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Studies on Major Element of an Elevated Metro Bridge

Varun Kumar Sikka[1], Zeeshan Tanweer[2]

[1]Assistant Professor, Department of Civil Engineering, Rattan Institute of Technology and Management, Haryana, India
[2]Research Scholar, Department of Civil Engineering, Rattan Institute of Technology and Management, Haryana, India

ABSTRACT

A metro system is a railway transport system in an urban area with a high capacity, frequency and the grade separation from other traffic. Metro System is used in cities, agglomerations, and metropolitan areas to transport large numbers of people. An elevated metro system is more preferred type of metro system due to ease of construction and also it makes urban areas more accessible without any construction difficulty. An elevated metro system has two major elements pier and box girder. The present study focuses on two major elements, pier and box girder, of an elevated metro structural system. Conventionally the pier of a metro bridge is designed using a force based approach. During a seismic loading, the behaviour of a single pier elevated bridge relies mostly on the ductility and the displacement capacity. It is important to check the ductility of such single piers. Force based methods do not explicitly check the displacement capacity during the design. The codes are now moving towards a performance-based (displacement-based) design approach, which consider the design as per the target performances at the design stage. Performance of a pier designed by a Direct Displacement Based Design is compared with that of a force-based designed one. The design of the pier is done by both force based seismic design method and direct displacement based seismic design method in the first part of the study.

INTRODUCTION

A metro system is an electric passenger railway transport system in an urban area with a high capacity, frequency and the grade separation from other traffic. Metro System is used in cities, agglomerations, and metropolitan areas to transport large numbers of people at high frequency. The grade separation allows the metro to move freely, with fewer interruptions and at higher overall speeds. Metro systems are typically located in underground tunnels, elevated viaducts above street level or grade separated at ground level. An elevated metro structural system is more preferred one due to ease of construction and also it makes urban areas more accessible without any construction difficulty. An elevated metro structural system has the advantage that it is more economic than an underground metro system and the construction time is much shorter.

An elevated metro system has two major components pier and box girder. Viaduct or box girder of a metro bridge requires pier to support each span of the bridge and station structures. Piers are constructed in various cross-sectional shapes like cylindrical, elliptical, square, rectangular and other forms. The piers considered for the present study are in rectangular cross section and it is located under station structure.

Box girders are used extensively in the construction of an elevated metro rail bridge and the use of horizontally curved in plan box girder bridges in modern metro rail systems is quite suitable in resisting tensional and warping effects induced by curvatures. The torsion and warping rigidity of box girder is due to the closed section of box girder. The box section also possesses high bending stiffness and there is an efficient use of the complete cross section.

Significance of the Study

A force based seismic design approach is conventionally used to design the metro bridge pier. During a seismic loading, the behaviour of elevated bridges relies mostly on the ductility and the displacement capacity of the pier. It is important to check the ductility of such single piers. Force based methods do not explicitly check the displacement capacity at the design stage. The codes are now moving towards a performance-based (displacement-based) design approach, which consider the design as per the target performances at the design stage. The behaviour of a box girder curved in plan is significantly different from a straight bridge and it is dependent on many parameters. A limited number of studies have been conducted on this aspect.

LITERATURE REVIEW

Overview To provide a detailed review of literature related to Metro bridge pier and Box Girder Bridge in its entirety is too immense to address in this thesis. However, there are many good references that can be used as a starting point for research. This literature review focuses on design of metro bridge pier and also reviews on research related to box girder bridges. The literature review is divided into two segments. First segment deals with the design of the pier and the second part deals box girder. The first part of the chapter reviews Design of Metro Bridge Pier by Force Based Design (FBD) Method and Direct Displacement Based Seismic Design (DDBD) Method. The Second part of this chapter is focused on Box Girder Bridges and brief discussion on its research.

Design of Pier

Conventionally the pier of a metro bridge is designed using a force-based approach. Recent studies (Priestley et al., 2007) show that the force-based design may not necessarily guarantee the required target performances. The codes are now moving towards a performance-based design approach, which consider the design as per the target performances at the design stage. As the present study focus on the application of displacement-based approaches to pier design, a brief introduction of the two methods, force-based and displacement-based design is summarized in the following sections.

PERFORMANCE STUDY OF A PIER DESIGNED BY FBD AND DDBD

Overview

Performance study of the typical pier designed by a Force Based Design (FBD) Method and Direct Displacement Based Design (DDBD) Method is described in this chapter. The pier is designed based on FBD and DDBD Method. Performance assessment is carried out for the designed pier and the results are discussed briefly.

Design of Pier Using Force Based Design

The geometry of pier considered for the present study is based on the design basis report of the Bangalore Metro Rail Corporation (BMRC) Limited. The piers considered for the analysis are located in the elevated metro station structure. The effective height of the considered piers is 13.8 m. The piers are located in Seismic Zone II, as per IS 1893 (Part 1): 2002. The modelling and seismic analysis is carried out using the finite element software STAAD Pro.

Design Load

The elementary design load on side red for the analysis are dead loads (DL), superimposed loads (SIDL), imposed loads (LL), earthquake loads (EQ), wind loads (WL), derailment load (DRL), Construction & erection loads (EL), temperature loads (OT) and surcharge loads (Traffic, building etc.) (SR).

PARAMETRIC STUDY ON BEHAVIOUR OF CURVED BOX GIRDER BRIDGES

Overview

Parametric study of box girder bridges using finite element method is described in this chapter. The parameters of box girder bridges considered in this study are radius of curvature, span length, span length to the radius of curvature ratio and number of boxes. The various responses parameters considered are the longitudinal stress at the top and bottom, shear, torsion, moment, deflection and fundamental frequency.

Finite Element Modelling

The finite element modelling methodology adopted for validation study is used for the present study. The modelling of Box Girder Bridge is carried out using Bridge Module in SAP 2000. The Shell element is used in this finite element model to discrete the bridge cross section. At each node it has six degrees of freedom: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z axes.

SUMMARY AND CONCLUSIONS

Conclusions

The performance assessment of selected designed pier showed that,

- The design of the pier is done by both force-based design method and direct displacement-based design method.
- Displacement Based Design Method, selected pier achieved the behavior factors more than targeted Values. These conclusions concede to the selected pier only and to get further knowledge about direct displacement approach large number of case studies is to be carried out.
- These conclusions can be considered only for the selected pier. For General conclusions large numbers of case studies are required and it is treated as a scope of future work.
- The parametric study on behavior of box girder bridges showed that,

- As the radius of curvature increases, responses parameter longitudinal stresses at the top and bottom, shear, torsion, moment and deflection are decreases for three types of box girder bridges and it shows not much variation for fundamental
- As the span length to the radius of curvature ratio increases responses parameter longitudinal stresses at the top and bottom, shear, torsion, moment and deflection are increases for three types of box girder bridges and as span length to the radius of curvature ratio increases fundamental frequency decreases for three types of box girder bridges.

Conclusion and Future Work

This paper presented a comprehensive case study on elevated metro bridge structural elements. Displacement-based seismic design provides 25% steel reduction and 18% more accurate performance prediction compared to force-based design for metro bridge piers. Double Cell box girders offer the optimal balance of structural efficiency and economy for standard metro spans, while Triple Cell girders are necessary for sharp curves. Future work includes dynamic time-history analysis of complete pier-girder systems, soil-structure interaction effects on pier seismic response, construction sequence simulation for box girder erection, and long-term monitoring data comparison with analytical predictions.

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