

# Development of a Drainage Control System for Water Leakage from Metro Bridge Expansion Joints

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*Abstract— The problem of leakage through the expansion joints of bridges carrying elevated metro lines is of great importance in urban engineering, as water leakage from such joints falls directly on the roads and footpaths, posing dangers of injury to pedestrians and vehicles, and deterioration of bridge structures such as the caps of piers. This research suggests a unique drainage scheme where there is provision of a 150 mm height wall that will collect all the water leaking out of the joints into a 50 mm drainpipe and transfer them to the ground level. Such a system will help in avoiding unnecessary water flow, prevent the structure from deterioration due to continued seepage and ensure safety of both pedestrians and vehicles. Additionally, this drainage arrangement will help in reducing maintenance needs of the system and increase its longevity. This paper presents an approach to the design and implementation of the suggested scheme.*

**Keywords— Expansion joints, Metro bridge drainage, Water leakage control, Pier cap deterioration, Pedestrian safety.**

## I. INTRODUCTION

Elevated metro bridges are an essential part of modern urban transportation systems, providing efficient and uninterrupted connectivity in densely populated cities. These structures are continuously exposed to environmental conditions such as rainfall, temperature variation, and moisture infiltration. One of the major maintenance issues observed in metro bridge structures is water leakage through expansion joints. Expansion joints are provided in bridges to accommodate thermal movement, vibration, and structural displacement; however, improper drainage and deterioration of these joints often result in leakage of rainwater onto roads, footpaths, and bridge substructures.

Continuous water seepage from expansion joints can create several problems, including slippery road conditions, inconvenience to pedestrians, traffic disturbances, and deterioration of structural components such as pier caps. In many metro corridors, leakage water directly falls from elevated bridges onto public roads, leading to safety hazards and increased maintenance requirements. Prolonged exposure to moisture may also result in corrosion of

reinforcement, concrete damage, and reduced service life of bridge components.

This study proposes a practical drainage control system for metro bridge expansion joints using a 150 mm protective wall combined with a 50 mm drainage pipe arrangement. The proposed system is intended to collect leakage water and safely divert it to ground level without affecting pedestrians or vehicles. The study focuses on improving public safety, minimizing structural deterioration, and enhancing the durability and maintenance efficiency of elevated metro bridge infrastructure.

### 1.1. INTRODUCTION TO EXPANSION JOINTS

Expansion joints form some of the key structural elements that are installed on bridges in order to allow for movement resulting from various factors such as changes in temperatures, vibrations from traffic loading, vibration from traffic vibration, shrinkage, and seismology among others. In elevated metro bridges, expansion joints play a significant role in ensuring that movements occur in a controlled manner in order to prevent the formation of stress and cracks on structural components.

However, despite being critical to the stability and durability of structures, expansion joints are subject to difficult environmental conditions such as water, dust, and traffic vibration. Damaged joints form the main sources of water leakage in elevated metro bridges, especially since rainwater that gets into joints drips directly onto roads, pedestrian walkways, as well as bridge substructure elements. This can pose safety hazards as well as cause deterioration of the structure, including corrosion of reinforced concrete and steel.

Management of leaking expansion joints has become one of the critical issues in metro structures, especially in urban settings. Therefore, there arises the need for an effective drainage system.



Figure 1: Expansion Joint in Metro

seepage water to reduce structural deterioration and improve public safety.

Objectives:

1. To study the causes of water leakage through expansion joints in metro bridges.
2. To design a 150 mm protective wall with a 50 mm drainage pipe system for controlled water diversion.
3. To reduce water accumulation on pier caps and improve pedestrian and vehicular safety below metro bridges.

#### 1.4. PROBLEM STATEMENT

The leakage of water from the expansion joints on elevated metro railway bridges allows water to fall straight on to the road surfaces and walking spaces, leading to various dangers and disruptions to the flow of traffic. Constant leakage of water results in water accumulation on the surface of pier caps, thus affecting the structure of bridges and requiring regular maintenance.

#### 1.2. MANAGING THE WATER LOGGING ON THE BRIDGE

Water collects in the top parts of metro bridges during rainfall due to insufficient drainage flow and constant exposure to the environment. Although there is drainage provided in the bridges, water usually collects in the vicinity of the expansion joint because the gap in the structure serves as a drainage point. Since the joint area becomes exposed to environmental elements, dirt accumulation and poor sealing performance result in water logging in the region.

The collection of large amounts of water at the region of expansion joints causes water leakage into the road and walkway beneath the bridge. Leakage of water from such a great height causes problems for both pedestrians and motorists. The risk of accidents on the slippery road increases when rain falls heavily.

Apart from external leakage, some of the leaking water is collected in parts of the structures, such as piers' caps, and support structure below the deck surface. Stagnation of water in such places can cause damage to the concrete as well as the reinforcement bars, staining and decrease in the life of bridge components. For this reason, it is imperative that leakage water should be collected and diverted appropriately through the expansion joints.

#### 1.3. AIM AND OBJECTIVES

Aim- To develop an effective drainage control system for elevated metro bridge expansion joints to prevent uncontrolled water leakage onto roads and pedestrians. The proposed system focuses on collecting and safely diverting

## II. LITERATURE SURVEY

The experiment on bridge expansion joint damage carried out by Li et al., (2023), was based on natural frequency analysis. The study analyzed how the bridge modal expansion joints behaved differently depending on varying damage states and curing periods. Deterioration in elements such as center beams, support bars, and anchorage concrete lowered the natural frequency of expansion joints. This is an indication of bridge damage. The study emphasized the need to keep track of expansion joint states in order to avoid leakage and substructure deterioration.

Transport Infrastructure Ireland, (2023), developed a standard guideline on the design, construction, inspection, and maintenance of road bridge expansion joints. The study focused on how bridge expansion joints could be designed and installed. In addition, the study analyzed the effects that improper drainage and defects have on expansion joints. Improper drainage and joint defects cause leakage, deterioration, and maintenance challenges.

The role of the joints in bridge structures and its significance in handling thermal effects, shrinkage, creep, and traffic load effects was discussed by Mohamed and Noothangal, (2022). Poor management of joints has been associated with concrete spalling, leakage, and deterioration of pier caps among other parts of the bridge. The researchers emphasized the necessity of proper management of expansion joints for better functioning of bridges.

Avudaiappan et al., (2021) studied the effect of thermal and earthquake loads on connections between pier and pier cap in integral bridges. Deterioration of the expansion joints may be associated with water leakage, concrete cracking,

and failure of the bridge substructure underneath. The study aimed at minimizing maintenance problems related to conventional expansion joints in bridge systems.

Phares and Ruble, (2020) conducted research on rapid repair and replacement of bridge deck expansion joints. Specifically, the use of ultra-high-performance concrete and hydro demolition process was considered in the study. The results revealed that expansion joints are some of the earliest bridge structures to undergo failure and that their repair would extend their useful lives and minimize maintenance time.

Jahren et al., (2017) conducted research about rapid replacement techniques for bridge deck expansion joints and various maintenance and rehabilitation practices. According to the findings, faulty expansion joints facilitate penetration of corrosive material through water to piers and abutments, leading to corrosion and deterioration. Therefore, the authors suggested improved maintenance practices for the purpose of increased durability of bridges.

Lima and de Brito, (2010), a management system for road bridge expansion joints should incorporate maintenance, rehabilitation, and defect classification. The authors found that expansion joints were among the main components of bridge maintenance costs. In addition, preventive maintenance could be used as a method of reducing deterioration and leakage problems in order to increase service life.

Chang and Lee's, (2001) research was assessment of various bridge expansion joint types through surveys, inspection, and data analysis. The most typical problems found included water leakage, corrosion, and deterioration. Consequently, the researchers concluded that appropriate material, installation, and maintenance of expansion joints were necessary conditions for improvement of their performance and extended life time.

Dahir and Mellott (1987), evaluated expansion joints systems that have been installed in Pennsylvania bridges. It was stated that a huge percentage of the expansion joints were allowing water to enter the bridges, thus causing deterioration due to contamination with chlorides and corrosion. Guidelines were given in terms of appropriate expansion joint systems.

Purvis and Berger (1983), there are maintenance problems related to bridge deck expansion joints and their effects on the bridges. Poorly performing expansion joints allow the water and contaminants to enter into bridge seats, bearings, and supports. This causes damage to the structure of the bridge, thus increasing maintenance costs.

**III. METHODOLOGY**

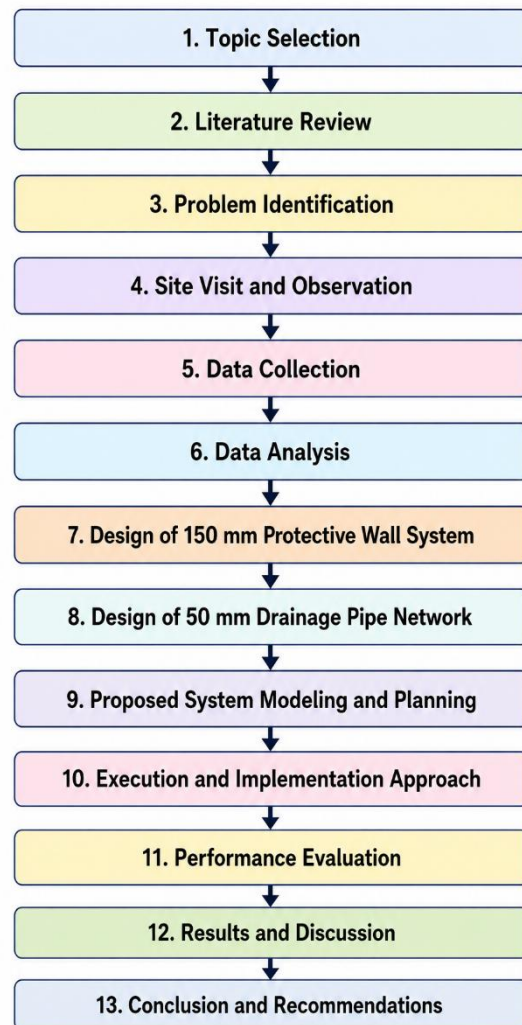


Figure 2: Flowchart of Methodology

**1. Topic Selection**

The issue that influenced the choice of the topic under investigation is the occurrence of the leakage of water at expansion joints of the elevated metro bridges. Water drops falling onto roads and other areas used by pedestrians cause numerous problems in urban territories. This project is aimed at designing a viable solution to control the leakage of water. Structural safety and sustainability of the infrastructure will be taken into consideration as well.

**2. Literature Review**

A thorough literature review was conducted relying upon articles published in journals, research papers, and other sources. The results of the previous studies contributed greatly to an analysis of the reasons for the leakage of water, deterioration of pier caps, and numerous issues that should

be addressed. Various expansion joints and drainage systems will be considered during the process.

### 3. Problem Identification

Water leakage at expansion joints of the elevated metro bridges caused by the rainfall is the main problem under discussion. Water drops falling onto roads and pathways of pedestrians create numerous troubles. Moreover, continuous seepage of water leads to its accumulation on the surface of pier caps. The issue may cause structural deterioration of such elements and even corrosion.

### 4. Site Inspection and Observation

Site inspections were made in order to examine the real conditions of metro bridge expansion joints as well as their water drainage systems. Locations of leakage, water pathways, and conditions of waterlogging were observed. In addition, conditions of the pier cap and the area surrounding this area which have been affected by the leakage were observed as well.

### 5. Data Collection

Data relevant to the condition of the expansion joints, degree of leakage, water pathways, and structural observation were gathered through field inspections. Measurements concerning the zone of the leakage and water drainage systems were taken. Data from photographic records and visual observation were recorded as well. Collected data served as input information regarding the real water leakage problems.

### 6. Data Analysis

Analysis of the collected data provided the researcher with an insight into the causes and consequences of water leakage through expansion joints. Areas where water accumulates, as well as its behaviour in relation to the pier cap, were observed in detail. Data analysis also identified sites where drainage systems were needed. This stage also served as a guide for the proposed design concept.

### 7. Design of 150 mm Protective Wall System

The idea of installing a 150 mm protective wall system has been recommended near the area of the expansion joints in order to collect the leaked water effectively and contain its flow. It will serve the purpose of preventing leakage water from entering and falling on roads or pedestrian walkways. Thus, proper planning of the system is required in terms of size and location.

### 8. Design of 50 mm Drainage Pipe System

A 50 mm drainage pipe system has been suggested for transferring leakage water through pipes from the proposed wall system to discharge at ground level. A proper drainage pipe system will not only facilitate controlled flow of water without disturbing the surrounding area but will also help avoid water stagnation around pier cap areas. Proper connectivity needs to be ensured.

### 9. Planning of Proposed Drainage Control System Model

A model of the proposed drainage control system has been created so that the concept could be understood easily along with its working principles and implementation procedures. In addition to layout planning, the system should have proper design of the proposed wall system and piping connections to ensure smooth drainage process.

### 10. Execution and Implementation Methodology

An execution method for implementation of the drainage system was also investigated in detail. Construction process, material needs, man-power requirements, and the method of installation was investigated. The implementation methodology was mainly directed towards reducing any disruption to ongoing metro bridge operations. Practical conditions at construction site and ease of maintenance were also considered.

### 11. Performance Evaluation

The performance evaluation of the proposed system is based on the efficacy of the proposed system in controlling the flow of leakage water. The performance evaluation takes into consideration the performance of the walls and pipes in ensuring proper flow of water. Issues regarding safety and efficiency of drainage were considered when evaluating performance.

### 12. Results and Discussion

The analysis of the results obtained was undertaken in context of the performance in terms of improving the drainage efficiency and increasing public safety. The drainage system proposed in this case proved capable of controlling leakage water from expansion joints. Controlling of uncontrolled water flow and protecting the piers' caps were found to be the key benefits.

### 13. Conclusion and Recommendation

The study concluded that the suggested drainage system will be effective in addressing issues relating to water leakages through the expansion joint of the metro bridge. The application of the protective wall and the pipe drainage

system enhance safety and prevents any damages to the structure. Recommendations have been made on how such a drainage system may be improved in the future.

#### IV. RESULT AND DISCUSSION

##### 4.1. PROBLEM DUE TO WATER LOGGING

Water logging caused by leakage at the expansion joint in an elevated metro bridge is a critical concern. During the rainy season, water collects around expansion joints that have been damaged or sealed inadequately and starts to leak out of them. Leakage water drips to the ground, causing water to log on the roads, pathways, and even public places located under the bridges. Continuous leaking of water on road surfaces results in slippery road surfaces and traffic hazards such as lack of visibility, which increases the probability of accidents.



Figure 3: Deterioration due to water seepage

In addition to posing dangers to public transport users, water leakage also creates problems regarding the structural elements of the bridge. Leakage of water causes moisture accumulation on structural elements and results in corrosion of concrete and reinforcement, deterioration of concrete, stains on the concrete surface, and a shortened lifespan of the structural elements. In most cases, leakage of water around structural elements of the bridges necessitates frequent maintenance work. Thus, efficient water management and drainage from expansion joints are vital for better performance of bridges.

##### 4.2. PROBLEMS FACED DUE TO WATER LOGGING

There are several challenges caused by water leakage from expansion joints of metro bridge structures. Rainwater collected within the cracks of the joint flows down onto the roadways and pathways located beneath the elevated metro

bridge structure. Water discharge from the expansion joints creates challenges for both pedestrians and motorists. There is also a risk of reduced visibility for motorists driving below the bridge. The continuous flow of water can also cause disruption during the rush hour period.

Apart from posing potential risks of accidents, water accumulation near the pier caps and roadway poses problems such as bad drainage system and unhealthy environment. It is possible for the roads to become slippery because of water accumulation, increasing the likelihood of accidents. Prolonged exposure to water may also lead to damage to the nearby structures.

Problems for People:

1. Slippery roads and footpaths
2. Possibility of an accident to pedestrians and vehicles
3. Traffic jams during rain
4. Splashes from water onto pedestrians and vehicles
5. Difficulties in seeing for motorists
6. Difficulty moving around under metro bridges
7. Puddles of water close to roadside areas
8. Damaged road surfaces and public areas adjacent to the roads
9. Bad smell resulting from water accumulation
10. Inconvenience for people during monsoons

##### 4.3. PROPOSED MEASURES FOR THE PROBLEM

The proposed 150 mm protective wall and drainage pipe system offers an effective solution for controlling water leakage from expansion joints in elevated metro bridges. The protective wall helps in collecting and restricting uncontrolled water flow near the expansion joint area, thereby preventing water from directly falling onto roads and pedestrian pathways. This improves public safety by reducing slippery road conditions, traffic disturbances, and inconvenience to pedestrians during rainfall. The wall also helps in minimizing water accumulation on pier caps, reducing the chances of concrete deterioration and reinforcement corrosion.

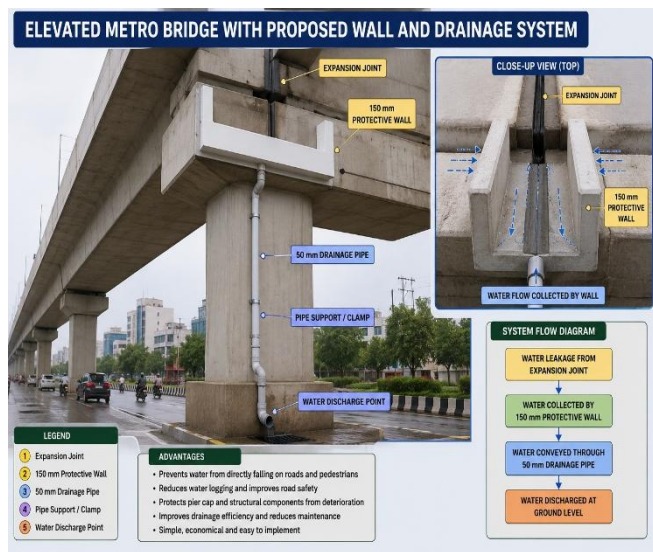


Figure 4: Drainage System for water

The 50 mm drainage pipe network safely diverts the collected leakage water to ground-level discharge points through a controlled flow path. This system improves drainage efficiency and prevents water logging near bridge components and roadside areas. In addition, the arrangement reduces maintenance requirements, improves structural durability, and enhances the overall service life of metro bridge infrastructure. The proposed system is simple, practical, economical, and can be easily implemented in existing elevated metro bridge structures for better water management and public safety.

## V. CONCLUSION

1. It was observed that the water leakage due to expansion joints in metro bridges posed several risks of injury to pedestrians and automobiles, along with water accumulation on the surface of the pier caps and structures.

2. The design of the protective wall up to a height of 150 mm proved to be a solution in the collection and limitation of water discharged from the expansion joints.

3. The installation of the drainage pipes having a diameter of 50 mm is efficient in diverting the water leakage to ground level.

4. The whole proposed system is not only safe but ensures proper drainage and longevity of structure.

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