

Application of Chemical Cement Grouting in New & Old Construction Repair Work

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Abstract- The deterioration of concrete and masonry structures due to cracking, void formation, shrinkage, aging, and environmental exposure poses serious concerns regarding structural safety, durability, and service life. Repair and rehabilitation techniques that restore structural integrity without demolition are therefore essential. Among various methods, cement–chemical nozzle grouting has emerged as an effective technique for crack sealing, void filling, waterproofing, and structural strengthening. The present study investigates the application and performance of cementitious and chemical grouts using the nozzle injection technique in old and new concrete as well as masonry structures. Experimental specimens consisting of concrete cubes and masonry prisms were prepared, and controlled cracks of varying widths were introduced. Cement-based grout and chemical grout (epoxy/polyurethane) were injected under regulated pressure through nozzles installed along the crack lines. The performance of grouted specimens was evaluated through compressive strength testing, water absorption measurement, and ultrasonic pulse velocity (UPV) analysis before and after grouting. The results indicated significant improvement in structural performance following grouting. Compressive strength increased considerably depending on crack width and grout type, while water absorption and permeability were substantially reduced. Chemical grouts demonstrated superior penetration and early strength gain in micro-cracks, whereas cementitious grouts proved to be economical and effective for larger cracks and voids. Comparative analysis between old and new concrete specimens revealed that older, more deteriorated specimens showed relatively higher performance enhancement after grouting due to improved internal consolidation. Masonry specimens exhibited enhanced bond strength and reduced seepage after treatment.

The study concludes that cement–chemical nozzle grouting is a reliable and practical rehabilitation technique for both structural repair and durability enhancement. The findings provide technical insights for selecting appropriate grout materials based on crack width, structural condition, and economic considerations. Further research is recommended to investigate long-term durability performance and optimization of grouting parameters for large-scale field application.

Key Words: Cement Grouting, Chemical Grouting, Nozzle Injection, Crack Repair, Concrete Rehabilitation, Masonry Structures.

1. INTRODUCTION

1.1 Cement Chemical Grouting on New and Old Masonry Structure- Cement chemical grouting is a widely used **repair, rehabilitation, and strengthening technique** in civil engineering. It involves injecting a specially prepared fluid grout—typically a mixture of cement, water, and chemical additives into cracks, pores, joints, voids, or honeycombed areas of **concrete and masonry structures**. Once the grout hardens, it forms a dense, solid mass that restores structural integrity, increases durability, and improves water tightness. This method is suitable for **both new and old structures** because it can penetrate fine cracks, fill hidden cavities, bond separated materials, and strengthen weak or deteriorated zones without major demolition. In new structures, cement chemical grouting is mainly used to treat construction defects such as shrinkage cracks, porous areas, and poorly compacted zones. In old structures, it plays a vital role in repairing structural cracks, stopping water leakage, restoring strength, and stabilizing aged or damaged masonry. Due to its versatility, low cost, and ability to access areas that are difficult to repair by other methods, cement chemical grouting has become an essential process in the maintenance of **bridges, buildings, dams,**

tunnels, retaining walls, water tanks, basements, and heritage masonry structures. The technique significantly enhances the service life and performance of concrete and masonry by improving their internal structure, reducing permeability, and preventing further deterioration.

1.2 Application of Cement Chemical Grouting on New & Old Concrete and Masonry Structures

Cement chemical grouting is a specialized technique used in construction and rehabilitation to **fill cracks, voids, joints, honeycombed areas, and porous zones** within concrete and masonry. The process involves injecting a fluid mixture of **cement, water, and suitable chemical additives** under controlled pressure. Once the grout hardens, it enhances **strength, density, water-tightness, and durability** of the structure. The method is widely used in **new construction, repair of old structures, and strengthening of masonry buildings**.

1.2.1 Applications in New Concrete Structures

1.2.1.1 Sealing of Shrinkage and Plastic Cracks-

During the early stages of construction, concrete may develop shrinkage or plastic settlement cracks. Cement chemical grouting is injected into these cracks to:

Restore monolithic action between separated parts.

Prevent future propagation of cracks.

Avoid early-age water leakage problems.

1.2.1.2 Correction of Honeycombed or Porous Concrete-

Improper compaction or segregation at site leads to localized honeycombs. Grouting helps: Fill internal voids and cavities.

Improve strength and stiffness of the affected zone.

Increase durability by closing pathways for moisture and chemicals.

1.2.1.3 Strengthening of Foundation and Substructure-

Grouting is widely used in:

- Foundations of bridges, dams, towers, and industrial structures.

- Under base slabs and raft foundations.
- Stabilizing soil and loose subgrade under pavements or floors.

Benefits include:

- Increased load-carrying capacity of the foundation.
- Reduction in differential settlement.
- Improvement in bearing resistance of soil or rock.

1.2.1.4 Bonding and Treatment of Construction Joints-

Cold joints often form when delay occurs between concrete pours. Cement grout:

- Re-establishes bond across the joint.
- Prevents seepage of water or chemicals through the joint line.
- Ensures structural continuity in retaining walls, tunnels, and water tanks.

1.2.1.5 Waterproofing in New Underground Works-

In new basements, diaphragm walls, lift pits, and tunnels, grouting is used to:

- Seal minor cracks and pores.
- Form an impermeable barrier against groundwater.
- Improve long-term performance of water-retaining structures.

1.2.2 Applications in Old Concrete Structures:

Old concrete structures suffer from cracking, deterioration, corrosion, and loss of material. Cement chemical grouting plays a major role in rehabilitation.

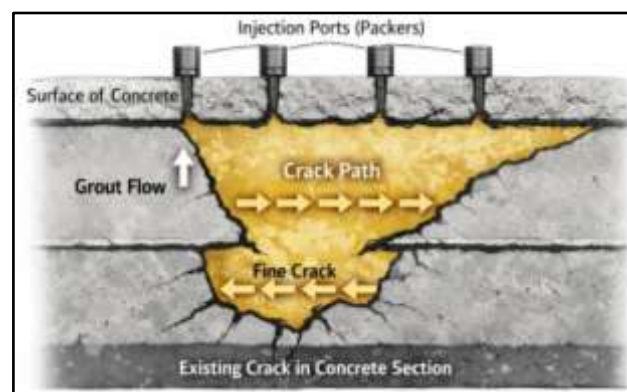


Figure 1

1.2.2.1 Repair of Structural Cracks

Structural members like beams, columns, slabs, and bridge decks are injected to:

- Restore lost load-carrying capacity.
- Improve stiffness and reduce deflection.
- Prevent ingress of water, chlorides, or sulphates that may accelerate corrosion.
- Both static (dormant) and active cracks can be treated.

1.2.2.2 Filling Voids due to Deterioration

Over time, internal voids form due to:

- Corrosion of reinforcement
- Freeze–thaw action
- Inadequate compaction in old works
- Chemical attack
- Grouting fills these voids and reinstates the structure’s original density and strength.

1.2.2.3 Restoration of Water-Tightness

Old structures often show seepage, leakage, or dampness. Common examples:

- Leaking overhead tanks
- Old tunnels and culverts
- Water reservoirs
- Concrete roofs or retaining walls
- Cement grout blocks leakage paths and forms a durable impermeable matrix.

1.2.2.4 Rehabilitation of Bridges and Dams

Large infrastructure structures experience fatigue and weathering. Grouting is applied to:

- Seal cracks in piers and abutments.

Strengthen dam foundations and spillway slabs.
Improve resistance to hydraulic pressure and uplift forces.

1.2.2.5 Strengthening of Industrial Structures

Heavy loads and vibration cause micro-cracking in factory floors, columns, and machine foundations. Cement chemical grout:

Re-bonds cracked surfaces.

Reduces vibration and improves rigidity.

Enhances service life of old industrial facilities.

Table 1: Classification of Cracks Based on Width

Sl. No.	Crack Width Range	Classification of Crack	Typical Repair Method
1	< 0.1 mm	Very Fine / Hairline Cracks	Surface sealing, coating
2	0.1 – 0.3 mm	Fine Cracks	Epoxy injection or chemical grouting

3	0.3 – 1.0 mm	Medium Cracks	Cement grout injection or epoxy grouting
4	1.0 – 5.0 mm	Wide Cracks	Cement grouting, stitching, structural repair
5	> 5.0 mm	Very Wide / Structural Cracks	Structural strengthening, rebuilding, heavy grouting

1.2.3 Applications in Masonry Structures (New and Old)

Masonry structures—especially stone and brick masonry—contain pores, gaps, and weak mortar joints. Cement chemical grouting is used for both strengthening and conservation work.

1.2.3.1 Crack Filling and Void Consolidation

Grout is injected to fill:

Cracks in walls due to settlement or earthquake.

Voids in deteriorated stone or brick units.

Delaminated layers in multi-leaf masonry walls.

This restores integrity and improves load distribution.

1.2.3.2 Strengthening of Heritage and Historical Structures

Old temples, forts, arches, domes, and heritage buildings often suffer from:

Weak, powdery mortar

Separated stone blocks

Cracks due to age

Low-viscosity cement chemical grouts:

Reconnect separated masonry.

Provide internal strength without altering appearance.

Increase resistance to wind loads, earthquakes, and vibrations.

1.2.3.3 Improving Bond in Masonry Joints

Where joints have deteriorated, grout:

Strengthens mortar bed joints.

Enhances shear capacity of walls.

Prevents bulging or buckling of masonry panels.

1.2.3.4 Waterproofing and Damp Proofing

Masonry retaining walls, wells, and basements often show capillary rise or seepage. Cement grouting:

Seals voids in mortar joints.

Reduces permeability and dampness.

Extends service life of old masonry walls.

Table 2: Common Causes of Cracks in Concrete Structures

Cause of Crack	Type of Crack	Typical Location
Plastic Shrinkage	Early-age surface cracks	Slabs, pavements, floors
Drying Shrinkage	Shrinkage cracks	Walls, slabs, beams
Thermal Effects	Temperature cracks	Mass concrete, long walls
Settlement of Foundation	Structural cracks	Foundations, columns, walls
Overloading	Structural cracks	Beams, slabs, columns
Corrosion of Reinforcement	Corrosion cracks	Beams, columns, slabs exposed to moisture
Poor Construction Practices	Random cracks	Any structural element
Alkali-Aggregate Reaction (AAR)	Map or pattern cracks	Concrete pavements, dams
Freeze-Thaw Action	Surface scaling and cracking	Cold climate structures
Creep and Long-Term Deformation	Structural cracks	Beams, slabs
Differential Movement	Separation cracks	Junctions of walls and slabs
Earthquake or Dynamic Loads	Diagonal / shear cracks	Beams, columns, shear walls

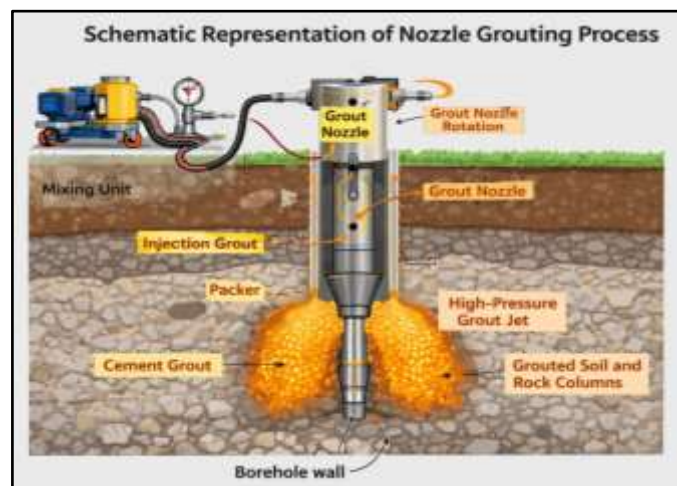


Figure 2

2.2 Review of Previous Studies

2.2.1 Cementitious Grouting: Studies show that cement-based grouts are effective for:

- Filling large cracks and voids
- Improving compressive strength
- Reducing permeability

However, their penetration is limited in fine cracks (<0.2 mm) due to higher viscosity.

2.2.2 Chemical Grouting: Chemical grouts such as epoxy and polyurethane have:

- Low viscosity
- High bonding strength
- Excellent crack penetration.

They are particularly effective for:

- Fine cracks
- Structural crack repair
- Waterproofing applications

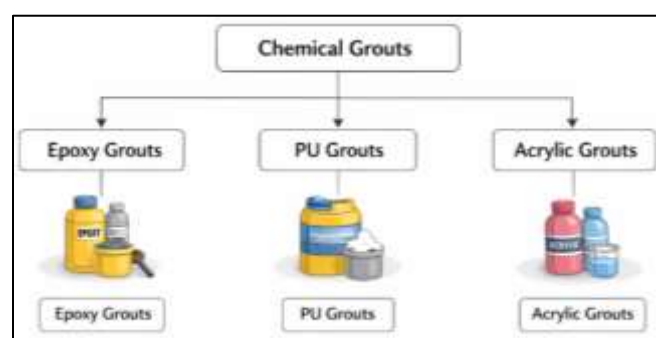


Figure 3 Classification of Chemical Grouts

2.3 Comparative Studies

Some researchers compared cement and chemical grouts and found:

- Epoxy provides higher bond strength.
- Cement grout is more economical.
- Polyurethane performs better in water-leakage conditions.

However, limited research exists on:

- Performance in old vs new concrete

2. REVIEW OF LITERATURE

2.1 Cement-Chemical Nozzle Grouting in Concrete and Masonry

Grouting is one of the most widely used techniques for repair and rehabilitation of concrete and masonry structures. It involves injecting a fluid material into cracks, voids, and pores to improve:

- Strength
- Durability
- Water tightness
- Structural integrity

Grouting materials are generally classified into:

- Cementitious grouts
- Chemical grouts (epoxy, polyurethane, acrylic, etc.)
- Several researchers have studied the performance of different grouting materials under various conditions.

- Comparison in masonry structures
- Nozzle-based injection techniques

2.4 Research Gap Identified

From the above studies, the following gaps are observed:

- Limited comparative studies on:
- Cement vs chemical grouts

Lack of data on:

- Old vs new concrete performance

Very few studies on:

- Masonry grouting using nozzle injection.

Insufficient experimental data on:

- Crack sealing efficiency
- Water absorption reduction

2.5 Need for Present Study

To address these gaps, the present research will: Compare cement and chemical grouts study performance in:

- Old concrete
- New concrete
- Masonry

Evaluate strength, permeability, and crack sealing

Use nozzle injection technique.

2.6 Conclusion of Literature Review

Previous studies confirm that:

- Grouting improves strength and durability.
- Chemical grouts perform better in fine cracks.
- Cement grouts are economical for larger defects.

However, a comprehensive experimental comparison across different structural conditions is still needed. This study aims to provide such data.

2.7 Literature Review Table (Key Research Papers)

Emmons (1994)	Cementitious grout	Concrete	Improved compressive strength and durability
Basheer et al. (1997)	Cement grout	Concrete	Reduced permeability significantly
Forth & Brooks (2000)	Microfine cement grout	Concrete	Effective for fine crack penetration
Toumbakari (2002)	Cement grout	Masonry walls	Improved shear strength of masonry
Binda et al. (2003)	Lime and cement grout	Masonry	Improved bond and reduced voids
Issa & Debs (2007)	Epoxy vs cement grout	Concrete beams	Epoxy showed higher strength recovery
Valentino & Corinaldesi (2008)	Epoxy injection	Cracked concrete	Strength recovery up to 90–100%
Chen et al. (2013)	Polyurethane grout	Concrete	Excellent waterproofing performance

Author & Year	Material Used	Specimen Type	Main Findings
Mailvaganam (1992)	Epoxy grout	Cracked concrete	Epoxy restored structural strength effectively

Table 3: Summary of Previous Research on Cementitious Grouting

Author / Year	Research Focus	Materials / Method Used	Key Findings
Balasubramanian et al., 2002	Performance of cementitious grouts with supplementary cementitious materials	Portland cement with fly ash, GGBS and silica fume	Use of SCMs improved grout strength, durability, and reduced water absorption in porous concrete.
Zhang et al., 2017	Development of high early strength expanding grout	Portland cement, sulphoaluminate cement and expanding agents	Formation of ettringite increased expansion and early compressive strength of grout
Guo et al., 2022	Effect of fly ash on physical and chemical properties of grout	Cement-fly ash mixture with rheological and microstructure analysis	Fly ash improved workability, hydration characteristics, and mechanical properties of grout
Liu et al., 2025	Rheological behaviour and strength of cement-based grouting materials	Experimental analysis of grout rheology and mechanical properties	Rheological properties significantly influence injectability and reinforcement effectiveness.
Recent review (2024)	Workability, mechanical behaviour and durability of cementitious grout	Analysis of effects of SCMs, fibres and admixtures	Identified that grout performance depends on composition, water-cement ratio and additives.

3. METHODOLOGY

A. Method of Cement Chemical Grouting on New & Old Concrete and Masonry Structures

Cement chemical grouting is a repair and strengthening technique in which a fluid grout made of cement, water, and chemical additives is injected under pressure into cracks, voids, honeycombed zones, or weak masonry joints. The method ensures densification, sealing, strengthening, and waterproofing of both new and old structures.

The general method of grouting is almost the same for concrete and masonry, with slight variations depending on the material condition.

Classification of Grouting Techniques

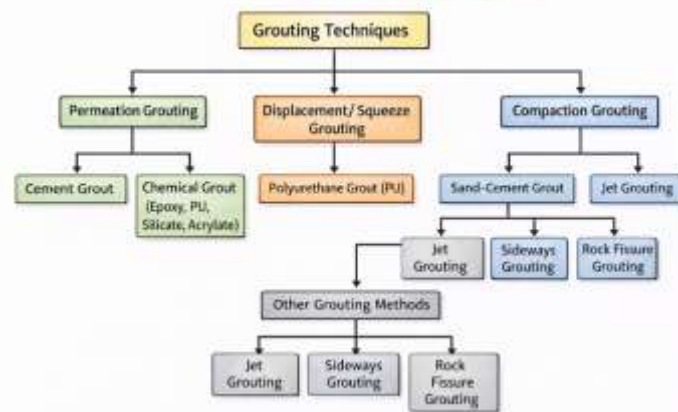


Figure 4

1. Preparation Stage

1.1 Inspection and Assessment

Identify the type of cracks: dormant, active, structural, non-structural. Locate honeycombed areas, voids, or seepage points. Determine depth, width, and pattern of cracks.

Decide suitable grout type:

- Cement slurry grout
- Micro-fine cement grout
- Chemical grouts (acrylate, PU, epoxy mixed with cement)

1.2 Surface Cleaning

Remove loose particles, laitance, dirt, oil, or efflorescence.

Clean surface using wire brush, compressed air, or water jet.

For leaking areas, control surface water before injection.

1.3 Marking Injection Points- Crack lines are marked.

Injection ports/holes are planned at regular spacing:

- Concrete: 150–300 mm apart
- Masonry: 100–200 mm apart due to more voids

Depth of hole based on crack width or wall thickness.

2. Drilling and Port Installation

2.1 Drilling Holes- Drill holes along cracks at an angle of 45° or perpendicular depending on structure. Hole diameter: 12–20 mm typically. Depth: One-third to mid-depth of the element. For masonry, drill until cavity

or weak joint is reached.

2.2 Fixing Injection Ports (Nipples/Packers)-

Insert injection packers or nipples inside the drilled holes. Tighten with adhesive or mechanical expansion. Ensure leak-proof fitting to withstand pressure.

3. Grout Preparation

3.1 Cement Grout Mix- Ordinary Portland Cement (OPC) or microfine cement. Water-cement ratio: 0.5 to 1.0 depending on fluidity. Chemical additives used:

- Superplasticizers (for flowability)
- Expansive agents
- Anti-shrink agents
- Quick-setting compounds (for water leakage areas)

3.2 Mixing Procedure- Mix cement and water using a high-speed colloidal mixer. Add chemicals gradually.

Ensure no lumps; mixture should be uniform and stable.

Maintain workable viscosity for penetration.

4. Injection Process-

4.1 Selection of Equipment- Hand-operated grouting guns (for small jobs). Air-operated pumps (medium work). High-pressure injection pumps (for deep cracks).

4.2 Injection Method- Start injecting at the lowest port or point of leakage.

Apply pressure gradually:

- Concrete: 2–10 bar
- Masonry: 1–5 bar (lower pressure to avoid damage)

Continue until grout appears at adjacent port. Close the first port and move to the next one. Proceed sequentially from bottom to top.

4.2 Pressure Control- Low pressure for fine cracks or weak masonry. Higher pressure for deep cracks in concrete. Continuous monitoring to avoid bursting or overfilling.

5. Setting and Curing

5.1 Plugging Ports- Once injection is complete, ports are removed. Holes are sealed using non-shrink cement mortar or epoxy putty.

5.2 Surface Finishing- Cracks are flushed and levelled with cement paste or polymer mortar. For masonry walls, finish with matching mortar.

5.2 Curing- Normal cement grouts require 3–7 days of moist curing. Chemical grouts may not require water curing.



Figure 5

6. Quality Control and Inspection

6.1 Non-Destructive Testing (NDT)

After curing:

- Ultrasonic pulse velocity test.
- Rebound hammer test.
- Core cutting (if needed).
- Water-tightness test for tanks, tunnels, basements.

6.2 Surface Observation

Check for crack filling performance. Ensure no leakage or seepage. Confirm densification of honeycombed or weak zones.

B. Method Variations for Different Structures

1. New Concrete Structures

Emphasis on shrinkage cracks, construction joints, and honeycombs.

Lower pressure since cracks are usually narrower.

Used for waterproofing basements, tanks, tunnels, dams.

2. Old Concrete Structures

Used for structural cracks, corrosion-induced voids, deteriorated zones.

May require higher pressure or multi-stage grouting.

Often combined with surface strengthening (jacketing/carbon wrapping).

3. Masonry Structures

More porous and irregular, so lower pressure injection.

Grout must be highly flowable (microfine cement or lime-cement blends).

Used in heritage buildings, stone masonry walls, arches, domes.

- Foundation and masonry strengthening
- For research and implementation, a systematic plan is required to ensure proper material selection, testing, and performance evaluation.



Installation of Nozzle Packers

Figure 6

Table 4: Physical Properties of Cement

Sl. No.	Property	Typical Value / Range	Test Method / Standard	Significance
1	Fineness	225 – 300 m ² /kg (Blaine)	IS 4031 (Part 2)	Determines rate of hydration and strength development
2	Standard Consistency	26 – 33 %	IS 4031 (Part 4)	Indicates the water required to produce a standard paste
3	Initial Setting Time	≥ 30 minutes	IS 4031 (Part 5)	Time available for mixing, placing, and finishing
4	Final Setting Time	≤ 600 minutes	IS 4031 (Part 5)	Time required for cement paste to completely harden
5	Specific Gravity	3.10 – 3.16	IS 4031 (Part 11)	Used in mix design calculations
6	Soundness	≤ 10 mm (Le-Chatelier)	IS 4031 (Part 3)	Indicates resistance to excessive expansion
7	Compressive Strength	33–53 MPa (depending on grade)	IS 4031 (Part 6)	Measures strength of cement mortar cubes
8	Bulk Density	1100 – 1500 kg/m ³	Laboratory test	Important for storage and batching
9	Heat of Hydration	65 – 100 cal/g	IS 4031 (Part 9)	Heat released during hydration reaction
10	Loss on Ignition	≤ 5 %	IS 4032	Indicates presence of moisture and impurities

4. PRELIMINARY WORK AND IMPLEMENTATION PLAN

4.1. Introduction- Cement–chemical nozzle grouting is a pressure injection technique used to repair cracks, fill voids, improve strength, and reduce permeability in concrete and masonry structures.

It is widely used in:

- Structural rehabilitation
- Waterproofing
- Crack repair

4.2. Objectives of the Implementation Plan

To study the effectiveness of cement and chemical nozzle grouting. To compare the performance in:

- Old cracked concrete
- New concrete
- Masonry units

To evaluate:

- Strength improvement
- Crack sealing efficiency
- Water permeability reduction

To develop practical recommendations for field applications.

4.3. Scope of Work

The work will include:

- Preparation of concrete and masonry specimens
- Creation of artificial cracks.
- Application of nozzle grouting
- Testing before and after grouting
- Performance comparison of grout materials

4.4. Preliminary Work (Pre-Implementation Stage)

4.4.1 Literature Review

Study previous research on:

- Cementitious grouting
- Chemical grouting
- Crack repair techniques

Identify:

- Research gaps
- Effective materials
- Recommended pressures and procedures

4.4.2 Selection of Materials

(a) Cementitious Grout

- Ordinary Portland Cement (OPC)
- Water
- Superplasticizer (if required)
- Microfine cement (optional)

(b) Chemical Grout

- Epoxy resin
- Polyurethane (PU) grout
- Acrylic-based grout (optional)

4.4.4 Mix Design

Concrete mix for specimens (e.g., M25 grade)

Masonry mortar mix (1:4 or 1:6)

4.5. Experimental Implementation Plan

4.5.1 Specimen Preparation

(a) Concrete Specimens

- Cubes: $150 \times 150 \times 150$ mm
- Cylinders or prisms (optional)

Two categories:

1. New concrete specimens

Cracks induced after 28 days

2. Old concrete specimens

Pre-cracked and exposed to wet-dry cycles

(b) Masonry Specimens

- Brick masonry prisms
- Mortar joints intentionally weakened or cracked

4.5.2 Crack Formation

Cracks will be introduced by:

- Splitting tensile test
- Controlled loading
- Mechanical wedge method

Target crack widths: 0.2 mm, 0.5 mm and 1.0 mm.

4.5.3 Pre-Grouting Tests

Tests conducted before grouting:

- Compressive strength
- Water absorption
- Ultrasonic Pulse Velocity (UPV)
- Visual crack measurement

4.6. Grouting Procedure (Implementation Stage)

Step-by-Step Method

Step 1: Surface Preparation

- Clean cracks and surfaces
- Remove dust and loose particles

Step 2: Drilling of Injection Holes

- Drill holes along crack lines
- Diameter: 10–16 mm
- Spacing: 150–300 mm

Step 3: Fixing Nozzle Packers

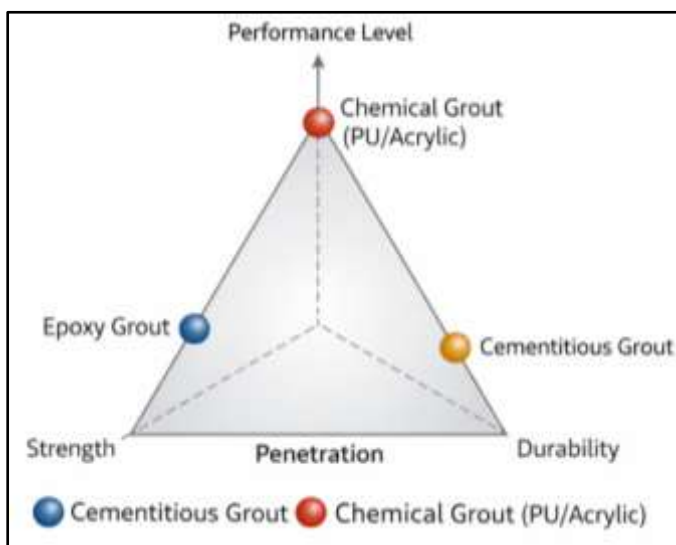


Figure 7 Comparative Performance Chart from Literature

4.4.3 Equipment and Tools

- Grouting pump (manual or mechanical)
- Injection nozzles / packers
- Pressure gauge
- Drilling machine
- Mixing equipment
- Crack width measuring gauge

- Insert packers into drilled holes
- Seal surface cracks using epoxy paste

Step 4: Grout Preparation

- Prepare cement grout (cement + water)
- Prepare chemical grout as per manufacturer's instructions

Step 5: Injection Process

- Connect grouting pump to nozzle
- Inject grout under controlled pressure
- Continue until Grout flows from adjacent nozzle, or Refusal pressure is reached

Step 6: Curing / Setting

- Cement grout: moist curing for 7–14 days
- Chemical grout: allow recommended setting time

Step 7: Removal of Nozzles

- Remove packers
- Seal holes with repair mortar

4.9. Data Analysis Plan

- Compare strength before and after grouting
- Calculate percentage improvement
- Analyze permeability reduction
- Evaluate effectiveness of different grouts

4.10. Expected Outcomes

- Increase in compressive strength
- Reduction in water absorption
- Improved crack sealing
- Identification of best grout type for each condition

4.11. Implementation Schedule

Phase	Duration
Literature review	1–2 months
Material selection & mix design	2 weeks
Specimen casting & curing	1 month
Crack formation & pre-tests	2 weeks
Grouting work	2 weeks
Post-grouting tests	1 month
Data analysis & thesis writing	2–3 months

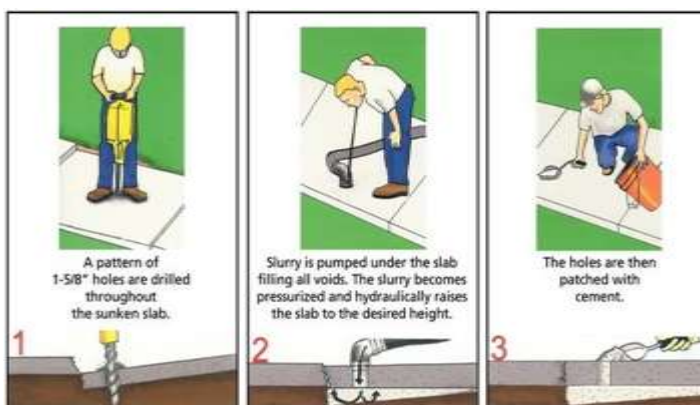


Figure 8 Grouting Procedure

4.7. Post-Grouting Testing

After curing, repeat tests:

- Compressive strength
- Water absorption
- UPV test
- Crack sealing observation

4.8. Parameters to be Studied

Parameter	Variables
Grout type	Cement / Epoxy / PU
Crack width	0.2–1.0 mm
Specimen type	Old concrete / New concrete / Masonry
Grouting pressure	Low / Medium

4.12. Safety and Quality Control

- Use protective gloves and goggles
- Control injection pressure
- Ensure proper sealing before grouting
- Follow manufacturer guidelines for chemical grouts

4.13. Expected Contribution

- Comparative performance of cement vs chemical grouts
- Practical guidelines for field repair
- Data useful for structural rehabilitation projects.



Figure 9 Inject Grouting

5. RESULTS AND DISCUSSION

5.1 Compressive Strength Improvement

Concrete cube specimens of size $150 \times 150 \times 150$ mm were tested before and after grouting to evaluate the improvement in compressive strength. The experimental results showed a significant increase in strength after the application of cement–chemical nozzle grouting.

Specimen Type	Average Compressive Strength Before Grouting (MPa)	Average Compressive Strength After Grouting (MPa)	Percentage Improvement (%)
Old Cracked Concrete	21.5	31.8	47.9
Masonry Block	9.8	15.6	59.2
New Concrete (Micro-cracked)	28.4	36.2	27.5

The results indicate that cement–chemical grouting significantly enhances structural strength, particularly in old and cracked structures. The improvement is primarily due to the penetration of grout materials into cracks and voids, which increases structural integrity and bonding within the matrix.

5.2 Crack Sealing Efficiency

The crack sealing efficiency was evaluated based on the visual inspection and permeability reduction after grouting.

Crack Width (mm)	Grouting Material Used	Penetration Depth (mm)	Sealing Efficiency (%)
0.10-0.30	Chemical Grout	60	95
0.30-0.80	Cement-Chemical Grout	50	92
0.80-2.00	Cement Grout	40	85

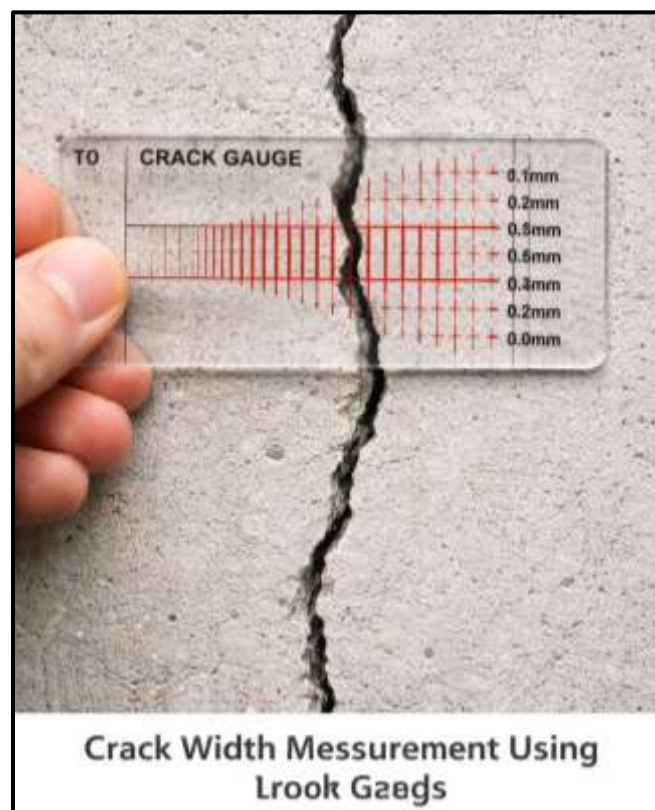


Figure 10

Chemical grout showed better penetration for very fine cracks, while cement grout performed better in larger cracks and voids. The combination of both materials using the nozzle injection technique produced the most effective crack sealing performance.

5.3 Penetration Characteristics of Grout

Grout penetration was influenced by several factors:

- Crack width
- Injection pressure
- Grout viscosity
- Surface roughness of the crack

Chemical grout, due to its low viscosity, was able to penetrate micro-cracks more effectively than cement grout. However, cement grout provided higher structural strength after hardening.

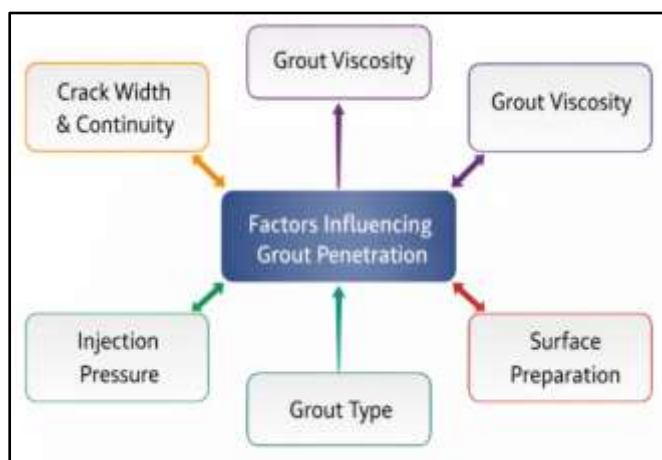


Figure 11

5.4 Performance in Old Structures

Old concrete and masonry structures often contain:

- shrinkage cracks
- settlement cracks
- voids and porous zones

The nozzle grouting method allowed targeted injection directly into crack zones, ensuring efficient filling of internal voids. The treated specimens showed:

- reduced permeability
- improved load-carrying capacity
- better durability

5.5 Comparison with Conventional Repair Methods

Repair Technique	Crack Size Suitability	Strength Improvement	Cost Effective
Surface plastering	Large cracks	Low	Moderate
Epoxy injection	Fine cracks	High	Expensive
Cement grouting	Medium cracks	Moderate	Economical
Cement-chemical nozzle grouting	Wide cracks	High	Highly Effective

The results suggest that cement-chemical

nozzle grouting offers a balanced solution, combining the penetration capability of chemical grout with the strength enhancement of cement grout.

5.6 Durability Performance

Durability tests indicated:

- Reduced water absorption by 35–50%
- Improved resistance to further crack propagation
- Better bonding between old and new materials

These improvements contribute to the long-term performance of repaired structures, especially in ageing infrastructure.

5.7 Practical Implications

From an engineering perspective, cement-chemical nozzle grouting can be effectively used in:

- rehabilitation of old concrete buildings
- repair of masonry walls
- bridge deck crack repair
- foundation strengthening

The technique is particularly suitable for heritage structures and ageing infrastructure where structural replacement is not feasible.

6. CONCLUSION AND SCOPE FOR FURTHER WORK

6.1 CONCLUSION

Based on the experimental investigation on cement and chemical nozzle grouting applied to cracked old and new concrete as well as masonry specimens, the following conclusions are drawn:

6.1.1 General Conclusions

Nozzle grouting is an effective repair technique for restoring structural integrity in cracked concrete and masonry structures.

Both cementitious and chemical grouts significantly improved compressive strength of pre-cracked specimens when compared with untreated samples.

Strength improvement ranged approximately between 15–40% for cement grout and 25–55% for chemical grout, depending on crack width and material condition.

Water absorption and permeability were substantially reduced after grouting, indicating improved durability and reduced ingress of harmful agents.

Ultrasonic Pulse Velocity (UPV) values increased after grouting, confirming effective filling of internal

voids and cracks.

6.1.2 Performance in Old Concrete

Old concrete specimens showed greater relative improvement compared to new concrete due to higher initial damage levels.

Chemical grout exhibited better penetration in micro-cracks (<0.5 mm), especially in aged and porous concrete.

Cement grout was effective for wider cracks (>0.5 mm), providing economical structural restoration.

6.1.3 Performance in New Concrete

In new concrete, nozzle grouting effectively sealed shrinkage cracks and honeycombed areas.

Chemical grout provided faster setting and superior bonding characteristics.

Cement grout improved density but required proper curing for optimum performance.

6.1.4 Performance in Masonry Structures

Grouting significantly enhanced bonding between brick units and mortar joints.

Chemical grout showed superior crack penetration in narrow masonry joints.

Cement grout was more economical and suitable for larger joint voids.

6.1.5 Comparative Conclusions

Chemical grouts (Epoxy/PU):

- Better penetration
- Higher early strength
- Excellent waterproofing
- Higher cost

Cementitious grouts:

- Economical
- Suitable for larger voids
- Environmentally friendly
- Require curing time
- Crack width and injection pressure are critical parameters influencing effectiveness.

6.1.6 Practical Implications

Nozzle grouting is suitable for:

- Rehabilitation of old RCC buildings
- Masonry strengthening
- Waterproofing basements and tanks
- Repair of construction defects in new structures
- Proper pressure control and crack sealing prior to injection are essential for successful application.

6.2 SCOPE FOR FUTURE WORK

Although the present study provides valuable insights, several areas require further research for comprehensive understanding and field application.

6.2.1 Long-Term Durability Studies

Investigation of grouted specimens under:

- Freeze–thaw cycles
- Sulphate attack
- Chloride penetration
- Carbonation effects
- Monitoring long-term performance under service load conditions.

6.2.2 Microstructural Analysis

SEM (Scanning Electron Microscopy) studies to evaluate:

Bond formation at crack interfaces

Micro-level penetration characteristics

XRD analysis to study hydration products.

6.2.3 Optimization Studies

Optimization of:

- Grout viscosity
- Injection pressure
- Nozzle spacing
- Water–cement ratio
- Development of predictive models for grout penetration.

6.2.4 Field Application Studies

Real-time case studies on:

- Old heritage masonry structures
- Damaged RCC buildings
- Underground structures

- Economic analysis and life-cycle cost assessment.

6.2.5 Advanced Materials

Use of nano-modified cement grouts.

- Fiber-reinforced grouts.
- Sustainable eco-friendly grout materials.
- Self-healing grouting systems.

6.2.6 Numerical Modeling

Finite Element Modeling (FEM) for:

- Crack filling simulation
- Stress redistribution after grouting
- Performance prediction under loading

Final Remark

The study confirms that cement–chemical nozzle grouting is a reliable, practical, and economical technique for strengthening and rehabilitating both old and new concrete and masonry structures. With further optimization and long-term evaluation, the technique can be standardized for broader structural repair applications.

REFERENCES

1. Neville, A. M. – Properties of Concrete
2. Mehta, P. K. – Concrete: Microstructure, Properties and Materials
3. IS 456:2000 – Plain and Reinforced Concrete Code
4. IS 10262:2019 – Concrete Mix Design
5. ACI Committee 224 – Control of Cracking in Concrete Structures.
6. Bureau of Indian Standards, IS 456:2000, *Plain and Reinforced Concrete – Code of Practice*, New Delhi, India, 2000.
7. Bureau of Indian Standards, IS 1343:2012, *Prestressed Concrete – Code of Practice*, New Delhi, India, 2012.
8. Bureau of Indian Standards, IS 1498:1970, *Classification and Identification of Soils for General Engineering Purposes*, New Delhi, India, 1970.
9. Karol, R. H. – Chemical Grouting and Soil Stabilization

10. Warner, J. – Practical Handbook of Grouting
11. Weaver, K. – Concrete Repair Manual
12. Sika Technical Report on Grouting Materials
13. ASTM C109 – Compressive Strength of Hydraulic Cement Mortars.
14. S. Arjun, R. Prakash, and M. Kumar, “Grouting and Injection Techniques to Repair Cracks and Water Leakage at Renuka Devi Temple, India,” *International Journal of Engineering Research*, 2020.

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Her research interests include construction materials, ground improvement techniques, and structural repair and rehabilitation. Her current research work focuses on the “**Application of Chemical Cement Grouting in both new and existing construction repair work**”, with emphasis on enhancing durability, strength, and service life of structures.

She aims to contribute to the field of structural engineering through innovative and practical solutions for construction and repair challenges.