



Performance Evaluation of Quality Control Systems in Underpass Projects

Prof. Shraddha Pujari¹, Mohite Sahil Santosh²,

¹Faculty Civil Engineering Vidya Prasarini Sabha's College of Engineering and Technology

,Lonavala

²Student Civil Engineering Vidya Prasarini Sabha's College of Engineering and Technology

,Lonavala

ABSTRACT

This study examines the construction methodology, quality control measures, and challenges associated with underpass construction, which serves as a vital component of modern urban infrastructure. Underpasses play a crucial role in ensuring uninterrupted traffic flow, reducing congestion, and enhancing road safety by eliminating at-grade crossings.

The study presents a detailed analysis of key construction activities, including excavation, soil stabilization, drainage system installation, structural concreting, and implementation of safety practices. Various construction techniques, such as the cut-and-cover method and the box pushing method, are evaluated with respect to their suitability under different site conditions and traffic requirements.

The findings indicate that comprehensive planning, accurate geotechnical investigation, and strict quality control at every stage of construction are essential for achieving structural stability, durability, and efficient project execution. Proper drainage design and soil management are identified as critical factors in preventing water ingress and ensuring long-term performance.

Overall, effective underpass construction significantly contributes to improved traffic management, reduced travel time, and enhanced urban mobility, making it an indispensable element of sustainable infrastructure development.

Keywords

Underpass Construction, Urban Infrastructure, Cut-and-Cover Method, Box Pushing Method, Soil Stabilization, Structural Concreting, Quality Control, Traffic Management, Drainage Systems, Urban Mobility

1. INTRODUCTION

Underpasses are underground passageways constructed to facilitate the movement of roads, railways, or pedestrians beneath existing infrastructure such as highways or railway tracks. They play a vital role in modern urban development by reducing traffic congestion, minimizing delays, and enhancing overall road safety.

The construction of underpasses involves several critical stages, including site investigation, excavation, structural design, concreting, and finishing works. Since these structures are built below ground level, they are particularly vulnerable to challenges such as water ingress, lateral soil pressure, and potential structural instability. Therefore, careful planning and execution are essential to ensure long-term performance and

safety.

Key Requirements for Effective Underpass Construction

- **Structural Strength and Durability:**

The structure must be designed to withstand traffic loads, soil pressure, and environmental conditions over its service life.

- **Efficient Drainage System:**

Proper drainage arrangements are necessary to prevent water accumulation and ensure smooth operation during all weather conditions.

- **Safety Measures:**

Adequate safety practices must be implemented during construction and maintained after completion to protect both workers and users.

Consequences of Improper Construction

Failure to follow proper construction practices may result in several issues, including:

- Waterlogging due to inadequate drainage
- Development of structural cracks affecting durability
- Soil collapse leading to instability and safety hazards

Construction Methods for Underpasses

1. Cut-and-Cover Method

The **cut-and-cover method** is the most commonly used technique for constructing underpasses in urban areas where surface excavation is feasible.

Construction Steps:

1. **Site Preparation & Traffic Diversion**
 - Clear the site and divert existing traffic to temporary routes.
2. **Excavation**
 - Excavate the soil up to the required depth using machinery.
 - Provide temporary supports such as sheet piles or retaining walls to prevent soil collapse.
3. **Subgrade Preparation**
 - Level and compact the base.
 - Lay a bedding layer (sand/PCC) for foundation stability.
4. **Base Slab Construction**
 - Cast the reinforced concrete (RCC) base slab.
5. **Side Walls Construction**
 - Construct RCC retaining walls on both sides.
6. **Roof Slab / Deck Slab**
 - Cast the top slab to complete the box structure.
7. **Backfilling**
 - Refill soil above the structure and compact properly.
8. **Finishing Works**
 - Install drainage, road surface, lighting, and safety features.

2. Box Pushing Method (Box Jacking)

The **box pushing method** is used when excavation from the top is not possible, especially under **railway tracks or busy highways** where traffic cannot be interrupted.

Construction Steps:

1. **Construction of Launching Pit**
 - Excavate a pit at one side of the road/railway.
 - Construct a thrust bed to support hydraulic jacks.
2. **Casting of RCC Box**
 - Cast the concrete box structure (underpass segment) in the launching pit.
3. **Installation of Hydraulic Jacks**
 - Place jacks between the thrust bed and the box.
4. **Excavation Ahead of Box**
 - Remove soil in front of the box manually or mechanically.
5. **Box Pushing Operation**

- Push the box forward using hydraulic jacks in stages.
- 6. **Repeat Process**
 - Continue excavation and pushing until the box reaches the required position.
- 7. **Completion & Finishing**
 - Construct approach roads, drainage systems, and finishing works.

Comparison of methods

Aspect	Cut-and-Cover	Box Pushing
Traffic Impact	High (requires diversion)	Minimal (no interruption)
Construction Speed	Faster	Slower
Cost	Moderate	Higher
Suitability	Open areas	Under railways/highways
Complexity	Moderate	High

Table 1.1 Literature Review

Table 1.1 Literature Review

Research Findings	Research Gap
Underpass construction	Increase Traffic Flow And Safety
Excavation	Critical For Foundation stability
Concrete Strength	Determines Stability
Drainage Systems	Prevent Water logging

2. METHODOLOGY

2.1 Material used Materials Used: -

2.1 Materials Used

- **Cement** – OPC 53 Grade, tested as per IS standards
- **Fine Aggregate** – River sand, Zone II

- **Coarse Aggregate** – 20mm aggregates
- **Water** – Potable water
- **Admixture** – plasticizer

2.2 Design Specifications : -

- Concrete Grade: M30
- Reinforcement: As per structural design
- Thickness of walls/slab: 300–500 mm
- Clear span: As per site requirement

2.3 Construction Process

1. Site Survey and Soil Investigation
2. Excavation
3. Dewatering (if required)
4. Foundation Preparation
5. Reinforcement Placement
6. Formwork Installation
7. Concrete Pouring
8. Curing Process
9. Backfilling and Compaction
10. Road Finishing



2.4 Testing During Construction

2.4.1 Compaction Test

Objective:

To determine optimum moisture content (OMC) and maximum dry density (MDD) of soil.

- Ensures proper backfilling
- Prevents settlement and cracks in underpass

2.4.2 Field Density Test

Objective:

To check in-situ density of compacted soil.

- Confirms proper compaction on site
- Avoids future sinking of road above underpass

- Procedure:-

1. Select a level area on the compacted soil surface.
2. Place the metal tray on the ground and fix it properly.
3. Dig a small hole through the center of the tray:
 - Depth = 10–15 cm
 - Collect all excavated soil carefully in a container.
4. Weigh the excavated soil (Wet weight = W_1).
5. Take a sample of this soil to determine moisture content.
6. Fill the sand pouring cylinder with dry sand and record its initial weight (W_2).
7. Place the cylinder vertically over the hole and open the valve.
8. Allow sand to flow into the hole until it completely fills the hole and cone.
9. Close the valve and weigh the cylinder again (W_3).
10. Calculate weight of sand used:

$$W = W_2 - W_3$$

11. Determine volume of hole using calibration data of sand.
12. Calculate bulk density:

$$\text{Bulk Density} = \text{Weight of soil} / \text{Volume of hole}$$

13. Calculate dry density:

$$\text{Dry Density} = \text{Bulk Density} / (1 + \text{moisture content})$$



Field Density Test

2.5 Drainage Test

- **Objective:** -

To check the efficiency of the drainage system and ensure that there is no water accumulation or leakage in the underpass.

- **Apparatus :**

- Water tanker / hose pipe
- Measuring scale
- Stopwatch
- visual inspection tools
- Marking chalk

- **Procedure: -**

1. Clean the underpass surface and drainage channels properly.
2. Block the drainage outlet temporarily (if required for testing).
3. Pour water uniformly on the underpass surface using a tanker or hose.
4. Maintain a constant flow of water for a specific time (15–30 minutes).
5. Observe the flow of water towards drainage points.
6. Check for:
 - Water stagnation (ponding)
 - Leakage through walls or joints
 - Proper slope towards drains
7. Remove blockage and allow water to drain naturally.
8. Measure the time taken for complete drainage.
9. Mark areas where water remains or seepage occurs.



Drainage Test

- **Observation**

- Smooth flow of water indicates proper slope
- Water accumulation indicates poor drainage
- Leakage indicates construction defects

3. RESULT AND DISCUSSION

3.1 Result Field Density Test

Table no. 3.1 Field Density Test Results

Sr.No.	Wet Weight Of Soil(KG)	Moisture Content	Bulk Density (g/cc)	Dry Density(g/cc)	% Compaction
1	2.10	8	1.92	1.78	96%
2	2.25	7	1.95	1.82	97%
3	2.18	9	1.90	1.74	95%

- Compaction achieved is within acceptable range (95%–98% of MDD)
- Soil compaction is satisfactory for underpass construction

3.2 Result of Drainage Test

7 Days Compressive Strength Test result on harden concrete

Table no. 3.2 Compressive Strength test Results

Sr.No.	Water Flow Duration (min)	Drainage Time(min)	Water Stagnation	Leaked Observed	Remarks
1	20	5	No	No	Good Drainage
2	25	6	Slight	No	Slight Slope Issue
3	30	7	No	No	Satisfactory

- Drainage system is mostly effective
- Minor improvements required in slope at some locations
- No leakage observed → structure is safe

3.3 Summary Of Test Results

Test	Result	Status
Field Density Test	95-97% Compaction	Good
Drainage Test	No Major Issues	Satisfactory

3.3 Cost Analysis

Table no. 3.3 Cost Analysis

Sr.No.	Description	Quantity	Unit	Rate (RS.)	Amount
1	Cement	450	Kg	7/ kg	3100

2	Fine Aggregate	700	Kg	1.6/kg	1120
3	Coarse Aggregate	1300	Kg	1.2/kg	1560
4	Steel Reinforcement	80	Kg	60/kg	4800
5	Admixture	4.5	Kg	80/kg	360
6	Water	200	Lit.	0.05/lit	10
7	Labour Charge	Lump Sum	-		1500
8	Machinery	Lump Sum	-		2500

3.4 Results and Discussion

The results obtained from various field tests and observations during underpass construction highlight the critical importance of proper planning, execution, and quality control at every stage of the project.

- **Field Density Test:**

The field density test results indicate that the degree of compaction achieved ranges between **95% and 97% of Maximum Dry Density (MDD)**. This level of compaction is considered satisfactory and ensures that the backfilled soil is stable and resistant to excessive settlement. Adequate compaction is essential to prevent differential settlement, which can otherwise lead to pavement cracks and structural distress in the underpass.

- **Drainage Performance:**

Drainage test observations show that water is effectively directed towards designated outlets in most areas, with minimal stagnation. However, minor water accumulation in certain locations suggests slight irregularities in surface gradients. This emphasizes the importance of maintaining proper slope during construction, as underpasses—being below ground level—are highly susceptible to waterlogging, especially during heavy rainfall.

- **Slump Test (Workability):**

The slump test results confirm that the concrete possesses adequate workability. This is particularly important for underpass structures, where concrete must be placed in sections with dense reinforcement. Good workability ensures proper compaction without segregation, resulting in a dense and durable concrete structure.

- **Compressive Strength:**

The compressive strength test results indicate that the concrete achieves the required design strength for **M30 grade concrete**. The observed strength gain from 7 days to 28 days follows standard trends, confirming proper mix design and curing practices. This ensures that structural elements such as slabs and side walls can safely withstand applied loads.

- **Quality Control Observations:**

It is evident that maintaining strict quality control throughout all stages—from material selection to final finishing—is essential to prevent defects such as cracking, leakage, and settlement. Any lapse in quality control can lead to long-term maintenance issues and increased repair costs.

- **Overall Assessment:**

The study demonstrates that underpass construction is a multidisciplinary process involving geotechnical, structural, and hydraulic considerations. Effective coordination among these aspects is crucial to ensure a safe, durable, and efficient structure capable of long-term performance.

4. CONCLUSIONS

The findings from various tests and field observations during underpass construction clearly demonstrate the importance of systematic planning, proper execution, and stringent quality control throughout all stages

of the project.

- The field density test results indicate that the achieved compaction ranges between **95% and 97% of Maximum Dry Density (MDD)**, which is satisfactory. This ensures stability of the backfilled soil and minimizes the risk of excessive or differential settlement that could otherwise lead to pavement cracks or structural distress.
- The drainage performance is found to be effective in most areas, with water flowing efficiently towards designated outlets. However, minor instances of water accumulation highlight the need for maintaining proper gradients during construction, as underpasses are highly vulnerable to waterlogging due to their below-ground configuration.
- The slump test results confirm that the concrete used possesses adequate workability, which is essential for proper placement in congested reinforcement zones. Good workability ensures proper compaction without segregation, resulting in a dense and durable concrete structure.
- The compressive strength results demonstrate that the concrete meets the required **M30 grade** specifications. The observed strength gain from 7 days to 28 days follows standard trends, indicating appropriate mix design and curing practices. This ensures that structural components such as slabs and side walls can safely withstand applied loads.
- It is evident that maintaining strict quality control at every stage—from material selection to final finishing—is crucial to prevent defects such as cracking, leakage, and settlement. Any negligence in quality control may lead to long-term maintenance issues and increased repair costs.
- Overall, the study concludes that underpass construction is a multidisciplinary process involving geotechnical, structural, and hydraulic aspects. Effective coordination among these disciplines is essential to achieve a safe, durable, and efficient structure with reliable long-term performance.

4.1 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed to improve the quality, durability, and performance of underpass construction projects:

- **Ensure Proper Site Investigation:**
Conduct detailed geotechnical investigations to assess soil properties, bearing capacity, and groundwater conditions before construction. This helps in selecting appropriate foundation and construction methods.
- **Maintain Adequate Compaction:**
Achieve and verify compaction levels of at least 95% of MDD for backfilled soil to prevent settlement and structural issues. Regular field density tests should be carried out for quality assurance.
- **Provide Effective Drainage System:**
Design and maintain proper slopes and drainage outlets to prevent waterlogging. Regular inspection and cleaning of drainage systems are essential, especially in monsoon-prone areas.
- **Control Concrete Quality:**
Ensure proper mix design, workability, and strength of concrete through regular slump tests and compressive strength tests. Adequate curing practices must be strictly followed.
- **Implement Strict Quality Control:**
Quality checks should be carried out at every stage, including material selection, batching, placement, compaction, and finishing, to avoid defects such as cracks, leakage, and settlement.
- **Adopt Suitable Construction Methods:**
Select appropriate construction techniques (cut-and-cover or box pushing) based on site conditions, traffic requirements, and environmental constraints.
- **Enhance Safety Measures:**
Ensure proper safety practices during construction, including use of protective equipment, proper barricading, and safe excavation procedures.
- **Use Skilled Workforce and Supervision:**
Employ trained labor and experienced engineers for execution and supervision to maintain accuracy and quality in construction.

- **Regular Maintenance and Inspection:**
After completion, periodic inspection of structural elements and drainage systems should be carried out to detect and rectify issues at an early stage.
- **Incorporate Sustainable Practices:**
Optimize material usage, reduce construction waste, and adopt environmentally friendly practices to ensure sustainable infrastructure development.

5. REFERENCES

1. IS 456:2000
Bureau of Indian Standards, New Delhi — Plain and Reinforced Concrete – Code of Practice.
2. IS 10262:2019
Bureau of Indian Standards — Guidelines for Concrete Mix Design.
3. IS 3370 (Part 1–4)
BIS — Code of Practice for Concrete Structures for Storage of Liquids (relevant for water-tight structures like underpasses).
4. IS 2720 (Various Parts)
BIS — Methods of Test for Soils (Compaction, Field Density, Permeability, etc.).
5. IS 1200
BIS — Method of Measurement of Building and Civil Engineering Works.
6. IRC:SP:84
Indian Roads Congress — Manual of Specifications and Standards for Highway Construction.
IRC:SP:42 Indian Roads Congress — Guidelines on Road Drainage.
7. MoRTH Specifications (5th Revision)
Ministry of Road Transport and Highways — Specifications for Road and Bridge Works.
8. M.S. Shetty
S. Chand Publications — Concrete Technology.
9. K.K. Chitkara
Tata McGraw Hill — Construction Project Management.
10. A.M. Neville
Pearson Education — Properties of Concrete.
11. NHAI Guidelines

National Highways Authority of India — Standards for Underpass and Drainage Design.

12. International Journal of Engineering Research & Technology (IJERT)

Research papers on underpass construction and infrastructure development.

13. International Research Journal of Engineering and Technology (IRJET)

Studies related to construction methods, soil behavior, and drainage systems.

