Repair And Retrofit of Unreinforced Masonry By Injection Grouting

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Abstract- *An experimental program investigating the effect of grout injection as a part of repair method of cracks in unreinforced masonry is investigated in this project. Several different formulations of cementitious grouts were found to be useful for injection into cracks in damaged old masonry to restore structural capacity and is also used to fill existing voids to strengthen deficient masonry. A procedure for injection of grouting of masonry is described, including specific descriptions of wall preparation, injection port location, grout mixing, and the injection process. Non-destructive testing is carried out to find the effectiveness of grout penetration and the test results of repaired masonry are compared with that of damaged masonry.*

Keywords- Cracks, Grout, Injection, Repair, Superplasticizers.

I. INTRODUCTION

Grout injection has gained popularity in recent years as an effective method for repairing or strengthening masonry walls. This researched technique involves low-pressure injection of fine cement-based grout into cracks, voids, collar joints, or cavities within masonry.Renovation, retrofit, and refurbishment of surviving buildings provides an opportunity to upgrade the energy performance of commercial building to improve their ongoing life.

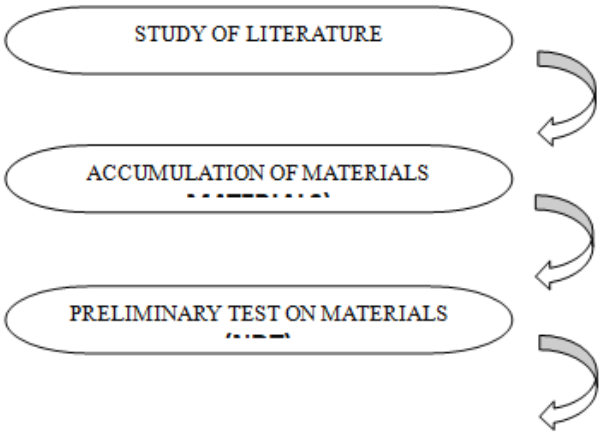
Existing masonry buildings often contain voids, cracks and weakness which can affect the structural capacity and safety of the building. Cracks in buildings can occur due to various reasons. Cracks maybe due to chemical reactions, changes in temperature and climate, foundation movements and settling of buildings, environmental stresses, earthquakes etc. Left unchecked, cracks can sometimes threaten a building's structural integrity, as well as allow moisture to penetrate into a wall system; so, it is usually beneficial to repair them. Injection of grout into cracks maybe used as a form of repair following a damaging event to restore the masonry to its original structural condition.

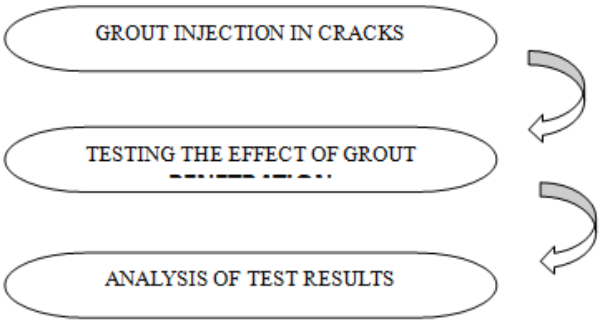
Injection grouting is a viable means to provide functional, durable and safe structures without physically altering the external aesthetics. The purpose of using a cementitious grout is that, Cementitious grouts can have properties similar to masonry in which the repair work is to be carried out and, when injected into cracks and voids, this cementitious grout provides a simple means for restoring or improving structural integrity without altering significantly the homogeneity of the base material.

II. OBJECTIVE

- To perform initial survey and to study the causes of cracks.
- To Carry out a nondestructive evaluation to monitor the strength of the damaged masonry using stress wave transmission method.
- To verify any insufficient grout penetration after injecting grout in cracks and a nondestructive test is carried to monitor the strength of the repaired masonry.
- To Compare the strength of the repaired masonry with that of the damaged masonry to indicate the effect of injection grouting as a repair technique.

III. METHODOLOGY





IV. INJECTION GROUTING

4.1 GENERAL

Many different schemes have been used for repairing or strengthening existing masonry buildings. Reinforced shotcrete or ferrocement overlays are useful for strengthening or consolidation purposes but by nature this treatment covers the masonry exterior, concealing the historical appearance of the structure. Certain situations may warrant more expensive treatments such as placement of steel reinforcement grouted into cores drilled in the plane of the wall. This technique is useful for some cases but tends to create zones with widely varying stiffness and strength properties. Cementitious grouts can have properties similar to masonry and, when injected into cracks and voids, provides a simple means for restoring or improving structural integrity without altering significantly the homogeneity of the base material. Cementitious-based grout is injected into larger cracks and empty collar joints in multi-wythe masonry to increase composite behavior and strengthen the wall against seismic excitations. This method has been approved for use by the City of Los Angeles. It is possible to fill narrow cracks provided a suitable grout is formulated.

4.2 INJECTION GROUTING PROCEDURES

The steps are outlined below and should provide a good basis for injection repair; however, it must be stressed that it will be necessary to adapt these procedures to varying situations. Guidelines summarized below are based in part upon recommendations provided by the City of Los Angeles.

4.2.1 INITIAL SURVEY AND REPAIR

Before proceeding with any repair or retrofit program, conduct a thorough assessment of material condition throughout the area to be repaired. This survey will not only identify potential areas for treatment, but will also serve as a basis for post-repair quality verification. The initial survey would include mapping the extent and size of any visible cracks, mortar joint delamination, or other damage. Units which exhibit extensive cracking, spalling, or crushing should be replaced. Mortar joints must be tight and capable of resisting injection pressure and, if necessary, deficient mortar should be raked and the joint repointed. Use units and mortar having a composition and strength similar to existing materials for repairing damaged areas.

4.2.1.1PRELIMINARY INSPECTION

1. LOCATION
   Krishnagiri District
2. PERIOD OF CONSTRUCTION = 1994
3. USE OF BUILDING =
   Residential Purpose
4. CHANGE IN BUILDING USE = None
5. STRUCTURAL CHANGES MADE IN THE PAST = None
6. YEAR OF FIRST DISTRESS NOTICED =
   2005
7. TYPE OF CEMENT USED =
   Ordinary Portland cement
8. TYPE OF STEEL REINFORCEMNT = Mild steel
9. SOURCE OF WATER USED FOR CONSTRUCTION = Local Bore Water

4.2.1.2 CLASSIFICATION OF CRACK

For determining a treatment procedure for the cracks, cracks have to be classified depending on its cause and nature.

CRACK-I

Fig 7.1 Crack I

- Class – class 2.

- Repair classification – patch repair.
- General observations –cracks observed till floor level.
- Repair requirements – crack sealing.
- Crack nature – major crack.
- Size of crack – wider than 5mm.

CRACK-II

Fig 7.2 Crack II

- Class – class 2.
- Repair classification – patch repair.
- General observations –vertical cracks observed on compound wall.
- Repair requirements – crack sealing.
- Crack nature – major crack.
- Size of crack – wider than 5mm

CRACK-III

Fig 7.3 Crack III

- Class – class 1
- Repair classification –superficial.
- General observations –horizontal cracks observed on masonry wall.
- Repair requirements – slight sealing on surface.
- Crack nature – minor crack.
- Size of crack – less than 5mm.

CRACK-IV

Fig 7.4 Crack IV

- Class – class 2
- Repair classification –patch repair.
- General observations –diagonal cracks observed on masonry wall.
- Repair requirements – sealing of cracks required
- Crack nature – major crack.
- Size of crack – wider than 5mm.

4.2.2 Non-Destructive Evaluation

This step is an important part of the repair procedure, since the subsurface cracks, voids and grout penetration can be determined by performing a non-destructive test. Any method working based on pulse wave transmission can be used (ultrasonic pulse velocity).

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.

Using ultra sonic pulse velocity machine

- Basic measurements t (μs)
- Pulse velocity V (m/s)
- Crack depth (m)

were calculated.

4.2.2.1 BASIC MEASUREMENTS

Grease was applied to two faces of the transducers and were placed on opposite sides of the calibration rod. The

transit time was calculated as 25.4μs same as the calibration number on the calibration rod.

4.2.2.2 PULSE VELOCITY

In order to determine the pulse velocity, it is compulsory to measure the path length between the two transducers. Press the transducers hardly onto the concrete opposite surfaces, and hold for a while to allow readings to be taken, wait until a consistent reading appears on the display screen of the instrument. Record the stable reading, which is the time (T) in microseconds (μs) for the ultrasonic pulse to travel the path length and pulse velocity (V) in m/s.

To determine the pulse velocity direct method was used, the pulse velocity (V) is given by: V = L/T

Path length between two transducers were measured to be 0.300m.

Transit time (T) = 107.0 μs
Pulse velocity (V) = 2803 m/s or 2.8 km/s

4.2.2.3 CRACK DEPTH

To determine the crack depth indirect method was used.
Input was given for the parameters

b = 0.150m,
2b = 0.300m

Now transit time t1, t2 and crack depth were measured to be
t1 = 28.7 μs,
t2 = 73.1 μs
Crack depth = 0.056m.

4.2.3 CLEANING AND SATURATION

The surface was flushed with water to remove the dirt present, the surface was saturated 24 hours prior to the injection and 30 minutes before injection of grouts which avoids the problem of grout stiffening.

4.2.4 CRACK INJECTION PORTS

Injection holes measuring 6 to 12 mm diameter are drilled for cracks less than 1mm wide and the ports are placed in the drilled holes. The placement of these ports is dependent upon the width and the roughness of the cracks. Using the sealant used for sealing the surface cracks the ports can also be sealed.

4.2.5 CRACK SEALING

In order to avoid grout leakage during the injection procedure the surface breaking cracks are sealed. The sealant used to seal the cracks must be able to withstand the injection pressure and also aid in rapid setting on the surface of the cracks. These sealants are removed after the injection procedure to make sure that the appearance does not get altered. Care must be taken to prevent the sealant from penetrating deep into the cracks.

4.2.6 GROUT MIX

An initial mixing time of 3 minutes is found to be sufficient. Remix periodically at approximately 5-minute intervals to keep all mix partic1es in suspension. It was found that by carefully designing a grout mix injection of cracks from 0.08 mm thickness to voids of 12 mm and larger is possible.

These grout formulations possess properties similar to the masonry being repaired, and would be economical for widespread use as a masonry repair material. Note that all mixes utilize a superplasticizer and have high water/cement ratios to provide grout which flows well into small voids and cracks. Polycarboxylate Ether Superplasticizer was used in this grout mix.

4.2.7 GROUT INJECTION

For injecting these cementitious grouts, a low-pressure injection is used. The grout is injected from lower nipple to upper till it comes out to the next higher nipple and then move to next higher nipple. This procedure is followed to fill the entire cracks. The injection pressure is always kept as low as possible to avoid any additional damages due to pressure during injection. The injecting process must be continuous without any time lapse during the injection of grout.

4.2.8 SURFACE CLEANING

Surface cleaning is carried out immediately after the injection to remove any spilled grout during the injection. A stiff brush or water is used to remove the extras on the surface.

4.2.9 REPAIR OF INJECTION HOLES

After cleaning the surface, the grout is allowed to cure for 24 hours. After the curing period the sealants can be removed using a hard brush or water and the ports are now removed and a suitable mortar similar to the masonry is

prepared and is packed firmly into the injection holes, prior to the placement of the mortar the holes must be saturated.

4.2.10 POST REPAIR TEST

The post repair test is the final step in this procedure and is carried out to find the effect of the grout penetration. Nondestructive test is carried to find the improvement in strength of the mortar and any insufficient penetration of the grout. In case of insufficient penetration additional injection is required.

Test were performed after a period of 9 days after removal of the sealants.

To determine the pulse velocity direct method was used.

- Path length between two transducers were measured to be 0.300m.

The transducers were placed on opposite faces of the surface and held for some time.

Readings were noted once a consistent reading appeared on the instrument.

- Transit time (T) = 109.0 µs
- Pulse velocity (V) = 3566 m/s or 3.5 km/s

V. RESULTS AND DISCUSSION

5.1 NON-DESTRUCTIVE TEST RESULTS

The quality of concrete in terms of uniformity, incidence or absence of internal flaws, cracks and segregation, etc., indicative of the level of workmanship employed; can thus be assessed using the guidelines given in Table 1

Table 1: Criterion for concrete quality grading

S.NO	PULSE VELOCITY (km/second)	CONCRETE QUALITY (Grading)
1	Above 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0 to 3.5	Medium
4	Below 3.0	Doubtful

5.1.1 COMPARISION OF PRE-REPAIR AND POST-REPAIR TEST

By Comparing the strength of the repaired masonry with that of the damaged masonry the effect of injection grouting as a repair technique can be established. By comparing the pulse velocity reading taken before repairing the crack and after repairing the crack, the grading of concrete can be evaluated from the above given table 1.

Table 2: Comparison of test results

S.NO	TEST PERIOD	DISTANCE (m)	TIME (µs)	PULSE VELOCITY (Km/s)	CONCRETE GRADING
1	DAY 1	0.300	107.0	2.8	Doubtful
2	DAY 10	0.300	109.0	3.5	Good

5.2 COMPRESSIVE STRENGTH (N/mm2)

When the pulse velocity is known it is easy to determine the compressive strength of concrete by using the graph shown in the Figure – 8.1 below which indicates the relationship between the pulse velocity and compressive strength of concrete.

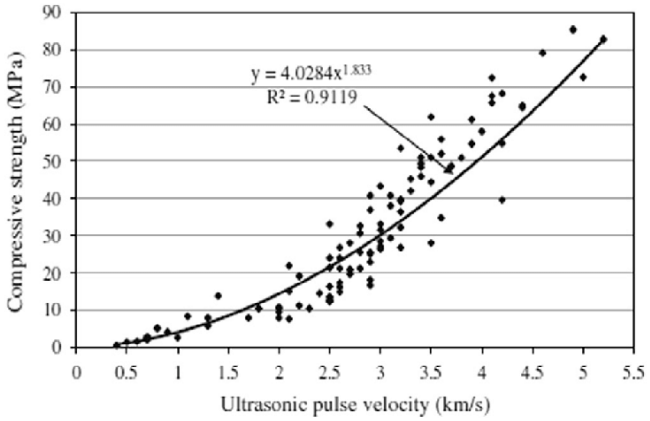


Fig 5.1 Compressive Strength V/S Pulse Velocity

Table 3: Compressive Strength of concrete

S.NO	PULSE VELOCITY (Km/s)	COMPRESSIVE STRENGTH (N/mm2)
1	2.8	26
2	3.5	40

From the above table the compressive strength of the concrete has been determined using the pulse velocity obtained. The results showed an increase in compressive strength by 53%.

VI. CONCLUSION

Injection of cement-based grout was an effective technique for repairing cracks, by using this method the quality of concrete and the compressive strength was restored up to 53% of the original strength. Based on the assessment the injection grouting had some economical features like it requires Minimal costs as such products are readily available and can be easily applied. This method required Minimal amount of material and very 'light' application made this method sustainable.This method had some advantages like No added mass, Available materials, Low disturbance, Low cost, can restore initial stiffness, Improves shear and compressive behavior.

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