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भारत सरकार - **GOVERNMENT OF INDIA**

रेल मंत्रालय - **MINISTRY OF RAILWAYS**

शॉटक्रीटिंग के लिए अनुशंसित कार्य

RECOMMENDED PRACTICE FOR SHOTCRETING



केमटेक/2018/सि/शॉटक्रीटिंग/1.0

CAMTECH/2018/C/SHOTCRETING/1.0

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अग्रम पंRDS
रेल अग्रदूत Transforming Railways

An ISO 9001-2008 Certified Organisation
उच्च अनुरक्षण प्रौद्योगिकी केन्द्र
EXCELLENCE IN MAINTENANCE

Indian Railways
Centre for Advanced Maintenance Technology

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प्राक्कथन

एक बड़ा संगठन होने के नाते भारतीय रेलवे के पास सिविल इंजीनियरिंग संरचनाओं और इमारतों की विशाल संपदा मौजूद है जिनकी सेवा अवधि के दौरान रखरखाव की आवश्यकता होती है।

शॉटक्रीटिंग एक प्रक्रिया है जिसमें संरचनात्मक रूप से दृढ और टिकाऊ निर्माण सामग्री का उपयोग करके कंक्रीट, चिनाई, लकड़ी या स्टील संरचनाओं की क्षतिग्रस्त सतह की मरम्मत की जाती है।

यह आशा की जाती है कि कैमटेक द्वारा तैयार पुस्तिका सिविल संरचनाओं के रखरखाव एवं निर्माण गतिविधिओं में लगे भारतीय रेलवे के इंजीनियरिंग कर्मियों को काफी उपयोगी होगी।

कैमटेक, ग्वालियर ***(डी. गोविंद कुमार)***
28, फरवरी 2018 ***प्रमुख कार्यकारी निदेशक***

Foreword

Indian Railways is a big organization having large assets of civil engineering structures and buildings, which require maintenance throughout their service life.

Shotcreting is a process to repair the damaged surface of concrete, masonry, wood, or steel structures by using structurally sound and durable construction material.

It is expected that the booklet prepared by CAMTECH will be quite helpful to the engineering personnel of Indian Railways engaged in maintenance and construction activities of civil structures.

CAMTECH, Gwalior ***(D. Govind Kumar)***
28, February 2018 ***Principal Executive Director***

भूमिका

नई कंक्रीट संरचनाओं का निर्माण करने के साथ-साथ मौजूदा संरचनाओं को पुनर्स्थापित और मरम्मत करने के लिए इंजीनियरों और तकनीकी कर्मचारियों द्वारा सन 1914 से वायवीय दबाव (*pneumatic pressure)* के तहत लागू एक निर्माण सामग्री के रूप में शॉटक्रीट (या स्प्रेड कंक्रीट) की तकनीक विकसित की गई है।

यह तकनीक कंक्रीट, चिनाई, लकड़ी या इस्पात की संरचनाओं जैसे सुरंग की लाइनिंग, पुल / बांधों, पियर्स / डॉक, रिटेनिंग वॉल, सीवर (स्टोर्म, सेनेटरी), हेडवॉल्स / विंग वॉल, बिल्डिंग, मेराइन संरचना तथा स्पिलवेज़ आदि की क्षतिग्रस्त सतह की मरम्मत में सफलतापूर्वक उपयोग की जाती है।

'शॉटक्रीटिंग के लिए अनुशंसित कार्य पर यह लघु पुस्तिका भारतीय रेलवे के एसएसई/जेई तथा अधिकारियों के मध्य शॉटक्रीट (स्प्रेड कंक्रीट) जो कि नई कंक्रीट संरचनाओं के निर्माण के साथ-साथ मौजूदा संरचनाओं की मरम्मत एवं पुनर्स्थापन में प्रयुक्त की जाती है, के बारे में जागरूकता पैदा करने और ज्ञान को प्रसारित करने के उद्देश्य से तैयार की गई है।

पुस्तिका का उद्देश्य सामग्री के रूप में शॉटक्रीट (या स्प्रेड कंक्रीट) तथा प्रक्रिया के रूप में शॉटक्रीटिंग के चयन, अनुपात, और इसके उपयोग के बारे में भारतीय रेलवे के सिविल इंजीनियरिंग स्टाफ को जो कि रखरखाव और निर्माण गतिविधियों में शामिल हैं, के लिए जानकारी एवं मार्गदर्शन प्रदान करना है।

यह पुस्तिका एक संदर्भ आलेख है जो कि वैधानिक नहीं है तथा इसमें दी गई सामग्री का उद्देश्य केवल मार्गदर्शन है। अधिक जानकारी के लिए, विषय पर उपलब्ध प्रासंगिक कोड, मैनुअल और रिपोर्ट का अध्ययन संदर्भ रूप में किया जाना चाहिए।

हम पुस्तिका में अधिक सुधार के लिए पाठकों से किसी भी सुझाव का स्वागत करते हैं।

कैमटेक, ग्वालियर ***(डी. के. गुप्ता)***

27, फरवरी 2018 ***संयुक्त निदेशक/ सिविल***

Preface

The technology like shotcrete (or sprayed concrete) as a construction material applied under pneumatic pressure has been evolved and practiced since 1914 by engineers and technical staff to build new concrete structures as well as to restore and repair existing structures.

It is successfully used in tunnel lining, in repair of damaged surface of concrete, masonry, wood, or steel structures in Bridges/ Dams, Piers/Docks, Retaining Walls, Sewer (Storm, Sanitary), Headwalls/Wing Walls, Buildings, Marine Structures, and Spillways.

This booklet on *'Recommended Practice for Shotcreting'* is prepared with the objective to disseminate knowledge and to create awareness among the SSE/JEs and officers of Indian Railways regarding shotcrete (or sprayed concrete) used to build new concrete structures as well as to restore and repair the existing structures.

The booklet is meant to provide information and guidance on the selection, proportioning, and application of shotcrete (or sprayed concrete) as material and Shotcreting as process to the civil engineering personnel of Indian Railways involved in maintenance and construction activities.

This booklet is a reference document, which is not statutory and contents are only for the purpose of guidance. For more in-depth information, the relevant codes, manual and reports on the subject may be referred.

We welcome any suggestions from our readers for further improvement.

CAMTECH, Gwalior ***(D. K. Gupta)***
27, February 2018 ***Joint Director/Civil***

संशोधन पर्चियों का प्रकाशन

इस लघु पुस्तिका के लिए भविष्य में प्रकाशित होने वाली संशोधन पर्चियों को निम्नानुसार संख्यांकित किया जाएगा।

केमटेक/सि/2018/शॉटक्रीटिंग/1.0 सीएस # XX दिनांक ----------

जहाँ "XX" संबन्धित संशोधन पर्ची की क्रम संख्या है (01 से प्रारम्भ होकर आगे की ओर)

प्रकाशित संशोधन पर्चियाँ

क्र.सं.	प्रकाशन की तारीख	संशोधित पृष्ठ संख्या तथा मद संख्या	टिप्पणी

ISSUE OF CORRECTION SLIPS

The correction slips to be issued in future for this booklet will be numbered as follows:

CAMTECH/C/2018/SHOTCRETING/1.0/CS # XX date .....

Where "XX" is the serial number of the concerned correction slip (starting from 01 onwards).

CORRECTION SLIPS ISSUED

S. No.	Date of issue	Page no. and Item No. modified	Remarks

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To ensure the long-term serviceability of any infrastructure, it is important to use the most advanced techniques available, both in the investigation phase and in maintenance.

1.0 परिचय/ Introduction

The purpose of this booklet is to provide information and guidance on the selection, proportioning, and application of shotcrete (or sprayed concrete). The process by which shotcrete is applied on to a surface is known as shotcreting.

Sprayed concrete is a single term that describes various components of a complete technology:

- shotcrete as material
- shotcreting as placing process
- shotcrete as construction method

These three components define a complete technology which has a long tradition, huge potential for innovation and a great future. Sprayed concrete was used for the first time in 1914 and has been permanently developed and improved over recent decades.

The use of shotcrete by engineers and technical staff to build new concrete structures as well as to restore and repair existing structures is well known and documented and it is perhaps the most diverse method available for concrete construction.

The use of this innovative technology is increasing day by day and procedures for its proper performance are well developed and high quality work is regularly obtained.

2.0 शॉटक्रीट के अनुप्रयोग के क्षेत्र/ Area of Application of Shotcrete

When properly applied, Shotcrete/ Gunite i.e. a structurally sound and durable construction material is frequently used to repair the damaged surface of concrete, masonry, wood, or steel structures in Bridges/ Dams, Piers/Docks, Retaining Walls, Sewer (Storm, Sanitary), Headwalls/Wing Walls, Buildings, Marine Structures, and Spillways.

Shotcrete in Building



In tunnel lining, sprayed concrete has become very important in stabilizing the excavated tunnel section. Modern tunnelling without sprayed concrete is inconceivable.

Shotcrete in Tunneling



Shotcrete/Gunite is also used for patch repair to the non-structural or minor structural cracks limited to crack sealing, restoring the lost cover concrete, if any due to corrosion of reinforcement.

Shotcrete can be used in accessible footing, footing walls, slabs, walls, columns, beams, stairs, filling of large voids etc.

3.0 शॉटक्रीट एवं इसकी विशेषताएँ/ Shotcrete and its Properties

Sprayed Concrete (i.e. Shotcrete or Gunite) is a mixture of cement, aggregate (fine and coarse) and water projected at a high velocity from a nozzle into place against an existing structure of formwork where it is compacted by its own velocity to produce a dense homogeneous mass.

The most commonly used terms are:

(a) Gunite, where maximum aggregate size is 10 mm.
(b) Shotcrete, where the maximum size of aggregate is beyond 10 mm and less than 1/3 of the buildup thickness.

Gunite (or shotcrete, as the case may be) produces a high quality material with the following desirable properties:

- Superior bonding ability, making it especially suitable for repair work on many types of structures.
  - Properly applied shotcrete is a structurally sound and durable construction material which exhibits excellent bonding characteristics to existing concrete, rock, steel, and many other materials.
  - These favourable properties are contingent on proper planning and supervision, and on the skill and continuous attention by the operating staff.
- Low water-cement ratio, resulting in high strength and low permeability.
  - The water cement ratio for shotcrete in place normally falls within the range of 0.35 to 0.50 by mass which is somewhat lower than for most conventional concrete mixes.
  - The grade of concrete i.e. the characteristic compressive strength of 15 cm cube at 28 days should be specified. Most reported values for 28-day strength are in the range of 20 to 50 N/mm^2. It is recommended that strength higher than 25 N/mm^2 be specified only for the most carefully executed shotcrete jobs.

- The drying shrinkage of shotcrete depends somewhat on the mix proportions used, but generally falls within the range of 0.06 to 0.10 percent.
  - This is rather higher than for most low-slump conventional concrete, which is generally placed in heavier sections using larger aggregate and leaner mixes. It will tend to give more shrinkage, cracking, and may require a closer joint spacing. The durability of shotcrete in laboratory tests and under field exposure has generally been good.
- Dense concrete, as a consequence of low water contentment and high impact velocity.
  - Pneumatically projected Shotcrete at high velocity onto a backing surface generates the force of spraying action that leads to compaction of the concrete or mortar which then forms layers of concrete to the required thickness. This mechanism reduces the rebound waste that occurs through the shotcreting process.
- Relatively simple work-area requirements.
  - Only an air compressor and a source of water being necessary. Easy transformation of concrete (or mortar) through a hose from the gun to the site of application.
- Resistance to weathering and many types of chemical attack because of being highly dense. Good abrasion resistance.
  - Properly applied shotcrete can have high strength, low absorption, good resistance to weathering, and resistance to some forms of chemical attack.
- Shotcrete offers advantages over conventional concrete in a variety of new construction and repair work.
  - It is frequently more economical because of the lesser forming requirements, and because it requires only a small, portable plant for manufacture and placement.
- Good refractory properties with proper aggregates.
- Shotcrete lends itself to the production of many shapes and thin sections with a minimum or no formwork at all.
- Many of the physical properties of sound shotcrete are comparable or superior to those of conventional concrete or mortar having the same composition.
- Improperly applied shotcrete may create conditions much worse than the untreated condition.

4.0 शॉटक्रीट सामग्रियाँ/ Shotcrete Materials

a) Cement: Cement requirements for shotcrete are similar to those for conventional concrete. Cement shall be ordinary Portland cement of 43 Grade conforming to relevant IS Code of Practice.

As per IS 9012: 1978 (Reaffirmed 2002), any of the following cements shall be used with the prior approval of the engineer-in-charge:

i) Ordinary or low heat Portlant Cement conforming to IS: 269 - 2015.
   - Low heat Portland cement conforming to IS : 269-2015 shall be used with adequate precautions with regard to removal of formwork, etc.
ii) Rapid hardening Portland cement conforming to IS : 8041-1990.
iii) Portland slag cement conforming to IS: 455-2015.
iv) Portland Pozzolana cement conforming to IS : 1489-2015.
v) High strength ordinary Portland cement conforming to IS : 8112-2013.
vi) Hydrophobic cement conforming to IS : 8043-1991.

b) Aggregates

(i) **Fine Aggregate (Sand):** Sand for shotcrete shall comply with the requirements given in IS : 383-1970 (Reaffirmed 2002) and graded evenly from fine to coarse as per Zone II and Zone III grading. Sand failing to satisfy this grading may, however, be used if preconstruction testing establishes that it gives good results.

In general, sand should neither be too coarse to increase the rebound nor too fine to increase the slump. Sand should preferably have a moisture content between 3 to 6 percent.

The grading of sand shall lie within the limits given below:

IS sieve Designation	Percent passing the sieve
4.75 mm	95-100
2.36 mm	65-90
1.18 mm	45-75
600 microns	30-50
300 microns	10-22
150 microns	2-8

(ii) **Coarse Aggregate:** Coarse aggregates when used shall comply with the requirements of IS : 383-1970 (Reaffirmed 2002). It shall, generally conform to one of the gradings given in Table below.

IS Sieve Designation (mm)	Percentage by Mass passing for Aggregate of Nominal Maximum Size		
	10 mm	12.5 mm	20 mm
25	-	-	100
20	-	100	90-100
12.5	100	90-100	-
10	85-100	40-70	20-55
4.75	10-30	0-15	0-10
2.36	0-10	0-5	0-5
1.18	0.5	-	-

All oversize pieces shall be rejected by screening, since they are likely to cause plugging of the hose.

For thick sections it may be advantageous to incorporate coarse aggregate in the mix provided adequate guniting equipment is available. The percentage of coarse aggregate may normally be kept as 20 to 40 per cent of the total aggregate and the mix shall be suitably designed.

c) Water: Water used for mixing and curing for shotcrete shall conform to the requirements of IS: 456-2000.

- Water shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances.
- Generally, Potable water is considered satisfactory for mixing and curing.
- The pH value of water shall be not less than 6.
- The presence of tannic acid or iron compounds is objectionable.
- Use of sea water is prohibited because of presence of harmful salts.

d) Admixtures: Admixture shall only be used if approved by the Engineer-in-Charge who shall be furnished with all required literature pertaining to its efficacy. Guniting admixtures & quick setting agents may be used to minimise the rebound loss and increase the bond & enable thicker layers per coat.

Admixture when used, shall meet the requirements of IS : 456-2000 and IS : 9103-1999.

5.0 रेंफोर्समेंट/ Reinforcement

Reinforcing bars if used shall conform to IS : 432 (Part I) – 1982 or IS : 1786–2008. Welded wire fabric conforming to IS : 1566–1982 also may be used.

Depending on the thickness and nature of the work, reinforcement may consist of either round bars, or welded wire fabric. Small sizes of bars shall be used, a 16 mm diameter bar being the normal maximum size. Where large bars are necessary, exceptional care shall be taken in encasing them with shotcrete.

- Suficient clearance shall be provided around the reinforcement to permit complete encasement with sound gunite/shotcrete. The clearance needed depends on the maximum size of aggregate in the mix and the size of reinforcement.
  - The minimum clearance between the reinforcement and the form or other backup material may vary between 12 mm for the case of a mortar mix and wire fabric reinforcements to 50 mm for the case of a concrete mix and 16 mm diameter reinforcing bars.
  - The minimum wire mesh spacing shall be 50 mm by 50 mm.
  - Clear spacing between parallel bars shall be at least 65 mm.
  - Minimum cover to reinforcement shall be as per IS: 456:2000.
  - As far as possible the bars shall be arranged so as to permit shooting from opposite side.
- Laps for bars and wire fabric shall receive special attention to prevent weak sections in the shotcrete.
  - Lapped reinforcing bars shall not be tied together; they shall be separated by at least 50 mm, wherever possible.
  - Wire mesh shall be lapped 1½ squares in all directions.
  - The minimum requirements of lap length shall be as specified in IS : 456-2000.
- For repair work, the reinforcement shall be fixed to existing masonry and concrete by wiring to nails driven into walls and secured rigidly so that the vibration resulting from the deposition of shotcrete will not impair or displace them.
- Additional reinforcement wherever the reinforcement diameter has been reduced by more than 15% with the necessary overlap or welding with the existing reinforcement shall be provided.

6.0 पूर्वनिर्माण टेस्टिंग/ Preconstruction Testing

A laboratory investigation shall, therefore, be carried out prior to the commencement of the work in order to check the operation of the equipment and the skill of the operating staff, and also to verify that the specified quality of shotcrete may be expected in the structure. The procedure for preconstruction testing shall be as recommended in following paragraphs:

1. Test panels simulating actual job conditions shall be fabricated by the operating staff, using the equipment, materials and mix proportions proposed for the job.

2. For the dry mix process, the amount of water added at the nozzle is adjusted so that the in-place shotcrete shall be adequately compacted and will neither sags nor shows excessive rebound. At least, two mixes shall be tested before deciding on the final mix proportions.

3. For the wet mix process i.e. similar to the dry mix process except that the entire mix is premixed to give a workability judged to be appropriate for the work, before it is introduced into the chamber of the delivery equipment. Tests on more than one mix design are usually recommended where it is desired to include coarse aggregate in the mix.

4. The panels are fabricated by gunning on to a back form of plywood. A separate panel shall be fabricated for each gunning position (for each mix design) to be encountered in the structure (i.e. slab, vertical and overhead sections). At least, part of the panel shall contain the same reinforcement as the structure, to show whether sound shotcrete is obtained behind the reinforcing rods. Generally the size of panel shall be not less than 75 x 75 cm. The thickness shall be the same as in the structure except that it shall normally be not less than 75 mm.

5. Cores shall be taken from the panels for testing. The cores shall have a minimum diameter of 75 mm and a length to diameter ratio of at least 1. The specimens shall be tested in compression at the age of 7 or 28 days or both as directed by Engineer-in-Charge. The result of the tests shall be compared with the cube strength taken earlier.

6. The cut surface of the specimen shall be carefully examined and additional surfaces shall be exposed by sawing or breaking the panel, if it is considered necessary by Engineer-in-Charge to check soundness and uniformity of the material. All cut and broken surfaces shall be dense and free from laminations and sand pockets.

7. It should be ensured from tests that a strength of about 25 MPa at 28 days is available for the mortar/concrete mix.

7.0 शॉटक्रीटिंग प्रक्रियाएँ/ Shotcreting Processes

Spraying of concrete/mortar may be done effectively either by Wet Process or by Dry Process. However both the systems have got advantage or disadvantage and shall be chosen as per specific site conditions.

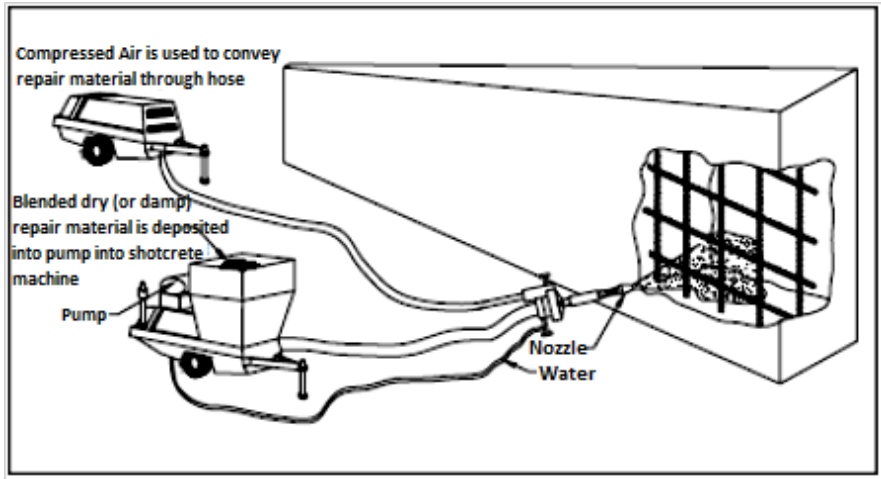
7.1 Dry Mix Process

The dry mix process is particularly favoured for repair work because the mix in its dry form can be batched as required and kept in stock at site prior to start of the shooting is unavoidable.

In this system materials like cement, sand or coarse aggregate is batched at site without addition of water. In case it is decided to use powder accelerator, the same shall be mixed with the above prebatched material and to keep at site in dry condition prior going for shooting.

The dry mix process shall consist of

- Thoroughly mixing the dry materials,
- Feeding of these materials into mechanical feeder or gun,
- Carrying the materials by compressed air through a hose to a special nozzle,
- Introducing water at nozzle point and intimately mixing it with other ingredients at the nozzle;
- Jetting the mixture from the nozzle at high velocity on to the surface to receive the shotcrete.



Note:

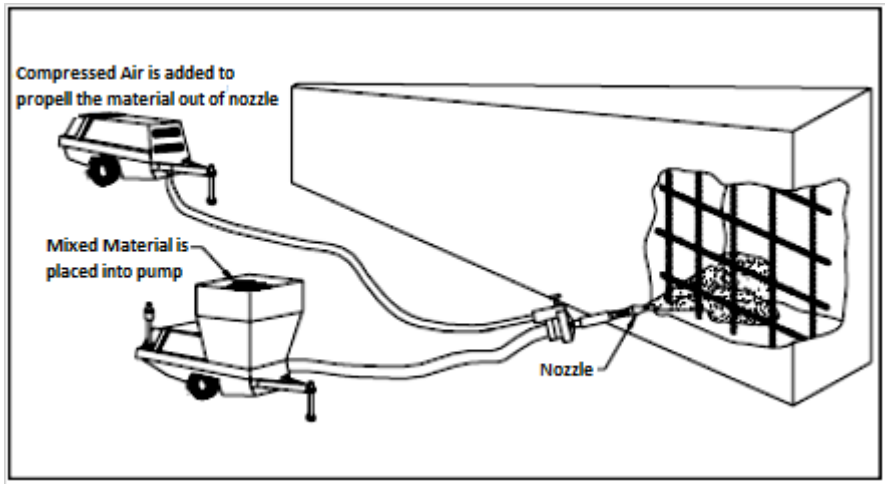
- Controlling of water-cement ratio is carried out by the nozzleman and may vary within a limited range. However, too little water will create excessive dust and will not allow the mixture compacting into a homogeneous mass. Similarly, too much water will increase the workability and cause a reduction in strength and induce shrinkage.
- Use of suitable steel or other fibres, microsilica, polymers and powder admixture shall be able to render better result with respect to strength and durability.
- Under no circumstance should rebound be reused. The amount of rebound is dependent on various factors such as nature of surface, direction of application, mix design and finally skill of the nozzleman. However, it is commonly seen that rebound loss in overhead shooting will always be higher than shooting on vertical surfaces.
- The optimum distance between the nozzlemen and the surface to be sprayed may be kept around 1.0 M.

7.2 Wet Mix Process

The wet mix process is a technique where a pre-batched mix of cement, aggregate and water is transported to the site and pumped to the nozzle by a concrete pump through flexible hoses (or pipes).

The wet mix process shall consist of

- Thoroughly mixing all the ingredients with the exception of the accelerating admixture, if used;
- Feeding the mixture into the delivery equipment;
- Delivering the mixture by positive displacement or compressed air to the nozzle;
- Jetting the mixture from the nozzle at high velocity on to the surface to receive the shotcrete.



Note:

- Since wet process needs larger volume to mix at a time and output is very high, it is generally less suitable than dry process in case of repair of any concrete structure.
- Wet mix process is usually employed for large volumes, thin sections and confined spaces.
- If specified, fibres of steel, poly propylene or other material, as may be specified, could also be used together with the admixtures to modify the structural properties of the concrete/mortar being placed in position.
- Ready to use pre-bagged dry mix micro-concrete using 3 mm aggregate and admixed with polymers, micro silica and superplasticizer is now available in the market. Use of such material will always render better result than the conventional cement-aggregate mix by way of reducing shrinkage, attaining

high flexural, compressive and tensile strength, reducing rebound loss and high build up thickness in one layer and thus improves the quality of the repair.

- The shotcrete mix design shall be developed by laboratory tests and field trials and got approved from Engineer-in-charge.

7.3 Comparison of Dry Mix and Wet Mix Processes

Shotcrete suitable for most requirements can be produced by either the dry-mix or wet-mix process. However, differences in the equipment cost, maintenance requirements, operational features, placement characteristics, and product quality may make one or the other more attractive for a particular application.

Dry Mix Process	Wet Mix Process
Mixing water instantaneously controlled at the nozzle by operator to meet variable field conditions.	Mixing water controlled at plant and measured at time of batching.
Longer hose lengths possible, if necessary	Normal pumping distances necessary.
Limited to accelerators as the only practical admixture.	Compatible with all ordinary admixtures. Special dispensers for addition of accelerators are necessary.
Use of air-entraining admixtures not beneficial. Resistance to freezing and thawing is poor.	Air entrainment possible. Acceptable resistance to freezing and thawing.
Intermittent use easily accommodated within prescribed time limits.	Best suited for continuous application of shotcrete.
Exceptional strength performance possible.	Lower strengths, similar to conventional concrete.
Lower production rates.	Higher production rates.
Higher rebound.	Lower rebound.
Equipment maintenance costs tend to be lower.	Equipment maintenance costs tend to be higher.
Higher bond strengths.	Lower bond strengths, yet often higher than conventional concrete.

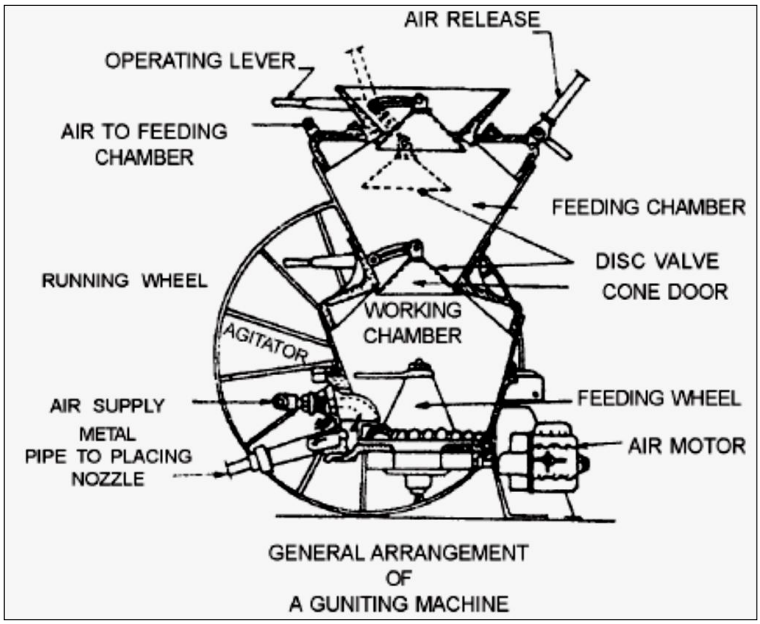
8.0 ड्राइ मिक्स एवं वेट मिक्स प्रक्रिया में प्रयुक्त उपकरण/ Equipments used in Dry Mix and Wet Mix Process

Batching and Mixing Equipment:

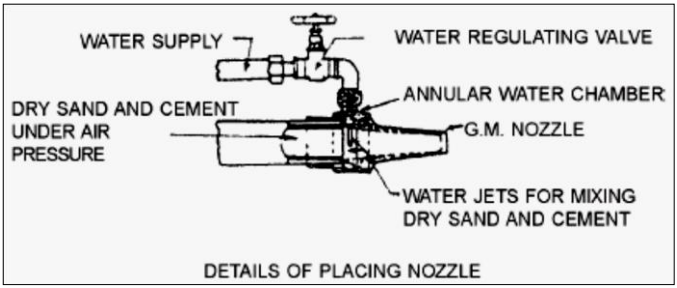
- Batching by mass is to be preferred and is strongly recommended.
- Fine Aggregate (in case of dry mix process) and Coarse Aggregates (in case of wet mix process) may be batched by volume if periodic checks are made to ensure that the masses are maintained within the required tolerance.
- Water may be batched either by mass or by volume.
- The moisture content of the sand is generally within the range of 3 to 6 percent and will depend upon the delivery equipment being used. Fluctuations in moisture content shall be avoided.
- The mixing equipment shall be capable of thoroughly mixing the specified materials in sufficient quantity to maintain continuity of placing.
- In dry mix process –
  - The mixing time shall be not less than 1 minute in a drum-type mixer; where other mixers are proposed, satisfactory evidence shall be presented that they are capable of thorough mixing.
  - The mixer shall be self-cleaning, capable of discharging all mixed material without any carryover from one batch to the next.
  - It shall be inspected and thoroughly cleaned at least once a day (and more often if necessary) to prevent accumulations of batched material.
- In wet mix process –
  - The required mixing time will depend on the mix being used and the efficiency of the mixer.
  - Delivery of concrete at the desired workability and uniformity from batch to batch is essential to a good shotcreting operation especially in vertical and overhead applications.

Delivery Equipment or Guniting Equipment: The delivery equipment shall comply with the requirements given in IS : 6433-1972 (Reaffirmed 2005).

- The pneumatic feed type delivery equipment is capable of applying high quality, low-slump mortar or concrete with the reliability needed for general construction and repair work.
- From a pressurised vessel in the equipment, the premixed materials and compressed air are discharged into the delivery hose. The material and air pass through the hose to the gunning nozzle which is fitted with an air ring for injecting additional compressed air.
- The delivery equipment shall be of a design and size which have given good results in similar work. It shall be capable of delivering the premixed materials accurately, uniformly, and continuously through the delivery hose. The size of the hose is generally within the range of 32 to 65 mm.
- Recommendations of the equipment manufacturers shall be followed with regard to the type and size of nozzle to be used, and the cleaning, inspection, and maintenance of the equipment.



GENERAL ARRANGEMENT OF A GUNITING MACHINE



DETAILS OF PLACING NOZZLE

Compressor for Air Supply: Properly operating air compressor of ample capacity is essential for a satisfactory shotcreting operation.

- The compressor shall be fitted with a moisture extractor to keep up a supply of clean, dry air adequate for maintaining a sufficient nozzle velocity for all parts of the work while simultaneously operating a blow pipe for clearing away rebound.
- The operating pressure is the pressure driving the material from the delivery equipment into the hose, and is measured by a gauge near the material outlet of the gun. The air pressure shall be uniformly steady (non-pulsating).
- For lengths of hose up to 30 m, air pressure at the gun shall be 0.3 N/mm^2 or more. Where the length exceeds 30 m, the pressure shall be increased by 0.035 N/mm^2 for each additional 15 m of hose required, and by 0.035 N/mm^2 for each 7.5 m that the nozzle is raised above the gun.

Pump for Water Supply:

- The water pressure at the discharge nozzle shall be sufficiently greater than the operating air pressure to ensure that the water is intimately mixed with the other materials.
- If the line water pressure is inadequate, a water pump shall be introduced into the line. The water pressure shall be uniformly steady (non-pulsating).

9.0 शॉटक्रीट के अनुप्रयोग/ Application of Shotcrete

Step – 1: Material – Full quantity of manufactured repair materials shall be received at site in factory sealed containers with labels legible and intact provided that the shelf life so permits. Otherwise substantial quantity as could be consumed within the storage period shall be received as per quantity approved by Engineer-in- Charge. Full quantity shall be worked out as theoretically required for consumption in the whole work.

Step – 2: Mix Design – The shotcrete mix design shall be developed by laboratory tests and field trials and got approved from Engineer-in-charge.

Step – 3: Pre-construction Testing – as described in Para 6.0 above.

Step – 4: Preparation of Surface: Surface preparation is almost similar to that for any spalled repair. A good base or foundation is necessary for proper and successful application of shotcrete. The surface area should be prepared by chipping or sand blasting and then thorough washing with water. Condition of surface dry, wet or epoxy coated does not affect significantly although a saturated brick, wetted surface is recommended.

- Where the shotcrete is to be placed against earth surfaces as in canal linings, such surfaces shall first be thoroughly compacted and trimmed to line and grade. Shotcrete shall not be placed on any surface which is frozen, spongy, or where there is free water. The surface shall be kept damp for several hours before applying shotcrete.
- The defective concrete shall be cut out to the full depth till sound concrete surface is reached. Under no circumstances should be thickness of concrete to be removed be less than clear cover to the main reinforcement. No square shoulders shall be left at the perimeter of the cut-off portion and all edges shall be tapered. Thereafter, all loose and foreign materials should be removed and the surface be sand blasted to make it rough to receive shotcrete after applying a coat of bonding epoxy as per recommendation of the manufacturer @ 1.0 kg per 1.5 sq. m. of surface area.

- The exposed reinforcement shall be thoroughly cleaned free of rust, scales etc. by wire brushing. Wherever the reinforcements have been corroded, the same shall be removed and replaced by additional reinforcement. Before application of gunite/shotcrete, a coat of neat cement slurry should be applied on the surface of the reinforcement.
- The lightly sticking materials and foreign matter from the exposed concrete surface and steel reinforcement shall be cleaned by suitable means.

Step – 5: Formwork –

- Formwork of plywood sheating or other suitable material shall be fixed true to line and dimension to get finished sides and edges of the gunited/shotcreted surface.
- Formwork shall be adequately braced to protect against excessive vibration, and shall be constructed so as to permit the escape of air and rebound during the gunning operation. Forms shall be oiled or dampened, and they shall be cleaned just before gunning.
- Formwork shall be necessarily required for first stage application of shotcrete/gunite on two opposite faces of rectangular columns and beams, whereas in second stage application of repair material on the remaining faces, gunited/shotcreted surface at edges/corners shall serve the purpose without requiring further formwork.
- Care shall be taken to avoid sand pockets behind the reinforcement.
- Adequate and safe scaffolding shall be provided so that the operator can hold the nozzle at the optimum angle and distance from the surface for all parts of the work. Scaffolding shall be constructed to permit uninterrupted applications of the shotcrete wherever possible.

Step – 6: Reinforcement – as described in Para 5.0 above.

Step – 7: Alignment & Thickness Control – Adequate ground wires shall be installed to establish thickness and surface planes of the shotcrete build-up. Both horizontal and vertical ground wires shall be installed at corners and offsets not clearly fixed by the formwork, for example, at

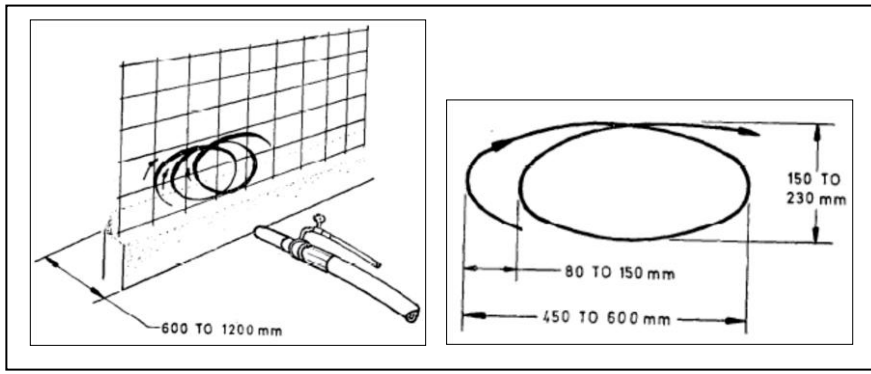
exterior corners of walls, column or beam corners, and other locations. Ground wires shall be tight and true to line, and placed in such a manner that they may be further tightened.

Step – 8: Passivating/Bond Coat – To protect steel reinforcement with a passivating alkaline layer provided all around its circumference along the length with strong adhesive to bond with applied repair concrete or mortar.

Step – 9: Placement of Shotcrete –

- Fresh gunite/shotcrete shall be applied at the earliest possible, when bond coat is still tacky.

- Maximum thickness to be applied in one pass will be, in general, limited to 25 mm for overhead application and 50 mm on sides. Where gunite is to be placed to a thickness of more than 50 mm on sides or 25 mm overhead, it is preferable for it to be built up in more than one application.
  - Each layer of shotcrete shall be built-up by making several passes or loops of the nozzle over the working area. This will be done by moving the nozzle rythmetically in series of loops from side to side and up and down. The shotcrete shall emerge from the nozzle in a steady, uninterrupted flow. If the flow becomes intermittent due to any cause, the Operator shall direct it away from the work until it again becomes constant.



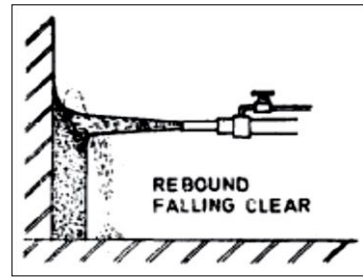
The distance of nozzle from work (usually between 0.5 and 1.5 m) shall be such as to give the best results for the working conditions. The nozzle shall be held perpendicular to the surface of application. However, when gunning through and encasing reinforcing bars the nozzle shall be held closer and at a slight angle to the perpendicular.

Also the mix shall be little wetter than normal but not so wet as to cause sloughing behind the bars. Where bars are closely spaced, more than one bar may be shot from each position.

- Application shall begin at the bottom for columns and beams and for slabs, the nozzle shall be held at a slight angle to the perpendicular so that the rebound is blown on to complete portion from where it shall be removed.

  The first layer shall at least completely embed reinforcement adjacent to the form. The thickness of layer is governed mainly by the requirement that the shotcrete shall not sag.

  Where thick layers are applied, it is important that the top surface is maintained on a 45^0 slope approximately, and that rebound is kept out of the work. As shown in adjoining figure for a shotcreting operation on a vertical wall, the top surface of the shotcrete is kept at 45^0 so that the rebound falls clear of the work.



- **Theoretical consumption of cement** - For working out the theoretical consumption of cement in shotcreting, following coefficients shall be added for accounting for the concrete wasted as loss due to rebound in various items.

  1. Ceiling of RCC slab - 40%
  2. Vertical faces of R.C.C. beams columns & R.C.C. walls
     a. with face width not exceeding 450 mm - 50%
     b. with face width exceeding 450 mm - 45%

- **Rebound:** Rebound is aggregate and cement paste that bounce off the surface during the application of shotcrete due to collision with the hard surface, reinforcement, or with the aggregate particles themselves.

  - The amount of rebound varies with the position of the work angle of the nozzle, air pressure, cement content, water content, size and grading of aggregate, amount of reinforcement and thickness of layer. Depending on the position of the work, the variation in the amount of rebound may be as below:

Surface	*Percentage of Rebound*
Floor or slabs	5-15
Sloping and vertical walls	15-30
Overhead work	25-50

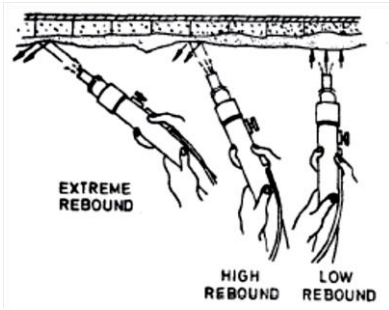


Fig (a) - Effects of the angle at which the shotcrete hits the wall on the percentage of rebound

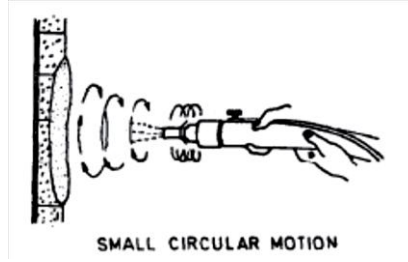


Fig (b) A small circular motion with the gun held in such a way as to provide 90^0 impact provides minimum rebound

Initially the percentage of rebound is large, but it becomes less after a plastic cushion has been built up. Rebound is much leaner and coarser than the original mix. The cement content of the in-place shotcrete is, therefore, higher because of rebound; this increases the strength but also the tendency towards shrinkage cracking.

Rebound shall not be worked back into the construction. If it does not fall clear of the work, it shall be removed. Rebound shall not be salvaged and included in later batches because of the danger of contamination; also it

may affect the cement content, state of hydration, and the grading of the aggregate.

- **Construction joints** – Construction joints shall generally be tapered to a thin edge over a width of 300 mm. However, in case of joints, which in the opinion of the Engineer-in-Charge are likely to be subjected to compressive stresses, square joints shall be provided by temporarily fixing the batten formwork of required thickness (usually a 25 mm thick board). In case of square joints, steps shall be taken by the Contractor to avoid or remove trapped rebound in the joint. The entire joint shall be thoroughly cleaned and the approved bonding coat applied prior to the application of additional shotcrete.

- **Preparation for succeeding layers** – When a layer of shotcrete is to be covered by a succeeding layer, it shall first be allowed to take its initial set. Then all laitance, loose materials and rebound shall be removed by brooming. Any laitance that has attained final set shall be removed by sand blasting and the surface cleaned with an air jet.

  In addition the surface shall be thoroughly sounded with a hammer for drummy areas, sags or any other defects, which shall be carefully cut out and replaced with succeeding layer as instructed by Engineer-in-Charge. Succeeding layers shall be shot within 4 to 8 hours to attain the required thickness. In case application of succeeding layer is delayed beyond 24 hours, then the bond coat shall be applied at the interface.

- **Suspension of work:** The application of shotcrete shall be suspended in condition of likely exposure to high winds, freezing or rain.
  - At the end of each day of work, or on stopping work for any other reason, the shotcrete shall be sloped off to a thin edge and then the work shall be resumed on next day after cleaning the surface of joint and applying a bond coat of approved formulation.

- **Finishing:** The natural gun finish is normally preferred from both the structural and durability considerations. There is danger that further

finishing may disturb the section, harming the bond between the shotcrete and reinforcement, and between the shotcrete and the underlaying material, and creating cracks in the shotcrete. Additional finishing may also be difficult to accomplish, especially for the drier mixes.

- 6 mm thick finishing coat with cement sand plaster 1:3 (1cement:3fine sand) (of least possible thickness) if felt necessary, shall be applied within 48 hours of application of shotcreted repair.

- **Inspection:** The shotcreting operation shall be continuously inspected by a qualified supervisor who shall check materials, forms, reinforcement, ground wires, delivery equipment, application of material, curing, and protection against high or low temperature. Each layer of shotcrete shall be systematically sounded with a hammer to check for drummy areas.

  - Cores shall be taken from the structural shotcrcte and shall be visually inspected by Engineer-in-Charge for evidence of poor workmanship. Cores shall be tested in tension to evaluate the quality of bond between new concrete/shotcrete/mortar and the parent concrete. If the failure is in the parent concrete the bond of new repair material shall be deemed to be satisfactory.
  - Such cores shall be taken as early in the job as practicable so that the data obtained can be used to effect improvements in later work.

- **Permissible tolerance:** The permissible tolerance on the thickness of the work executed by shotcrete shall be -3mm to +8mm.

- **Quality control:** Small un-reinforced test panels, at least 30 cm square and 75 mm thick shall be periodically gunned, and cores shall be extracted and compressive tests shall be performed periodically in the same manner as at step-4 above. The frequency of samples shall be one sample for every 10 cum of gunite/shotcrete.

  - In addition, concrete cubes prepared by directly gunning into 15 cm cube mould, shall also be used for day-to-day quality control tests. One sample comprising of three test specimens for testing at 28 days, shall be taken for every 5.0 cubic metre of concrete. Additional cubes if instructed by

Engineer-in-Charge shall also be taken for each sample to determine the strength of gunite/ shotcrete at seven days.

- All the specimen shall be tested as described in IS 516-1959 (Reaffirmed 2004).
- The gunite shall be deemed to comply with the strength requirements if the test results satisfies the acceptance criteria as per IS : 456-2000.

Step – 10: Curing – Good curing is particularly important for the very thin sections, rough surfaces, and mixes of low workability normally associated with shotcrete. It is generally recommended that surfaces be kept continuously wet for at least 7 days (IS : 456-2000).

Step – 11: After RCC columns/beams are cured and completely dried, a protective coating shall be applied over it for protecting the reinforcement and concrete.

10.0 सुरंग शॉटक्रीटिंग कार्य के लिए अल्कली-फ्री एक्सिलेटर / Alkali-free Accelerator for Tunnel Shotcreting Work

10.1 General

- Accelerators may be used to achieve a fast set and to get sufficient early strength development. The proposal along with references from suppliers shall be obtained and submitted to the Engineer for Notice of No Objection.
- Accelerating admixtures shall be compatible with the cement used. The compatibility shall be tested in the laboratory by the Manufacturer and verified by the Contractor in field suitability tests to achieve the required properties for early and final strength as proposed by the Contractor.
- Only alkali-free accelerators shall be used. The alkali content shall be less than 1% mass.
- The dosage rate determined by the field suitability tests shall not exceed 2% of the cement content of the mix design by weight. The dosage of accelerator shall be kept to the minimum required for spraying in-situ.
- Automatic devices shall be used to add the accelerator.

10.2 Accelerators for wet shotcreting

Shotcrete accelerators work on the C3A (tricalcium aluminate) content of the cement, influencing the rate of hydration, resulting in heat evolution and early age formation of calcium silicate hydrate (C-S-H) gel. Alkali-free accelerators are used in tunnel shotcreting and provide major advantages in the field of industrial health and safety. There are two main types of accelerators used in wet mix.

Sodium silicate-based accelerator	Non- Sodium silicate based accelerator
• They increase cohesion within the mixture through gelling of water and decrease the set time of cement. • They have high alkali content and can be quite caustic, as the pH is above 11. • They make the mixture stiffened rapidly and can significantly decrease the final or 28-day strength of the mix i.e. up to a 50% reduction. Even a dosage of 5% by weight of cement has been known to decrease ultimate strength by as much as 25%. • They can decrease waterproofing characteristics due to leaching of lime when the concrete is subjected to continuous moisture. Potentially negative effect is that these accelerators increase the risk of alkali-silica reaction (ASR) and leaching of water-soluble portions. • They are relatively low in cost, so they are popular in instances where shotcrete is needed to attain a quick stiffening and then gain some early strength rather quickly. • They are not recommended for permanently exposed shotcrete.	• They are based on a combination of sulphates and oxides of aluminium compounds with some special additives to boost their effectiveness. • They are a little more sensitive than sodium silicates to several environmental and material conditions and do not have quite as severe a detrimental effect on 28 - day strength when used at normal dosages. • They promote massive crystallisa-tion of ettringite prisms which are responsible for rapid setting. • Most modern-day specifications where accelerators are required insist on alkali-free accelerators. They do not have any effect on ASR. Although many alkali-free accelerators range from pH 2 to 3, which is fairly acidic. • They set the concrete very quickly and allow the material to build to higher thickness. By adding shotcrete accelerator at the nozzle the shotcrete sets immediately following the impact.

11.0 गुणवत्ता आश्वासन के पहलू/ Quality Assurance Aspects

11.1 Preproduction Phase

- Quality Assurance (QA) activities on a shotcrete project should be directed to obtaining compliance with the contract requirements. (Quality of materials used in production of shotcrete and of in-place shotcrete)
- Prior to start of production of shotcrete for any permanent work, the required material, equipment, and procedural submittals should be reviewed by the competent authority to verify compliance with the contract requirements.
- Test panels shot to verify the proposed mixture performance should be visually examined by QA personnel to confirm uniformity of the shotcrete. Specimens should be taken from the test panels to verify that the specified strength is being attained.
- Test panels shot to evaluate a nozzleman's qualifications should be thoroughly examined by a QA representative experienced in shotcrete work.
- The quality of dry-mix shotcrete is particularly dependent on the skill of the nozzleman, because his ability to control the amount of water being added to the mixture and to shoot test panels to quality is essential.

11.2 Production Phase

An ongoing program of QA inspections and testing will be required to verify continued conformance with the contract requirements. Consistent materials, mixture proportions, and production methods are necessary for uniform in-place shotcrete.

- Manufacturer's certified test results for the cementitious materials, admixtures, curing materials, reinforcement, and fibers should be reviewed to verify continued conformance with the contract requirements.

- Data from test reports must be reviewed to determine contract compliance and, more importantly, product performance.
- Depending on the size and criticality of the project, QA testing of materials and shotcrete may be required to verify compliance with contract requirements.
- The quality of the shotcrete should be thoroughly evaluated by visual inspection. Surfaces should be inspected for uniformity, voids at thesurfaces, varying finish conditions, dry conditions, seepage of water, cracking, and damaged sections.

12.0 ऑपरेटर की कुशलता/ Skill of Operator

- The quality of shotcrete depends to a great extent on the skill of the operator in much the same way as the quality of a weld depends on the welder. The foreman, nozzleman, and delivery equipment operator shall be experienced in similar capacities for a sufficient period to be fully qualified to perform his duties.
- A method used for checking the qualifications of a nozzleman is to gun test panels 60 cm or 90 cm square, and 50 mm or more thick, using typical reinforcement for the job.
- Compressive strength tests are made on cubes of various sizes sawed from these panels. When the test panel is cored, cut up, or broken open, it will indicate not only the strength, but also of suitability of the mix, the electiveness of the reinforcement, and the skill of the nozzleman.

13.0 शॉट क्रीट के लिए स्पेसिफिकेशन्स/ Specifications for Shotcrete

1. **Cleaning concrete / masonry / rock surface** for guniting / shotcreting by sand blasting method as per specifications including cleaning by air and water jets after sand blasting cost of all materials, labour, machinery, scaffolding etc., complete with initial lead for sand upto 1 km and all lifts. (Unit – Sqm) (Ref.: Schedule of Rates 2011-12, Water Resources Department, Govt. of Karnataka, www.kbjnl.com)

2. **Providing 40 mm thick shotcreting in layers** to concrete / masonry surface in cement concrete 1 : 2 : 2 proportion by weight using 6 mm down size hard graded crushed aggregate including cost of all materials, machinery, labour, cleaning joints / surface, scaffolding wherever required and all other ancillary operations etc., complete with initial lead upto 1 km and all lifts.

   (Unit – Sqm)

   (Ref.: Schedule of Rates 2011-12, Water Resources Department, Govt. of Karnataka, www.kbjnl.com)

3. **Shotcreting R.C.C. columns, beams and slabs etc.** in layers with approved design mix concrete having the specified minimum characteristic compressive strength [with ordinary portland cement, coarse sand and graded stone aggregate of 10 mm maximum size in proportion as per design criteria] including the cost of centering and shuttering at edges and corners etc. as directed by Engineer-in-Charge. The rates shall include the providing necessary ground wires etc. The levelling gauges, if used, shall be paid separately. (Unit – Sqm)

   (Ref.: Para 8.5.2 of CPWD's Handbook on Repairs and Rehabilitation of RCC Buildings)

4. **Wet curing** of shotcreted or plastered surface or RCC work as per specifications by keeping it continuously wet for a minimum period of seven days with regular sprinkling of water by keeping the surface continuously wet. (Unit – **S**qm per layer)

   (Ref.: Para 8.6.1 of CPWD's Handbook on Repairs and Rehabilitation of RCC Buildings)

5. **Shotcreting using synthetic polyester fibre** in tunnel to a thickness of 50 mm in one layer with contractor's shotcreting machine in cement concrete of M25 grade including through cleaning of rock surface with water under pressure. The rate includes contractor's materials including synthetic polyester fibre, compressor, cement concrete mixer, scaffolding with all lead & lift/descent etc. complete and as directed by Engineer-in-Charge.

   (Unit – Sqm)

   (Ref.: Tender Document vide Tender Notice No. KR/1/58/06/13, dtd. 11/03/2013 of Konkan Railway Corporation Limited (A Govt. Of India Undertaking), www.konkanrailway.com)

***

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टिप्पणी / NOTES

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गुणवत्ता नीति

रेलों में यात्री और माल यातायात की बढ़ती माँग को पूरा करने के लिए गुणवत्ता प्रबंध प्रणाली में अनुसंधान, डिज़ाइनों और मानकों में उत्कृष्टता तथा सतत सुधारों के माध्यम से सांविधिक और नियामक अपेक्षाओं को पूरा करते हुए सुरक्षित, आधुनिक और किफ़ायती रेल प्रौद्योगिकी का विकास करना।

QUALITY POLICY

To develop safe, modern and cost effective Railway technology complying with Statutory and Regulatory requirements, through excellence in Research, Designs & Standards and Continual improvements in Quality Management System to cater to growing demand of passenger and freight traffic on the Railways.

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हमारा उद्देश्य

अनुरक्षण प्रौद्योगिकी और कार्यप्रणाली को उन्नयन करना तथा उत्पादकता और रेल्वे की परिसंपत्ति एवं जनशक्ति के निष्पादन में सुधार करना जिससे अन्तर्विषयों में विश्वसनीयता, उपयोगिता और दक्षता प्राप्त की जा सके।

यदि आप इस संदर्भ में कोई विचार और सुझाव देना चाहते हों तो कृपया हमें इस पते पर लिखें।

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OUR OBJECTIVE

To upgrade Maintenance Technologies and Methodologies and achieve improvement in Productivity and Performance of all Railway assets and manpower which inter-alia would cover Reliability, Availability and Utilisation.

If you have any suggestion & any specific comments, please write to us:

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