularities (maximum tolerance ± 1mm in height)

iv) Design shall be checked for the actual inclination in seating if larger inaccuracies than those specified are permitted.

v) For cast-in place concrete construction of superstructure, where bearings are installed prior to its concreting, the forms around the bearings shall be soft enough for easy removal. Forms shall also fit the bearings snugly and prevent any leakage of mortar grout. Any mortar contaminating the bearings during concreting shall be completely removed before setting.

vi) For precast concrete or steel superstructure elements, fixing of bearing to them may be done by application of epoxy resin adhesive to interface, after specified surface preparation. The specifications for adhesive material, workmanship and control shall be approved by the Engineer. Care shall be taken to guard against faulty application and consequent behaviour of the adhesive layer as a lubricant. The bonding by the adhesive shall be deemed effective only as a device for installation and shall not be deemed to secure bearings against displacement for the purpose of design.

As a measure of ample safety against accidental displacement, the bearings shall be placed in a recess, as shown in Fig. 9 of IRC: 83 (Part II).

5.3.8 Seating of Elastomeric Bearings on a Non-Horizontal Plane

Installation of elastomeric bearings on a Non-Horizontal Plane shall be as follows:

Elastomeric bearings shall be delivered with MS backing plate fastened to the bearing from the manufacturer. Template of 6mm M.S. plate and of size same as bearing holding base plate with matching holes for the anchor screws shall be used. Anchors shall be fitted to the templates with the anchor screws but with MS washers in place of elastomer washers. The above template assembly shall be fitted in the form work at its proper location and in a vertical plane. After casting of the pedestal and removal of the form work, the template is to be removed.

A. Installation with Face Plate and without Template in-situ Casting

i) The sub-assembly of elastomeric bearing with the MS backing plate shall be fitted to the embedded anchors with anchor screws and elastomeric washers replacing the steel washer.

ii) A clearance is required between the stainless steel face of the elastomeric bearing and that of the vertical face of the face plate with stainless steel top installed on the projection below the soffit. This shall be achieved by inserting removable steel sheeting of thickness as per the drawing, during preparation of the form work before casting of the superstructure.

iii) The face plate with stainless steel top and pack plate shall be assembled with the anchors with elastomeric washers and anchor screws.The assembly shall be fitted in the form work at its proper location and in a vertical plane. The removable steel shims shall be removed at an appropriate time after the casting of the super-structure.

B. Installation with Face Plate and with Template in-situ Casting

i) Template of 6 mm MS plate and of size same as face plate with stainless steel top and matching holes for the anchor screws shall be used. Anchors shall be fitted to the templates with the anchor screws but with MS washers in place of elastomer washers. Separate screws may be used in case of inconvenience of fixing the washers in the length of original anchor screws. The above template assembly shall be fitted in the form work for the super structure at its proper location and in a vertical plane.

ii) After removal of the superstructure form work, the template shall be removed.

iii) The face plate with the required thickness of pack plate shall be loosely fitted to the anchors embedded in the projection below the superstructure, with elastomer washers and anchor screws.

iv) The sub-assembly of elastomeric bearing with the MS backing plate shall be fitted to the embedded anchors in the pedestal with anchor screws and elastomeric washers replacing the steel washer this time.

v) The required clearance between the stainless steel face of the elastomeric bearing and that of the vertical face plate installed on the projection below the soffit shall be checked. After adjustment of the required working clearance the small gap between the vertical face of the projection below the soffit and the back of the face plate (with pack plates, if any) shall be grouted with epoxy grout.

5.4 POT BEARINGS

5.4.1 General

Pot type bearings shall consist of a metal piston supported by a disc or reinforced elastomer confined within a metal cylinder to take care of rotation. Horizontal movement, if required, shall with a system of sealing rings be provided by sliding surfaces of PTFE pads sliding against stainless steel mating surfaces. The pot bearings shall consist of cast steel assemblies or fabricated structural steel assemblies.

Provisions of IRC-83 (Part I) shall be applicable for all metallic elements. Provisions of IRC:83 (Part II) shall be applicable for all elastomer elements. When any item is not covered by IRC:83 (Parts I and II), the same shall be as per guidelines given hereunder and BS:5400 (Sections 9.1 and 9.2), except that no natural rubber shall be permitted. If there is any conflict between BS on the one hand and IRC on the other, the provisions of IRC will be guiding.

Combination bearings using any judicious combination and sliding element shall be permitted. Some examples are shown in **Table 5.3** below.

Table 5.3 : Combination of Elements for POT Bearings

Name	Rotation Element	Sliding Element	Generally for
Pot	Pot	None	Vertical Load
Elastomer	Elastomer	None*	Horizontal Buffer

Pot PTFE	Pot	PTFE-SS**	Vertical Load and Horizontal Load
Spherical Knuckle PTFE	Spherical Knuckle	PTFE-SS**	Vertical Load and Horizontal Load
Elastomer PTFE	Elastomer	PTFE-SS**	Transverse Guide
Elastomer SS**	Elastomer	SS-SS**	Transverse Guide

* Elastomer shall permit movement by shear

** Stainless Steel

For special and innovative bridges, new combinations beyond what is indicated may be required. The same may be used after approval by the Engineer.

5.4.2 Fabrication

i) The surface mating with the PTFE in the sliding pair shall be of corrosion resistant stainless steel. Normally, the stainless steel shall form the upper component. The stainless steel shall overlap the PTFE after full movement on all sides. If stainless steel sheet is used, it should be bonded by continuous welding along the edges. Adhesive or any other bonding can be approved by the Engineer. The surface shall be prepared by thorough cleaning to remove grease, dust or any other foreign substance.

ii) PTFE modular sheets of the sliding pair shall be located by confinement assisted by bonding. Confined PTFE shall be recessed into the metal backing plate. The shoulders of the recess shall be sharp and square to restrict the flow of PTFE.

iii) The thickness of the PTFE shall not be less than 4.5mm with projection above the recess not exceeding 2.0mm. When the piston is subjected to tilting, the seal must slide along the wall and alter its shape according to the angle of tilt. At the same time, it must be sufficiently rigid to bridge the gap between the piston and the wall of the pot. However, the percentage of plan area of the lubrication cavities to the gross area shall not exceed 25 per cent. The depth of the cavity shall not exceed 2.0mm.

iv) The diameter to thickness ratio of the confined elastomer shall not exceed 15. The surface of the confined elastomer shall be smooth.

v) A seal shall be provided to prevent extrusion of the confined elastomer between the piston and the pot wall. The seal should stay functional under the loads and rotations acting on it. Additional seal shall be provided to prevent entry of dust into the pot. Sealing rings for pot bearing shall be fabricated from stainless steel. When the piston is subjected to tilting, the seal must slide along the wall and alter its shape according to the angle of tilt. At the same time, it must be sufficiently rigid to bridge the gap between the piston and the wall of the pot.

vi) The hardness of the piston and pot wall at their contact region shall be minimum 350BHN to reduce wear. The surface finish of the pot base in contact with the confined elastomer shall be very smooth.

vii) All bearings shall be installed with anchor and anchor screws or some similar device such that while replacing, the bearings can be removed with minimum lifting of the superstructure.

viii) The external surfaces of the assemblies shall be completely cleaned by sand blasting. After sand blasting, dust shall be removed from the surface using clean and dry compressed air or a clean brush after which suitable coating shall be applied.

ix) Pot bearings including all parts as shown on the drawings shall be fully shop assembled at the manufacturer's works to ensure proper fitting of all the parts.

5.4.3 Materials for POT/ PTFE Bearings

a) Steel

i) Structural steel shall conform to IS:226 or IS:2062, as applicable.

ii) Cast steel shall conform to Gr.280-520W of IS:1030 with 0.3 to 0.5 per cent copper added to increase the corrosion resistance properties.

iii) Stainless steel shall conform to AISI:304 or X04Cr 18 Nil) of IS:6911 for ordinary applications. For applications with adverse / corrosive environment, the stainless steel shall conform to AISI:316L or O2Cr17Ni12Mo2 of IS:6911.

b) PTFE

PTFE (poly tetra fluoro ethylene) shall be of unfilled pure virgin quality. It shall be free sintered. The mechanical properties of unfilled PTFE shall comply with Grade A of BS:3784.

c) Elastomer

The confined elastomer inside pot will have the following properties:

i) Hardness	IRHD	IS:3400 (Part II)	50 + 5
ii) Min. tensile strength	MPA	IS:3400 (Part I)	15.5

iii) Min. elongation at break shall be as per Table 5.1 "Properties of Elastomer"
Max. compression set and Accelerated ageing)
For other details, refer to Para 5.3.1

5.4.4 Workmanship

5.4.4.1 Welding

All welding shall conform to IS:9595 with electrodes of suitable grade as per IS 814. Preheating and post weld stress relieving shall be done as per IS:9595.

a) Cast Steel assemblies: Cast steel for pot bearing assemblies shall conform to requirements of relevant IS. Castings shall be true to the forms and dimensions shown on the drawings, and shall be free from pouring faults, sponginess, cracks, blow holes and other defects affecting their appearance or their strength. Warped or distorted castings shall not be accepted. Exposed surfaces shall be smooth and dense.

All irregularities, fins or risers shall be ground off flush with the adjacent surface. Castings with visible cracks, blow holes, or similar blemishes shall be rejected if the

imperfections are located on bearing surfaces or cannot be remedied to the satisfaction of the Engineer.

Imperfections which are not located on bearing surfaces shall be cleaned out, filled with weld metal of the appropriate composition and ground flush with adjacent surfaces.

b) Structural steel assemblies: Defects arising from the fabrication of the steel shall be inspected by the Engineer, who will decide whether the materials may be repaired by the Contractor or will be rejected. The cost of repairs or replacement shall be borne by the Contractor.

All steel whether fabricated or not, shall be stored on platforms, skids, or other supports above the ground and adequately protected against corrosion. Excessively rusted, bent or damaged steel shall be rejected.

All plates shall be flat, and rolled bars and shapes straight before marking out or being worked. Straightening shall be done by methods which shall not damage the material. Sharp kinks and bends shall be the cause for rejection.

Steel may be flame cut to shape and length so that a regular surface, free from excessive gouges and striation is obtained. Flame cutting by hand shall be done only with the approval of the Engineer. Exposed corners shall be machined or ground.

c) Tolerances

i) Plan dimensions : -0 to +5mm

ii) Overall height : -0 to +3mm

iii) Height of elastomer :$\pm$ 5 percent

iv) Height of any steel component

a) Machined : -0 to + 1mm

b) Un-machined : Class of IS :4897

v) Stainless steel sliding surface

a) Flatness : 0.0004L, where L= length in direction of measurement

b) Surface Finish : Ra $\leq$ 0.25 pm as per IS:3073

d) Painting

i) All non-working surfaces shall be coated with two coats of epoxy primer and one or more coat each of epoxy intermediate and finish, total thickness $\leq$ 0.150 μm or any other painting scheme as approved by the Engineer.

ii) Silicon grease shall be applied at the PTFE /SS interface after testing.

iii) Anchor sleeves shall be cement coated at the manufacturer's works.

5.4.5 Test

Raw Materials: Necessary test certificates for all raw materials listed in Para 5.4.3 above shall be furnished by the manufacturers. Reference may also be made to Para 5.3.1 for tests on elastomers.

Test on Casting: Tests specified in IS:1030 shall be performed. Castings shall be ultrasonically tested and certificates submitted. Quality level of castings shall be level 3 as per IS:9565.

Test on Welding: All welding shall be tested by Dye Penetration method. Butt welding shall be tested by Ultrasonic method. Soundness of welding shall be certified by the manufacturer.

Acceptance test on Bearing

i) All bearings shall be checked for overall dimensions.

ii) All bearings shall be load tested to 1.1 times maximum design capacity including seismic force. Bearing tested at higher loads cannot be used.

iii) A pair of bearings selected at random will undergo testing in order to determine the coefficient of friction "μ". The coefficient of friction shall be $\leq$ 0.05 at the design load.

iv) Two bearings selected at random shall be tested for permissible rotation.

5.4.6 Installation of POT –cum-PTFE Bearings

a) General

i) Care shall be taken during installation of the bearings to permit their correct functioning in accordance with the design scheme.

ii) To prevent contamination, dismantling of the bearings at site shall not be done.

iii) The load shall be transferred on to the bearings only when the bedding material has developed sufficient strength. The props for the form work shall be removed only after lapse of appropriate time. In special cases, this can be ensured by suitable devices like jacks etc.

iv) Temporary clamps and shims (introduced to maintain working clearance) shall be removed at an appropriate time, before the bearing is required to permit movement.

v) Permitted installation tolerance of the bearing from plane of sliding shall be maintained.

vi) Cement based non-shrink grout with air releasing additive and epoxy based grout, whichever is specified, shall be first tried at the site. For the proprietary grout mixes, appropriate instructions from the manufacturer shall be followed specially with regard to the following:

a) Preparation $\rightarrow$ concrete cleaning, roughening, pre-soaking, etc.
b) Forms $\rightarrow$ sturdiness, leak proofing, shape, header funnel vents, etc.
c) Bearing Base $\rightarrow$ cleaning, etc.
d) Placement $\rightarrow$ mixing, consistency, time period, finishing etc.
e) Protection $\rightarrow$ curing, ambient temperature, etc.
f)

b) In-situ Casting of Superstructure

i) Form work around the bearing shall be carefully sealed to prevent leakage.

ii) Sliding plates shall be fully supported and care taken to prevent tilting, displacement or distortion of the bearings under the weight of wet concrete.

iii) Bearings shall be protected during concreting operation. Any mortar contaminating the bearing shall be completely removed before it sets.

c) Seating of bearing

A. Using Template

i. Template with required rigidity and matching holes corresponding to the base of the bearing shall be used.

ii. All the anchors shall be fitted to the lower face of the template using the anchor screws but with steel washer replacing the elastomer washers. Separate screws may be used in case of inconvenience in the length of the original anchor screws.

iii. The template assembly shall be located with regard to level and alignment. It shall be ensured that the top of the anchors lie in a horizontal plane at the required elevation. The anchors shall be tied / welded to reinforcements to avoid displacement during concreting.

iv. Concreting of the pedestal / pier cap shall be done to a level leaving a gap of 25-50mm below the template.

v. The template and steel washers shall be removed prior to placement of the bearing assembly with temporary clamps. The bearing assembly shall be fitted to the anchors with the help of anchor screws and elastomer washers. Level at the bearing shall be checked.

vi. The gap below the bearing assembly shall be grouted with cement based grout. Reference may be made to Para 5.4.6 (a) (vi)

B. Without Template with Gap

i. Pockets commensurate with the sizes of the anchors shall be kept in pedestals during concreting of the same. The pedestal shall be cast approximately 25mm short of the required finished level.

ii. Anchors shall be fitted to the bearing bottom with elastomer washers and anchor screws. The bearing assembly shall be seated in the location on steel chairs / packs. The anchors fitted below the bearing shall go into pockets in the bed block. Level and alignment of the bearing shall be checked. It shall be ensured that the bearing sits in a horizontal plane.

iii. The gap below the bearing assembly including anchor pockets shall be grouted with cement based grout.

C. Without Template without Gap

Elongated pockets commensurate with the sizes of the anchors shall be kept in pedestals during concreting of the same. The geometry and location of the anchor pockets (with tapered funnel extension, if required) shall be such that after placement of the bearing the pockets can be successfully grouted. The pedestal shall be cast 5mm to 15mm short of the required finished level. The required level shall be achieved by chipping before placement of the bearing. Careful control shall be exercised to cast at the exact finished level or 1mm to 3mm down from the required finished level.

D. Seating of bearings shall be as per manufacturer's instructions.

5.4.7 Inspection and Testing

Where any patents are used, the manufacturer's certificate with test proofs shall be submitted along with the design and got approved by the Engineer before their use in work

5.4.8 Tests and Standards of Acceptance

The materials shall be tested in accordance with these specifications and shall meet the prescribed criteria.

The work shall conform to these specifications and shall meet the prescribed standards of acceptance.

5.5 MEASUREMENTS AND RATES FOR ALL TYPES OF BEARINGS

5.5.1 Measurements for payment

Bearings shall be measured in numbers, unless otherwise specified in the contract, according to their types, capacities and particular specifications given on the drawings.

The quantity of elastomeric bearings shall be measured in cubic centimeters of finished dimensions.

5.5.2 Rate

The contract unit rate of each type of bearing shall include the cost of supplying and fixing the bearings in position complete as specified on the drawings or as directed by the Engineer. The rate shall also include the cost of samples and their testing when desired by the Engineer.

In case of steel bearings the rates shall include the cost of all nuts, bolts, the cost of all tests prescribed in the specifications and shown on the drawings.

Where the Department supplies the bearings, the rate for fixing them shall include the cost of anchor bolts and grouting materials their fixing, transport of bearings from the place of supply to the site, handling and placing them in position as per direction of the Engineer unless specified otherwise.

5.6 RIVER TRAINING AND PROTECTION WORKS

5.6.1 The following section covers works provided in the rivers / streams for safely guiding flow of water and preventing damage to bridge and approach banks by scour, undermining, outflanking etc. This work shall consist of construction of embankment of guide bund and provision of pitching/revetment on slopes, apron, toe protection, curtain walls etc., as indicated on the drawing in accordance with these specifications or as approved by the Engineer.. The provisions given hereunder are applicable only to guide bunds for bridges across alluvial rivers. Guide bunds for bridges across sub mountain rivers shall call for supplemental specifications.

5.6.2 Guide Bund

5.6.2.1 Guide bunds shall generally be made of locally available materials from the river bed preferably not Cohesionless soil. Trial pits shall be taken in borrow holes to examine suitability of soil for construction and also to decide the types of earth moving machinery to be arranged. The borrow pits should be sufficiently away from the location of any apron. No borrow pits should be dug on the river side of the guide bunds.
Construction of guide bund shall be taken in hand along with the construction of the bridge. Every effort shall be made to complete the work of the guide bund in one working season. Where there is any doubt about completion of the whole guide bund within one working season, suitable measures shall be planned and executed for protection of completed work. In such cases the construction of guide bund shall be started from abutment towards upstream. It shall be built up and compacted in accordance with relevant specifications for construction of a bank as given in Chapter 1 unless otherwise specified.

5.6.2.2 The Contractor shall furnish his proposed methodology and sequencing of works for approval of the Engineer. It should include details regarding transport of stones from the quarries to the site of work taking into account the quantities of stone required to be transported every day, type of transport facility available and labour available for loading and unloading and for laying within the time frame for construction of guide bund. Adequate reserve of stones should be maintained for major works as decided by the Engineer. Stones shall be stacked sufficiently away from the main channel of the river, as instructed by the Engineer.

5.6.2.3 Where the alignment of guide bund or the approach embankment crosses a branch channel of the river, the branch channel may be either diverted to the main channel of the river with the help of spurs, etc., or closed by a properly designed closing dyke or closure bund before taking up construction of guide bund. Such work shall be separately paid for, unless otherwise provided in the contract.

5.6.2.4 Guide bunds shall be provided with a slope pitching with stones laid over a filter media or as shown in the drawing. The toe will be protected with an apron laid horizontal on bed, all as shown in drawing or as directed. Normally stones weighing not less than 35 kg shall be used for pitching, unless otherwise specified Apron shall be laid at as low level as possible by excavation of bed. Material thus excavated can be used for construction of guide bund, if found suitable and approved by the Engineer. Detailed specifications for Pitching and Apron have been given in subsequent Paras.

5.6.3 Filter Media for Pitching

A filter has to be provided below the layer of pitching stone over the finished earth bank, so that it forms a barrier. Otherwise, the flowing water will tend to suck the soil particles forming the bank through the interstices between stones in the pitching. A graded filter media of specified thickness (one layer preferably 200 to 300 mm thick and not less than 150mm thick) is therefore provided below the stones so as to prevent the flow of finer soil through to the pitching. The filter will not only prevent escape of embankment material through the voids of stone pitching, but also allow free movement of water through it so as to prevent any uplift head

developing against the pitching stone. The filter media will be made up of granular material as given below -

The material for filter shall consist of coarse sand, gravel or stone chips. The gradation of material shall satisfy the following requirements. It will be made up of one or two layers of material satisfying the following criteria.

D15 (Filter) / D85 (Base) <5 ;

4 < D15 (Filter) / D15 (Base) <20 ; and

D 50 (Filter) / D 50 (Base) < 25

In the above relationships, D15 means the size of sieve which allows 15% of material to pass through. Similar is the meaning of D 50 and D 85. If filter is provided in two layers, the above mentioned requirement will be followed for each layer.

5.7 STONE OR BLOCK KANKAR PITCHING

Note:- The position, dimensions and slope of the pitching shall be as shown in the drawings or specified by the Engineer. The pitching will be hand packed or roughly deposited as ordered by the Engineer or as shown in the drawing.

5.7.1 Material and Laying

a) Pitching Stone: The pitching stone shall be obtained from sources approved by the Engineer. The stone shall be sound, hard and durable. The stone should weigh between 35 to 60 kg and no stone shall be less than 15 cm in any direction unless otherwise specified, except the smaller stones for filling gaps. Payment for stone supplied shall be made after deduction for voids/ shrinkage is made at 15% of stack measurement, unless otherwise specified.

b) Pitching Methodology. Dry stone pitching shall be of two kinds - dressed stone pitching and rough stone pitching.

i) Rough Stone pitching*:* The stones for rough stone pitching shall be set in the work as received from the quarry and without any dressing except knocking off weak corners and edges with a mason's hammer. A small proportion of stone chips may be allowed to show in the face work. The face stones must in general weight at least 35 kg and be well bedded and hand set. The ground on which the pitching shall be done will be dressed to the correct profile and joint openings to the underlying fill shall be avoided by carefully arranging the various sizes of stones, and by closing the openings with small stone fragments or smaller size stones. The work shall be done so as to have a reasonably smooth surface and uniform thickness. In *roughly deposited pitching*, the stone shall be roughly levelled off to the correct section.

c) Precautions to be taken in Laying

i) All earth surfaces that are to be pitched and subsequently exposed to the action of running water, shall be covered with a filter layer of gravel, ballast or quarry chips to a depth of 15 cm to 30 cm as ordered by the Engineer, or with two layers of bricks laid flat before the placing of pitching stone, as mentioned in para 5.7.3. The bricks, when used, shall be laid flat in a diagonal manner with top layer being

laid in directly opposite direction to the lower layer. This filter layer prevents the finer material of the bank from being sucked out by the flowing water,

ii) For pitching carried out below water level, the stone shall be thrown carefully so that it may spread as uniformly as possible. This shall be ensured by taking frequent soundings to guide the dumping of stone. For this, necessary arrangement including bamboo poles, plank pathways, floating bridges or boats etc. shall be provided by the contractor and the element of their cost is included in the rate. Pitching under water shall, as far as possible, be carried out when the water level is at its lowest.

iii) Before laying stones, the sides of the bank shall be trimmed to the required slope and template cross walls shall be built to the full height of the intended thickness of slope and apron at intervals of 30m to ensure regular straight work and a uniform slope throughout.

5.8 APRON AND CRATING

5.8.1 Apron pitching

a) Apron pitching stone should only be flung in as it will lie and should be roughly levelled off to the correct section. There is no advantage in hand packing the apron pitching and this should never be done. Size of stone used shall vary between 35 kg and 60 kg and the proportion of different sizes shall be decided by the Engineer, unless otherwise specified in Drawings and Contract Documents.

b) The stones shall not be dressed except knocking of weak edges and corners with a mason's hammer. The face stones must be bigger size stones selected from the lot.

c) For pitching carried out under water the stone will be thrown carefully so that it may spread as uniformly as possible. For this reason, man with poles or sounding leads must be engaged to take frequent soundings to guide the work people where to throw the stone. The cost of bamboo and plank pathway will be borne by the Contractor and if floating bridges are necessary, their erection and maintenance will also be borne by the Contractor.

Pitching under water should where possible shall be carried out when the water level is at its seasonal lowest.

5.8.2 Rate

The rates cover the cost of all labour as well as the supply by the Contractor of all tools and plants required for the execution of the work.

The supply of boulders for protection works shall be as specified in the rate (either by the contractor or by the Railway). Stones shall be stacked properly, measured and recorded in the measurement book before utilisation in pitching or any other protection works. Payment for stone supplied shall be made after deduction for voids/ shrinkage is made @ 15% of stack measurement, unless otherwise specified.

5.8.3 Sausage and Crated stones

Galvanized iron wire: GI wire used for crating and sausages shall be of mild steel quality conforming to the IS Specification No.280-1978. The wire shall be sound,

free from splits, surface flaws, rough jagged and imperfect edges and other harmful surface defects. The minimum tensile strength shall be 32 to 44 kg / mm^2 and the galvanised coating shall conform to the test given under clause 10 of IS:280.

Stones : Shingle boulder weighing 35 kg. to 60 kg (size between 20 and 40 Cm) as specified in contract or by the Engineer shall be used in filling the sausage crates with stones of smaller size to fill up the gaps in between. For pitching also size of stones used will be of similar size.

Crating

i) Sausage – Standard practice for netting wire sausage is with 4mm dia, (8 SWG) galvanized wire mesh of 15 cm or 10 cm, double locked and non slipping type.

ii) Sausage Crate – In case of rectangular sausage crate the same quality of materials and procedure for weaving as shown in approved drawings shall to be followed. The sequence of operations for assembling the crate and the process narrated for end binding with illustrations should be followed as in approved drawings. In absence of any drawing following guide lines (extracted from Section 2503.3 of MOST specifications) may be followed.

" The mesh of the crate shall not be more than 150 mm".

Wire crates for shallow or accessible situations shall be 3 m x 1.5 m x 1.25 m in size. Where they have to be deposited and there is a chance of overturning, the crate shall be divided into 1.5 m compartments by cross netting. For deep and inaccessible situations, wire crates can be made smaller subject to the approval of the Engineer.

Wire crates built in-situ, shall not be larger than 7.5 m x 3.0 m x 0.6 m, nor smaller than 2 m x 1m x 0.3m. Sides of large crates shall be securely stayed at intervals of not more than 1.50 m to prevent bulging.

Wherever possible, crates shall be placed in position before filling with boulders. The crates shall be filled carefully by hand packing of the boulders as tightly as possible and not merely throwing stones or boulders."

5.9 MEASUREMENTS AND RATE FOR ALL TYPES OF PROTECTION WORKS

5.9.1 Measurements

i) The protection works shall be measured as set forth below. If so directed by the Engineer for measurement, the materials may have to be stacked at site before laying and nothing extra will be paid for this stacking.

ii) The earthwork in construction of embankment for guide bund shall be measured in cubic metres unless otherwise specified. The boulders /cement concrete blocks and wire crates in apron shall be measured in cubic metres.

iii) The filter and stone pitching shall be measured separately in cubic metres unless otherwise specified.

iv) Rubble stone/ cement concrete blocks, flooring and cement concrete bedding shall be measured in cubic metres for each class of work. Preparation of base for laying the flooring shall be deemed incidental to the work.

v) For laying apron, excavation upto an average depth of 150 mm shall be deemed to be included in the main item and shall not be measured separately unless otherwise specified. Excavation more than 150 mm shall be measured in cubic metres as given in Chapter 1 for earthwork. If any of the quantity excavated is used in the guide bund, such quantity will be deducted from such measurement for excavation.

5.9.2 Rate

i) The unit rate for construction of embankment for guide bund shall cover the cost of all materials and labour in setting out, excavation, transportation, laying, compacting, tools, equipment, sampling and testing, supervision and all incidentals necessary for completing the work according to these specifications.

ii) The unit rate for one cubic metre of finished work of apron shall include cost of all materials, labour, tools and plant for completing the work according to above specifications. Excavation upto an average depth of 150 mm shall also be deemed to be included in the rate for dressing of the bed. Excavation beyond this depth shall be paid for separately unless otherwise specified.

iii) The unit rate for one cubic metre of filter or stone/ cement concrete block pitching on slopes shall include the cost of preparing the bases putting to profiles, laying and compacting the filter and stone pitching of dry rubble / cement concrete block revetment for embankment slopes to the specified thickness, lines, curves, slopes and levels and all labour, material, tools and plant for completing the work as per these specifications.

5.10 SPECIFICATIONS OF STEEL WIRE ROPENET FOR ROCKFALL PROTECTION WORKS

High strength steel wire rope nets comprise of galvanized steel wire ropes in both vertical and horizontal directions. At the intersections, vertical and horizontal chords have a tucked joint fixed with special clamps. The nets comprise an upper hang portion with only vertical chords for anchorage and a lower net portion with both vertical and horizontal chords so as to retain the boulders. The appropriate aperture size and length of the hang and net portions are selected to suit site requirements. The product is suitable for rock-fall protection applications requiring high strength and durability.

5.10.1 Specifications of High Strength Steel Wire Ropenets

Property	Specification
Product Types	450mm x 600mm
Properties of the Steel Wire Rope	
Material	Galvanised Steel Wire Rope
Rope Grade	1770 N/mm2
Nominal Diameter	9 mm
Min. breaking force	4500 Kgf
Construction of wire rope	6 x 19 with fibre (polypropylene) core*

Tensile Strength of wires & zinc coating	IS : 1835 – 1976
Properties of the Ropenet	
Construction of the net	Joints tucked in one direction and clamped
Aperture Size	450mm (horizontal) x 600mm (Vertical)
Tensile Strength of Net Vertical Direction : Horizontal Direction :	 8500 Kg/m 6700 Kg/m
Punching strength	7000 Kg
Dimensions of Ropenet	
Length of hang portion	6 m (or as per site requirement)
Length of net portion	10 / 15 / 20 / 25 / 30 / 35m (as per site requirement)
Width	5m (± 5%)

*See Construction of rope

Note: 9mm steel wire rope for Ropenet to be specifically made with pitch of 75± 5mm to suit specific application of fabrication of Ropenets. Hence, BIS Specifications need to be referred for guidelines only.

5.10.2 Construction of Rope

6 x 19 S (9-9-1) with fibre (Polypropylene) core or 6 x 19 M (12/6-1) with fiber (Polypropylene) core as per IS : 2266-2002

a) If it is 9-9-1, diameters of wires in 3 layers may be as follows :
   Outer 9 wires of 0.72 mm diameter
   Middle layer 9 wires of 0.42 mm diameter.
   Centre wire 1 of 0.92 mm diameter.
b) If it is 12/6-1, diameters of wires in 3 layers may be as follows :
   Outer layer – 12 wires of 0.60 to 0.63 mm diameter
   Middle layer – 6 wires of 0.60 to 0.63 mm diameter
   Centre layer – 1 of 0.72 to 0.76 mm diameter.

5.10.3 Tensile Strength of Wire & Zinc Coating

As per IS : 1835-1976

i) Strength of wires : 1770 N/mm2

ii) Zinc Coating AB type as follows :

Diameter of Wires in mm	Zinc Coating in gm/sqm
0.40-0.50	60

0.50-0.60	70
0.60-0.80	85
0.80-1.00	95





5.10.4 Installation Methodology

The installation of High Strength Steel Wire Ropenets and Hexagonal Double twisted wire meshfor rock fall protection involves the following steps:

5.10.4.1 Site Preparation

Remove all surface vegetation including trees & shrubs in the cutting where rope netting has to be done. Loose boulders have to be removed in block condition on slope of rock cutting including removing of loose rock/undulations & dressing side slope to facilitate spreading of Ropenet.

5.10.4.2 Top anchoring

Position of top anchoring should be at a minimum distance of 6 m from the face of cutting. For any deviation from the above mentioned, approval of Engineer-in-Chief is mandatory.

In case of soft soil or moorum present on top of cutting, a top trench of 1.0 m depth & 0.6 m width has to be excavated at a distance of approximately 6.0 m from edge of cutting for top anchoring of Ropenet. Ropenets are available with eyes or loops in vertical chords for anchoring.

A Precast RCC beam of 0.15 m x 0.15 m x 2 m of M15 concrete is used for top anchoring. RCC beam is inserted through loops of chords & beams are placed inside excavated trench.

Precast beam alongwith anchoring chords is embedded inside trench by M10 concrete of 0.3 m depth. After curing of concrete, the trench is filled with backfill muck with moderate compaction.

5.10.4.3 Lacing of adjacent ropenets and / or Hexagonal wire mesh with Ropenets

After top anchoring of ropenets, adjacent nets are laced so as to form a continuous net. If Hexagonal wire mesh is also specified, mesh is laced beneath ropenet. Specially designed galvanized steel spiral locks are used for lacing. One spiral lock for each mesh of net is used.

5.10.4.4 Spreading

After lacing, the continuous nets / nets and mesh are rolled from top to bottom of cutting so as to cover the cutting.

5.10.4.5 Intermediate anchoring

Nets are anchored on the cutting slope using anchor bolts/fasteners of 10–12 mm diameter and 110mm length. For every 5sqm of surface area, one anchor bolts is fixed with epoxy coated M.S. plate of 200mm x 200mm x 6mm as washer. Intermediate anchoring is required so that nets take the shape of cutting profile and hug the rock surface. Anchor bolts are fixed by drilling a hole for anchors and applying a torque of 65 to 70 Nm after washer plates are placed over the ropenets.

5.10.4.6 Bottom Anchoring

HYSD bolts of 1m depth & 16mm diameter, having a thread of 200mm on top are used for bottom anchoring. Bottom anchoring is done in a staggered manner such that each vertical chord of ropenet is anchored.

A drill hole of 20 mm diameter is made with the help of a jack hammer upto a depth of 1m in a staggered manner. Each hole is filled with 3-4 cement capsules and bolts are driven to desirable depth. Nuts are tightened on threaded portion of anchor bolts after epoxy coated washer plates of 200 mm x 200 mm x 6 mm are placed over ropenet.

5.11 SPECIFICATIONS OF GEOMAT FOR EROSION CONTROL WORKS

Geomat is a composite mat comprising of a layer of bio-degradable mulching material sandwiched between and mechanically bonded to two layers of polymer netting. The product combines the moisture retention and soil enrichment characteristics of the mulch with tensile strength and durability of polymer netting.

Geomat consisting of three layers shall be held together at every 100mm spacing in a staggered manner with the stitching thread of the same material of Geomat in both directions.

The netting used for fabrication of Geomat shall be depth stretched in autoclave so as to achieve good knot tightness, uniformity of mesh size & good dimensional stability of netting.

5.11.1 Technical Specifications

Property	**Specifications**
Top and bottom layers of polymer net	
Material and Structure	Polymer netting comprising of tensile elements of circular cross-section in two orthogonal directions with knotted joints
Aperture size	20 (± 2) mm x 20 (± 2) mm
Tensile strength Top net	 1.0 kN/m (minimum in both directions)

Bottom net Combined strength	1.8 kN/m (minimum in both directions) 2.8 kN/m (minimum in both directions)
Type of joint	Knotted
Middle layer of bio-degradable mulch	
Material	Coir fibre
Weight	300 (± 20) gms/m^2
Dimensions of Geomat	
Length	10 / 12 / 15 m (depending on site requirement)
Width	5 m (minimum) without any joints/seams.

Note :

1. Length of Geomat could be varied to suit site requirements.

2. Spacing : Composite mat to be held together at every 100mm. Spacing of stitches in a staggered manner in both direction.





5.11.2 Installation Methodology for Geomat

Installation of Geomat involves following steps :

5.11.2.1 Sub-grade Preparation

An inspection is performed to check up the ground surface for any ridges or major undulations etc. Ridge, undulations if any shall be removed using filling or cutting the same. Existing slope is leveled & gullies formed are properly filled up.

An identified accepted good vegetative soil will be brought to site and stacked.

5.11.2.2 Top Anchoring

Geomat is anchored at top in an anchor trench of size 500mm x 500mm. After anchoring, trench is filled with excavated soil.

5.11.2.3 Laying

A 100mm thick layer of fertile soil is spread on the surface of leveled slope. Geomat is rolled over the slope

5.11.2.4 Overlaps

Overlap on the length of coir mat, if required is minimum 250mm. Adjacent panels of Geomat shall be stitched together using the same twine used in manufacture of product.

5.11.2.5 Intermediate Anchoring

Geomat is anchored on slope surface using U-Pins (MS pins of 6mm diameter and size 100 x 300 x 300 mm) at 1 pin per 2 sqm of Geomat.

5.11.2.6 Vegetation

Once Geomatis properly laid and anchored on the slopes; readymade Grass sods with minimum 50mm bottom soil are placed over Geomat so as to completely cover it. It is advisable to spray fertilizers on the grass sods atleast once while watering. Watering is done at least for one week. Vegetation will be better if watering is continued for 2 weeks.

In case of any damage found on coir mat while installing, a coir mat patch shall be covered over damaged area extended beyond damaged area a distance of 300mm.

5.12 SPECIFICATIONS OF MECHANICALLY WOVEN DOUBLE TWISTED HEXAGONAL SHAPED WIRE MESH GABIONS

5.12.1 Mechanical Properties

a. Tensile Strength – Tensile strength of wire used for mechanically woven, double-twisted hexagonal shaped mesh, lacing wire and stiffener, when tested shall be in accordance with requirements of specification BS 1052 – (350 to 550 N/mm^2) at minimum elongation of 10%.

b. Tensile strength of Mesh Panel –Minimum tensile strength of Mesh panel must be 32 kN/m in the parallel to twist direction.

5.12.2 Physical Properties

a. Zinc Coating – Coating weights shall be **Heavily Galvanized** conforming to requirements of specifications : ASTM A 641.

b. Adhesion of Zinc Coating – No flakes shall be observed while testing for adhesion of Zinc coating as per ASTM A 641.

Mesh Type	10 x 12	Specifications
Mesh Opening 'D' mm	**100**	**EN10223**
Mesh Tolerance	**+16% to –4%**	**EN10223**
Unit Dimensions	L x W x H	
Tolerances in sizes of units	**L & W +/- 5%: H <= 0.3m +/- 10%: H > 0.3m +/- 5%**	**ASTM A975**
Characteristics	Only Zn + PVC Coated	
Mesh Wire Dia mm	2.7/3.7 (I.D/O.D)	**EN10223**
Tolerance (+/-) mm	**0.08**	**BS1052**
Zn Coating Min (gsm)	**240**	**ASTM A 641**
Selvedge / Edge Wire Dia mm	3.4/4.4 (I.D/O.D)	**EN10223**

Tolerance (+/-) mm	**0.10**	**BS1052**
Zn Coating Min (gsm)	**260**	**ASTM A 641**
Lacing Wire Dia mm	2.2 / 3.2 (I.D/O.D)	
Tolerance (+/-) mm	**0.06**	**BS1052**
Zn Coating Min (gsm)	**220**	**ASTM A 641**
PVC Coating		
Thickness Nominal (mm)	**0.50**	**ASTM A 975**
Thickness Minimum (mm)	**0.38**	**ASTM A 975**
Hardness	**Between 50-60 Shore D**	**ASTM D 2240**
Colour	**Grey RAL 7037**	**ASTM D 1482**
Tensile Strength	**Min. 20.6 MPa**	**ASTM D 412**
Specific Gravity	**1.3 to 1.35**	**ASTM D 792**





5.12.3 Installation Methodology

5.12.3.1 Assembly

Gabions are supplied folded flat and packed in bundles. Larger units may be supplied in rolls. Units are assembled individually by erecting the sides, ends and diaphragms, ensuring that all panels are in correct position and tops of all sides are satisfactorily aligned. The four corners shall be connected first, followed by the internal diaphragms to the outside walls. All connections should use lacing wire. Procedure for using lacing wire consists of cutting a sufficient length of wire and first looping and/or twisting the lacing wire to wire mesh. Proceed to lace with alternating double and single loops through every mesh opening approximately every 150mm, pulling each loop tight and finally securing the end of lacing wire to wire mesh by looping and/or twisting.

5.12.3.2 Installation

After initial assembly, gabions are carried to their final position and are securely joined together along the vertical and top edges of their contact surfaces using the same connecting procedure(s) described in the previous section. Whenever a

structure requires more than one layer, upper empty baskets shall also be connected to the top of the lower layer along the front and back edges of contact surface using the same connecting procedure(s) described in previous section.

5.12.3.3 Filling

Gabions shall be filled with rock or stone fill. Rock for gabions shall be hard, angular to round, durable and of such quality that they shall not disintegrate on exposure to water or weathering during the life of structure. Gabion rocks shall range between 150mm and 200mm. Range in sizes shall allow for a variation of 5% oversize and/or 5% undersize rock, provided it is not placed on gabion exposed surface. During filling operation, good hand packing & stone placement is required to minimize voids. Exposed faces of vertical structures may be carefully hand placed to give a neat, flat and compact appearance. Care shall be taken when placing fill material to assure that sheathing on PVC coated baskets will not be damaged. Cells shall be filled in stages so that local deformation may be avoided, i.e. at no time shall any cell be filled to a depth exceeding (0.30 m) higher than the adjoining cell. It is also recommended to slightly overfill the baskets to allow for settlement of the rock. Behind gabion walls, compact the backfill material simultaneously to same level as the filled gabions.

5.12.3.4 Internal Connecting Wires

Internal connecting wires should be used when a structure requires layers of gabions to be stacked on top of each other. Internal Connecting Wires shall connect exposed face of a cell to the opposite side of cell. An exposed face is any side of a gabion cell that will be exposed or unsupported after the structure is completed. Lacing wire or prefabricated internal connecting wires may be used.

1m High Gabions

1.0 m high gabions shall be filled in three layers, 0.3m at a time. Connecting wires shall be installed after the placement of each layer, i.e. at 0.3m high and 0.6m high.

0.5m High Gabions

0.5 m high gabions do not require connecting wires unless the baskets are used to build vertical structures. In some cases, these units shall be filled in two layers; connecting wires shall be installed after the placement of the first layer.

5.12.3.5 Lid Closing

Once the gabion baskets are completely full, the lids will be pulled tight until lid meets the perimeter edges of basket. Lid must then be tightly laced and/or fastened along all edges, ends and tops of diaphragm(s) in the same manner as described in the previous section.

5.12.3.6 Backfilling

Suitable backfill material as per project specifications should be provided after a layer of gabions is erected. Layer wise compaction needs to be done. Ensure a light weight roller is used when compacting upto a distance of 1.0m from the gabion. Adequate care should be taken so that Geotextile is not damaged.

5.13 SPECIFICATIONS OF POLYMER ROPE GABIONS

The polymer ropes shall be manufactured from polypropylene. Polymer Rope Gabions shall be fabricated from polymer rope nets (4 strands - 9 mm dia rope) with woven joints and mesh sizes as mentioned in the specifications. Length of gabions will be decided by ease of handling and site conditions. All gabions shall be supplied in the collapsed form, either folded and bundled or rolled for shipping.

Gabions of length more than 1.5m shall have diaphragms at a spacing of 1.0m. It is suggested to use PP Tarred rope gabions than normal PP rope gabions for its better abrasion resistance and UV resistance.

5.13.1 Specifications

The specifications of PP Tarred Rope Gabions of 9mm Dia. rope, 4 strand, with aperture sizes of 100mm x 100mm and 150mm x 150mm with/without lid and slings are given in Table 1 to 4.

Specifications of 9mm Tarred Rope Gabion, 100mm X 100mm Mesh Size : 4 Strand

Properties	**Specifications**
Size of body and border rope	9 mm having a weight of 42gm/m with a tolerance of ±8%.
Material of rope	PP (with adequate UV stabilizer)
Mesh opening size	100mm X 100mm
Tensile Strength	(a) 9 mm PP Tarred Rope 1560 Kg Breaking Strength (min.) (b) Rope Net 15000 Kg /m width Breaking Strength (c) Punching Shear Strength 6000 Kg.
Structure of the rope	4 strand shroud laid
Construction of net	Woven joint at the intersection of ropes
Abrasion resistance	The rope when tested as per procedure shall have a residual B.S. of at least 90% of the stipulated rope strength at the end of 1000 cycles.
Thermal Stability	The rope when tested as per procedure shall have a residual strength of 90%.
Type approval as per OCIMF 2000 by LRA / ABS / BVQI	Type approval Certificate from LRA / ABS / BVQI to be submitted.
Cyclic Load Fatigue Test (TCLL)	Minimum 60 % of NWBS Certificate from independent Inspection Agency such as LRA / ABS / BVQI to be submitted
Wt. % of Tar	5 to 10 %
Resistance to UV radiation	Material shall be adequately UV stabilized

Note :

1. Testing of Linear Density & Pitch (Length of Lay) of 9 mm 4-Strand PP Rope to be done as per Indian Standard IS 7071: 1992 (Part I to III).

2. Breaking strength of Rope, Rope Net, Abraded rope and Rope subjected to thermal stability to be done as per IS 7071 - Part IV 1986.





Installation Guidelines

Profileshall be prepared to the extent shown on the plans or as directed by the engineer. All Loose or unwanted materials shall be removed. All depression shall be carefully backfilled up to desire grade and compacted. Any buried debris protruding from foundation that will impede proper installation and final appearance of gabion or gabion mattress shall also be removed and void carefully backfilled and compacted as specified in the drawing.

Gabions shall be filled with rock or stone fill. The rock for gabions shall be hard, angular to round, durable and of such quality that they shall not disintegrate on exposure to water or weathering during life of structure. Gabion rocks shall range between 150mm and 200mm. Range in sizes shall allow for a variation of 5% oversize and/or 5% undersize rock, provided it is not placed on the gabion exposed surface.

During the filling operation good hand packing & stone placement is required to minimize voids. The exposed faces of vertical structures may be carefully hand placed to give a neat, flat and compact appearance. Cells shall be filled in stages so that local deformation may be avoided, i.e. at no time shall any cell be filled to a depth exceeding (0.30 m) higher than the adjoining cell. It is also recommended to slightly overfill the baskets to allow for settlement of rock. 1m high gabions shall be filled in three layers, 0.3m at a time.

Once gabion baskets are completely full, lids will be pulled tight until lid meets the perimeter edges of basket. Lid must then be tightly laced along all edges, ends and tops of diaphragm(s) in the same manner as described in previous section.

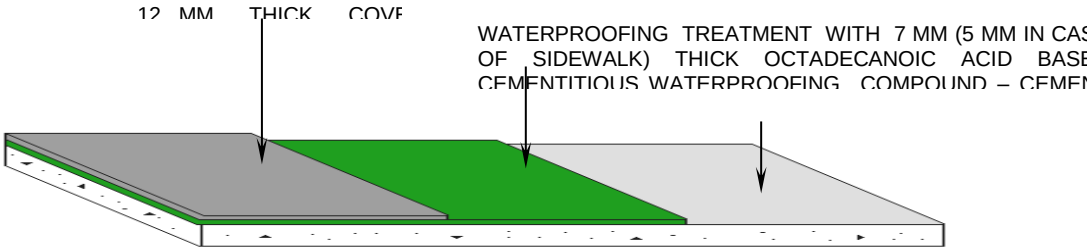
5.14 SURFACE PROTECTION OF CONCRETE BRIDGES, CULVERTS AND SIMILAR STRUCTURES

5.14.1 Piers, Substructures and Box Bridges or Culverts in River Beds and Sidewalks(zero permeability when tested for water pressure as in IS 2645:2003)

Specification :

Thorough cleaning of the surface to remove all loose materials, dirt, laitance, etc. : preparing the surface by wetting thoroughly; etching the wet surface with muriatic acid; mopping up excess acid and washing the surface thoroughly; treating the surface by applying a two-layer plaster; the first layer shall be 7 mm (5 mm in case of sidewalk) thick with cement (OPC or slag), admixed with an octadecanoic acid based cementitious waterproofing compound (bulk density not greater than 0.5 gm/cc, moisture content less than 2.0% and free fatty acid less than 0.2%), conforming to test provisions of IS 2645:2003, but with zero permeability under a waterhead of 20 metres, and having the additional properties of making cement plasticized and less porous, in the weight ratio of 50:3 for cement and waterproofing compound; finally providing the second layer in the form of a protective plaster (12 mm thick) of cement-sand (1:2.5), containing polyester fibre as secondary reinforcement @ 0.25% by weight of cement, before the first plaster will have cracked or dried up; followed by curing for seven days in the case of work with OPC or fourteen days in the case of work with slag cement (Note : Where the velocity of stream or river is expected to cause erosion of the surface protection layer, necessary jacketing of the treated surface with concrete of adequate thickness shall be provided at extra cost)

Other Details :



SCHEMATIC VIEW

1) MATERIAL : The material shall be a powder that can be uniformly mixed with cement (OPC or slag) and it must have been in use in projects of Indian Railways for at least 6 years.

2) TEST : The two-layer surface protection system shall be tested according to test provisions of IS:2645-2003 under a waterhead of 20 metres. The test shall be conducted at National Test House or at any other laboratory approved by the Engineer-in-charge.

3) CLEANING THE SURFACE : Surfaces shall be thoroughly cleaned to remove all growths, plaster, dirt, laitance, any other loose or soft material and all other non-structural work. Any grease, oil, paint, etc. shall be removed.

4) PREPARING THE SURFACE : The concrete surface shall be prepared for the waterproofing treatment by wetting the surface (to prevent absorption of acid) thoroughly and etching the surface by a liberal application of muriatic acid. Should a single application of the acid fail to lead to a rough texture (similar to the texture of a fine grained sand paper), the acid may have to be re-applied. In between

applications of acid, the surface should be rubbed with a stiff brush and washed. Excess acid shall be removed when it will stop reacting (formation of gas bubbles) with cement mortar in concrete, which may take 5-10 minutes. The surface shall be washed. Alternatively, the concrete surface is roughened with a water jet or by sand blasting, or the bond can be improved with the use of a polymer bonding agent

5) PREPARING THE PASTE OF CEMENT AND WATERPROOFING COMPOUND : 3 kgs of the waterproofing compound is mixed uniformly with 50 kgs of OPC or slag cement. Water (@ an approximate water/cement ratio of 0.35), small quantities at a time, is added to and mixed with the admixture of cement – waterproofing compound. A paste is thus formed.

6) PREPARING THE MORTAR FOR COVER PLASTER : The cement (OPC or slag)-sand mortar in the ratio of 1:2.5 is prepared in the normal way with the addition of water (@ a water-cement ratio of not higher than 0.4). Polyester fibre @ 0.25% by weight of cement is added as secondary reinforcement in making the cement-sand mortar. This mortar for the cover plaster is kept ready before the application of the paste of cement-waterproofing compound.

7) APPLICATION : The cleaned and etched surface is properly wetted and the excess water is removed or a polymer bonding agent is applied. A 7 mm (5 mm in the case of sidewalk) thick layer of the plaster of the cement-waterproofing compound is provided on the wet surface, followed by the application of the 12 mm thick cement-sand cover plaster when the first layer plaster of cement-waterproofing compound starts developing surface cracks. The cracks in the first layer plaster are healed with the application of a gentle pressure with a trowel before the application of the cover plaster and an even finishing of the surface.

8) CURING : The treatment is cured with water for at least 7 days in the case of work with OPC and at least 14 days in the case of work with slag cement.

5.14.2 Underside of Bridge Decks, Girders, Inside of Box Girders, Railings, etc. of Bridges and Piers and Substructures which are not in River Bed

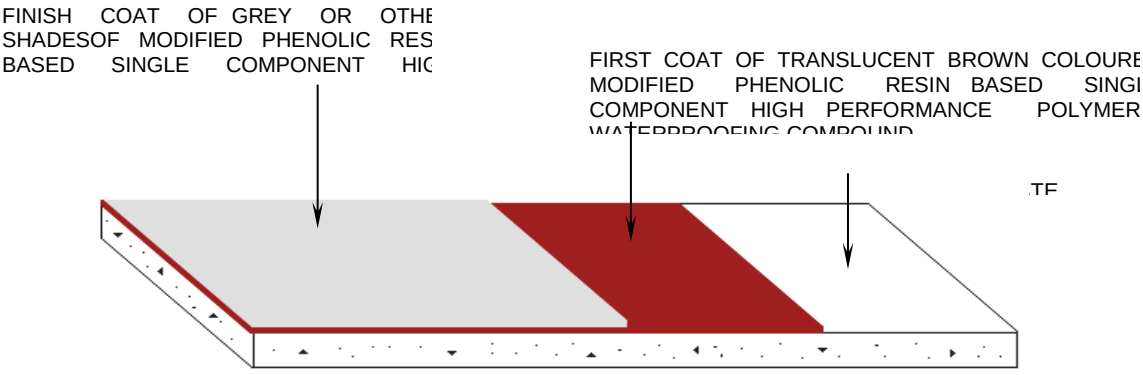
(zero permeability when tested for water pressure as in IS 2645:2003)

Specification :

Thorough cleaning of the surface to remove all loose materials, dirt, laitance, etc.; drying the surface naturally or mechanically; blowing away dust particles by electrically operated blower or sweeping off by cleaning brush; applying on a dry surface (@ 0.30 litre per square metre) with a brush or spray gun a coat (DFT of 100-150 micron) of a translucent brown coloured modified phenolic resin based single component high performance polymeric waterproofing compound (sp. gr. 0.87, rosin content nil and a solid content of minimum 0.47%), with demonstrable properties of impermeability of treatment under a waterhead of 20 metres, when applied in two coats and tested as in IS 2645-2003, having the additional properties of resistance to acids; applying (@ 0.25 litre per square metre) a coat of a modified phenolic resin based top-coat of grey or other shades, (sp. gr. 0.85), the combined

treatment having the property of impermeability when tested under a waterhead of 20 metres as in IS:2645-2003; the top-coat will be applied before the first coat becomes tack-free

Other Details :



SCHEMATIC VIEW

1) MATERIAL : The phenolic resin based materials of both the first and top coat are miscible with MTO and these must have been in use in projects of Indian Railways for at least 3 years.

2) TEST : The base coat material, when applied in two coats, as well as the surface protection system of a base coat and a top coat shall have zero permeability when tested in accordance with test provisions of IS:2645-2003 under a waterhead of 20 metres. The test shall be conducted at National Test House or at any other laboratory approved by the Engineer-in-charge.

3) CLEANING AND PREPARING THE SURFACE: The surface is cleaned thoroughly to remove all loose materials, dirt, laitance, any foreign material, etc., and it is permitted to dry naturally or mechanically. Dust particles are removed with an electrically operated blower or sweeping off with a hand brush.

4) APPLICATION : Honeycombed areas of the concrete surface are repaired and permitted to dry. A coat of the translucent brown coloured modified phenolic resin based single component polymeric waterproofing compound is applied with a bristle brush or a spray gun. As the coating dries naturally but before it becomes tack free a coat of the top coat material is applied with a bristle brush or a spray gun. The coating is permitted to dry naturally for at least a day. In the event there will be rain before the application of the top coat, the rain water shall be removed, the surface permitted to dry, and the first coat pressed (not rubbed) with a piece of the finest grain emery cloth before the application of the top coat on the day after the rain or thereafter.

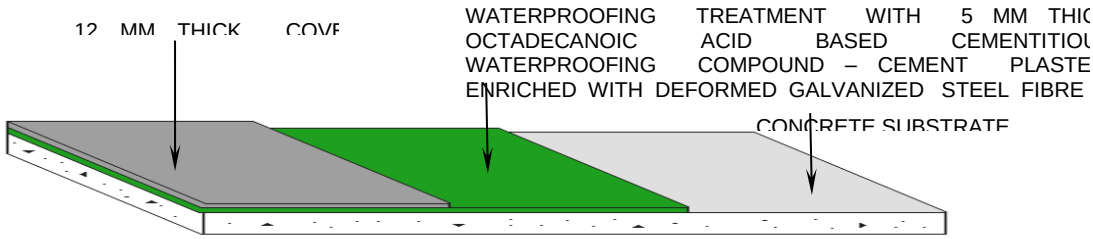
5.14.3 Bridge Deck (zero permeability when tested for water pressure as in IS 2645:2003)

Specification :

Thorough cleaning of the surface to remove all loose materials, dirt, laitance, etc.; preparing the surface by wetting thoroughly; etching the wet surface with muriatic acid; mopping up excess acid and washing the surface thoroughly; treating the surface by applying a two - layer plaster; the first layer shall be 5 mm thick with cement (OPC or slag), admixed with an octadecanoic acid based cementitious waterproofing compound (bulk density not greater than 0.5 gm/cc, moisture content not greater than 2.0% and free fatty acid not greater than 0.2%), conforming to test provisions of IS:2645-2003, but with zero permeability under a waterhead of 20 metres, and having the additional properties of making cement plasticized and less porous, in the weight ratio of 50:3 for cement and waterproofing compound; further admixed with deformed (sinusoidal form) galvanized steel fibre (150 gm per square metre of surface area), not thicker than 24 gauge and having a UTS of not less than 500 MPa; finally providing the second layer in the form of a protective plaster (12 mm thick) of cement-sand (1:2.5), containing polyester fibre as secondary reinforcement @ 0.25% by weight of cement, before the first plaster will have cracked or dried up; followed by curing for seven days in the case of plastering with OPC or fourteen days in the case of plastering with slag cement and providing a wearing course in the case of bridge decks. (Provide a wearing course at extra cost)

Note :The treatment is to be topped with a wearing course, the cost of which is not included

Other Details :



SCHEMATIC VIEW

1) WATERPROOFING MATERIAL : The material shall be a powder that can be uniformly mixed with cement (OPC or slag) and it must have been in use in projects of Indian Railways for at least 6 years.

2) STEEL FIBRE : The deformed galvanized steel fibre shall be no longer than 50±5 mm and it shall not be thicker than 24 gauge with a UTS of not less than 550 MPa.

3) TEST : The two-layer surface protection system shall be tested according to test provisions of IS:2645-2003 under a waterhead of 20 metres. The test shall be conducted at National Test House or at any other laboratory approved by the Engineer-in-charge.

4) CLEANING THE SURFACE : Surfaces shall be thoroughly cleaned to remove all growths, plaster, dirt, laitance, any other loose or soft material and all other non-structural work. Any grease, oil, paint, etc. shall be removed

5) PREPARING THE SURFACE : The concrete surface shall be prepared for the waterproofing treatment by wetting the surface (to prevent absorption of acid) thoroughly and etching the surface by a liberal application of muriatic acid. Should a single application of the acid fail to lead to a rough texture (similar to the texture of a fine grained sand paper), the acid may have to be re-applied. In between applications of acid, the surface should be rubbed with a stiff brush and washed. Excess acid shall be removed when it will stop reacting (formation of gas bubbles) with cement mortar in concrete, which may take 5-10 minutes. The surface shall be washed. Alternatively, the concrete surface is roughened with a water jet or by sand blasting, or the bond can be improved with the use of a polymer bonding agent.

6) PREPARING THE PASTE OF CEMENT AND WATERPROOFING COMPOUND: 3 kgs of the waterproofing compound is mixed uniformly with 50 kgs of OPC or slag cement. Water (@ an approximate water/cement ratio of 0.35), small quantities at a time, is added to and mixed with the admixture of cement – waterproofing compound. Deformed steel fibres@ 750 gm per bag of cement are added to the paste of cement-waterproofing compound and the paste is remixed.

7) PREPARING THE MORTAR FOR COVER PLASTER : The cement (OPC or slag)-sand mortar in the ratio of 1:2.5 is prepared in the normal way with the addition of water (@ a water-cement ratio not higher than 0.4). Polyester fibre @ 0.25% by weight of cement is added as secondary reinforcement in making the cement-sand mortar. This mortar for the cover plaster is kept ready before the application of the paste of cement-waterproofing compound, admixed with steel fibres.

8) APPLICATION : The cleaned and etched surface is properly wetted and the excess water is removed or a polymer bonding agent is applied. A 5 mm thick layer of the plaster of the cement-waterproofing compound, enriched with steel fibres, is provided on the wet surface, followed by the application of the 12 mm thick cement-sand cover plaster before the first layer plaster of cement-waterproofing compound starts developing surface cracks. The cracks in the first layer plaster are healed with the application of a gentle pressure with a trowel before the application of the cover plaster and an even finishing of the surface.

9) CURING : The treatment is cured with water for at least 7 days in the case of work with OPC and for at least 14 days in the case of work with slag cement.

Note :The treatment is to be topped with a wearing course, the cost of which is not included.

Chapter- 6

Permanent Way Work

The following codes, manual, standards and guidelines shall be used for different items of Permanent Way Works for execution, quality assurance, tests, check and acceptance and forms parts of the specification.

1. Indian Railway Permanent Way Manual , July 2019 (with latest CS)
2. Manual of Instructions on Long Welded Rail, 1996 (with latest CS)
3. Manual for Ultrasonic Testing of Rails and Welds -2012 (with latest CS)
4. IRS Specification for Fusion Welding of Rails by Alumino – Thermic Process -2012 (with latest CS)
5. RDSO Guidelines for Handling and Stacking of Rails (CT-Rail Handling dated 05.11.2014
6. Manual for Glued Insulated Rail Joints – 1998 (with latest CS)
7. Manual for Flash Butt Welding of Rails – 2012 (with latest CS)
8. Indian Railways Standard Schedule of Dimensions 2004 (with latest CS)
9. General & Subsidiary Instruction
10. Indian Railways Small Track Machine Manual
11. Track Manual Volume-I
12. Track Manual Volume-II
13. Indian Railway Works Manual
14. Manual For Reconditioning Of Medium Manganese (MM) Steel Points And Crossings, SEJs
15. Work Procedure For Reconditioning Of Cupped At Welding Joints And Wheel Burn/Scabs Using “Robotic Welding Machine” (Provisional) 2019
16. Indian Railways Code For The Engineering Department
17. Accident manual
18. IR GCC 2019