International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 7 ǁ July. 2013 ǁ PP.64-69

Vacuum Technology for Restoration of Concrete Structure

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ABSTRACT: *This paper deals with the causes, problems and vacuum applied solutions to various concrete deterioration problems. Many companies have performed, and are presently performing, restoration of concrete structures. The methods presented here are unique method and technologies. They have applied on an array of members and structures to restore many different types of deteriorated and disrepair conditions. After explaining the basic techniques and the materials used in these various methods and processes, several applications are described to demonstrate individual successes. Cores taken after many of the in-situ restored projects demonstrate the strength increase and therefore, should provide longer life of the structure after the rehabilitation is completed in a wide and extensive range of conditions.*

KEYWORDS: *Vacuum, Core, Injection grouting,*

I. INTRODUCTION

Most, of all, common defects in concrete, masonry and stone begin with and are ultimately associated with cracking. While some cracking may not threaten the structural integrity or even diminish the structural performance of the member or structure, they allow moisture penetration that will contribute greatly to the related problems of delamination and spalling.By closely situating the repair resin into the micro fractures, the useful life of the repair will be greatly extended. Commonly used methods of repair include routing and sealing with sealant, pressure injection of epoxy or polymer fillers, application of surface coatings or overlays and/or removal and replacement patching. It is very difficult to employ these conventional techniques to repair members with irregular surfaces. A vacuum is defined as a diluted gas, or the corresponding state at which its pressure or density is lower than that of the ambient surrounding atmosphere. Unlike conventional pressure methods, which "push" the materials along the repair zone, negative force methods "pull" the material into the zone. The application of negative pressure will withdraw air and moisture from the repair zone prior to the installation of appropriately selected repair resins. Using this technology, there is no compression of the liquid repair resin. Consequently, the inherent tendency to "burst" the damaged or deteriorated member, so characteristic of conventional pressure methods, is totally eliminated using vacuum technology.

II. OUTLINE OF WORK

To carried out the experimental approach on concrete element, for checking the strength behaviour with and without injection grouting and to provide an alternate approach to the more permanent repairs of concrete, masonry and stone using vacuum technology to position ultra-low viscosity resins into voids, cracks and interconnecting crack networks.

III. METHODOLOGY

For testing the specimen following methodology has been adopted.

[1] Casting of 3 slabs of M15 grade with ID mark A, B, C of
[2] size 600mm x 600mm x 200mm in a box formwork of
[3] plywood 12 mm thick without compaction.
[4] All the three slabs A, B, C of M15 grade have different
[5] cement content.
[6] After de-shuttering the box, cure the concrete specimen for
[7] 28 days.
[8] After 28 days of curing, initially ultra sonic pulse velocity
[9] test was conducted for all the marked slabs.
[10] After Ultra Sonic Pulse Velocity (USPV), injection
[11] grouting is done for slab B and slab C.
[12] After injection grouting of slabs B and C, again UPV is
[13] done for slab B and slab C for comparing the result with
[14] injection grouting and without injection grouting.

[15] Then take the Core test for all three slabs A, B, C.
[16] Conduct the Rapid Chloride Penetration Test (RCPT) and
[17] Water penetration test for all three slabs A, B, C.
[18] Compare the results of three slabs A, B, C.

IV. DATA ANALYSIS

Following are the test conducted on slabs A, B, C during testing purpose to get the result.

1.) Cube Test
2.) Ultrasonic Pulse Velocity (USPV)
3.) Core test
4.) Rapid Chloride Permeability Test (RCPT)
5.) Water Penetration Test.

2.1.Cube Test

Concrete cube testing is a simple, cost effective test of the compressive strength of concrete, providing you peace of mind that your concrete is fit for purpose. Samples are taken from the concrete while being poured then cast and cured under IS standard conditions. They are then water cured for a specified period of 28 days then crushed to determine the maximum compressive strength.

The following table show the result of M15 concrete for 7 and 28 days.

7 DAYS CUBE TEST OF 150X150X150 MM

Sr No	Weight (Gms)	Load (KN)	Compressive Strength MPa (N/mm^2)	Avg. Compressive Strength MPa (N/mm^2)
1	8296	643.2	28.59	28.271
2	8319	629.7	27.98	
3	8308	635.6	28.25	

28 DAYS CUBE TEST OF 150X150X150 MM

Sr No	Weight (Gms)	Load (KN)	Compressive Strength MPa(N/mm^2)	Avg. Compressive Strength MPa (N/mm^2)
1	8381	879.7	39.09	38.383
2	8222	895.8	39.81	
3	8206	815.6	36.25	

2.2.Injection Grouting: Epoxy Injection Grout consists of a base component containing solvent free epoxy resin plus a low viscosity liquid hardener. Epoxy Injection Grout may be placed by free flow under gravity or may be injected using a suitable hand or mechanical pump. Grouting of gap dimensions0.1mm to 10mm may be easily achieved. The system gives rapid strength gain obtaining mechanical properties several times those of high quality concrete.

Fig . 1 Injection grouting in a slab

2.3.Ultra Sonic Pulse velocity test

This test is done to assess the quality of concrete by ultrasonic pulse velocity method as per IS: 13311 (Part 1) – 1992. The underlying principle of this test is –The method consists of measuring the time of travel of an ultrasonic pulse passing through the concrete being tested. Comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity etc

Pulse Velocity (km/second)	Concrete Quality (Grading)
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.0	Doubtful

Fig.2. Conducting UPV on slab

V. CORE TEST.

This is one of the very reliable tests adopted for checking the compressive strength of the 'In situ concrete". Other physical properties such as density, water absorption can also be measured from the core concrete. In addition chemical properties of concrete specimen for its cement content, carbonation depth, chloride and sulphate content may be measured. Though this test may become partially destructive for beams / columns, but it can be used for slabs, walls, where partial destruction of concrete due to core cutting do not disturb the stability of the member. In this method concrete cores of sizes ranging from 20 mm to 150 mm in diameter and 50 mm to 500 mm long are drilled out by a diamond cutters. The recommended diameters are 100 to 150 mm, but if the drill depth is insufficient as in of case slabs, then smaller diameters may be used but not less than three times nominal aggregate size. The core diameter to length ratio shall be normally between 1.0 to 2.0(preferably 2.0) the core diameter shall be at least three times the nominal maximum size of aggregate. Reinforcement shall be avoided in the core. At least three cores shall be tested for acceptable accuracy. These cylindrical concrete cores are then made smooth at both ends (if required) and then tested for compressive strength. If required capping of the faces shall be done. The strength of capping material shall be higher than that of concrete in the core. Cap shall be as thin as practicable. The specimen shall be cured in water for 48 hours before testing. The cylindrical strength is then co-related to cube strength. IS – 516 suggest a multiplying factor of 1.25 for converting cylindrical strength to equivalent cube strength. In addition a correction factor for height to diameter ratio shall be applied as given in IS – 516. IS – 456 states that the concrete in the member represented by a core test shall be considered acceptable, if the average equivalent cube strength of core is equal to at least 85 % of the cube strength of the grade of concrete specified, but no individual core has a strength less than 75 %

5.1.RCPT (Rapid Chloride Permeability Test) : The Evaluation of permeability of concrete to chloride ions is an essential step for concrete in marine atmosphere, as this parameter indicate the quality f concrete in terms "durability" briefly the ingress and built of chloride in the vicinity of the reinforcing bar in concrete initiate and accelerate the corrosion process. Hence concrete with low chloride ions permeability is specified for concrete in a structure wherever chloride is present in environment..The RCP Test essentially consists in subjecting a concrete specimen, in the form of "Disc" (95mm diam and 51mm thick) to a direct current (DC) of 60 volts across its two faces. The specimen is placed in between two chambers one with Sodium Hydroxide (0.3N) and the other with sodium chloride (3%) solutions. The current passing through the specimen, the specimen is monitored regularly over six hours. The total charge that has passed through the specimen is

calculated an is the value of product of time in seconds and current in amperes and the unit is "Coulomb".Quality of concrete samples can be evaluated easily by Rapid Chloride Permeability Test (RCPT). The test involves application of an electrical field across specimen and the measurement of parameters considered to be related to the diffusion coefficient of ions. ASTM (Electrical indication of Concrete's ability to Resist Chloride ion Penetration) and AASHTOT277 has such tests widely adopted. It has been found that there is a good correlation between coulombs thus obtained, the averages of the chloride concentration, when tested accordingly to AASHTO designation. T-277 (Resistance of concrete to chloride ion penetration). Thus AASHTO, T-277 (ASTM-C-1202) classifies the chloride permeability of concrete in five classes from "High "to "Negligible" on the basis of the value of the coulomb.

Table 2. Limiting value for RCPT

Charge Passed (Coulombs)	Chloride Ion Penetration
>4000	High
2000 - 40000	Moderate
1000-20000	Low
100-1000	Very Low
<100	Negligible

5.2.Water Permeability Test : The durability of concrete is closely related to its permeability. The permeability indicate the rate at which aggressive agent can penetrate to attack the concrete and the steel reinforcement. Permeability of concrete field of study, since concrete is heterogeneous blends of materials. Furthermore the concrete properties change with the age. Permeability is the ability to transport different fluids and gases, likes water, chlorides sulphates or oxygen. There is a good relationship between permeability and water cement ratio.
A concrete structure is considered to be of adequate durability if it performs in accordance with its intended level of functionality and serviceability over an expected or predicted life cycle. Durable concrete must have the ability to withstand the potentially deteriorative conditions to which it can reasonably be expected to be exposed.

The water permeability limit should be less than equal to 25mm.

Fig. 3. Water Permeability apparatus

Table 3. Limiting value for water permeability

Water Permeability			
ID Marks	Wt. of cube in Kg	Water penetration Depth in mm (average of three reading)	MORT and H Limit
Sample A	5.744	38	25mm
Sample B	5.952	22	25mm
Sample C	5.890	18	25mm

VI. RESULTS AND DISCUSSION

6.1. For Cube test – Sample achieved more than 100% strength in 28 days

6.2.UPV test - Before injection grouting.

SAMPLE	RANGES
SLAB B	3.436
SLAB C	3.497

After injection grouting.

SAMPLE	RANGES
SLAB B	3.689
SLAB C	3.683

6.3.Core test

SAMPLE	Core Strength(N/mm^2)
SLAB A	31.490
SLAB B	31.988
SLAB C	32.010

6.4.RCPT

SAMPLE	RCPT value (Coulomb)
SLAB A1	1356
SLAB B1	995

6.5.Water Permeability test:

SAMPLE	Water Penetration (mm)
SLAB A	38
SLAB B	22
SLAB C	18

VII. CONCLUSIONS

After conducting all the relevant tests on concrete specimen by visiting the construction sites it was found that the Vacuum technique by injection grouting method is useful for strengthening of concrete, because this method is most commonly used for preparing work. As per its working speed, it is most suitable for all structural elements with faster result and consumes less time for excavation. It also give equivalent strength to the structure as compared to the conventional method and enhances durability So without breaking the structural elements or patching, the vacuum technique by injection grouting helps in filling the voids, cracks (micro, hair, major) and makes them strong and durable. It is cost effective and convenient method of repairing and restoration, which requires less but skilled personnel for operation.

VIII. ACKNOWLEDGMENT

Data collection and analysis of all testing results is done at Contech lab (CCRL) ltd in airoli. For injection grouting also chemicals are given by Krishna conchem. I am very fortunate to work under the guidance of Mr. Vikram tambvekar and Mr. M.K. kamat and Mr. Milind Kamat. I am also thankful for Mr. Narendra Potnis for allowing me for numerous site visits and give me more practical knowledge regarding grouting work. Last but not least I would also like to thank my guide Dr. Abhaykumar S Wayal, who guided me throughout the entire period of my project work.

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