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Analysis of a Substructure Part of Metro Structure as Per Live Data Using Analysis Tool : A Review

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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. The Metro System is used in cities, agglomerations, and metropolitan areas to transport large numbers of people. An elevated metro system is a 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: a pier and box girder. The present study focuses on two major elements, pier and box girder, of an elevated metro structural system.
The parametric study on behaviour of box girder bridges showed that, as curvature decreases, responses such as longitudinal stresses at the top and bottom, shear, torsion, moment and deflection decreases for three types of box girder bridges and it shows not much variation for fundamental frequency of three types of box girder bridges due to the constant span length. It is observed that as the span length increases, longitudinal stresses at the top and bottom, shear, torsion, moment and deflection increases for three types of box girder bridges. As the span length increases, fundamental frequency decreases for three types of box girder bridges. Also, it is noted that 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 increased for three types of box girder bridges. As the span length to the radius of curvature ratio increases, fundamental frequency decreases for three types of box girder bridges.
In this paper we are presenting review of literatures related to analysis of girders and bridge superstructure.

Keywords : Elevated Metro Structure, Bridge Pier, Box Girder Bridge, Direct Displacement Based Seismic Design, Performance Based Design, Force Based Design.

I. INTRODUCTION

Metro Product is utilized in metropolitan areas, agglomerations, and urban centers to move large figures of individuals at high frequency. The grade separation enables the metro to maneuver freely, with fewer interruptions and also at greater overall speeds. Metro systems are usually situated in subterranean tunnels, elevated viaducts above street level or grade separated at walkouts. A heightened metro structural product is a more preferred one because of easy construction and it makes cities readily available with no construction difficulty. A heightened metro structural system has the advantage that it's more economic than a subterranean metro system and also the construction time is a lot shorter. A heightened metro system has two major components: a pier and box girder. Viaduct or box girder of the metro bridge requires a pier to aid the each length of the bridge and station structures. Piers are built in a variety of mix sectional shapes like round, elliptical, square, and rectangular along with other forms. The piers considered for that present study have been in a rectangular mix section which is located under station structure. Box girders are utilized extensively in the making of a heightened metro rail bridge and using horizontally curved in plan box girder bridges in modern metro rail systems is very appropriate in fighting off tensional and warping effects caused by curvatures. The tensional and warping rigidity of the box girder is a result of the closed portion of the box girder. This area section also offers high bending stiffness and there's a competent utilization of the complete mix section.

Fig 1. Girder Bridge

II. Literature Review

Nadavala Mahesh and G Tamilanban (2016) research paper concentrated on two major elements, pier and box girder, of the elevated metro structural system. Throughout a seismic loading, the conduct of merely one pier elevated bridge relies totally on the ductility and also the displacement capacity. The style of the pier was completed by both the pressure-based seismic design method and the direct displacement-based seismic design method in the study. Within the second part, parametric study conduct of box girder bridges is transported out by utilizing finite element methods. These parameters are utilized to assess the responses of box girder bridges, namely, longitudinal stresses at the very top and bottom, shear, torsion, moment, deflection and fundamental frequency of three kinds of box girder bridges. The moving load analysis is conducted for a live load of two lanes IRC 6 Class A (Tracked Vehicle) loading for the cases considered by utilizing SAP 2000. The longitudinal stress at the very top and bottom, shear, torsion, moment, deflection and the fundamental frequency is calculated and in contrast to Single Cell Box Girder (SCBG), Double Cell Box Girder (DCBG) and Triple Cell Box Girder (TCBG) bridge cases for a number of parameters viz., the radius of curvature, span length, and span length towards the radius of curvature ratio.

The modelling of Box Girder Bridge was transported out using Bridge Module in SAP 2000.

In the case of the Direct Displacement Based Design Method, the selected pier achieved the conduct factors greater than the targeted Values. It's observed that because the span length increases longitudinal stresses at the very top and bottom, shear, torsion, moment and deflection increases for 3 kinds of box girder bridges. Because the span length increases, the fundamental frequency decreases for 3 kinds of box girder bridges. Also, it's noted that because the span length towards the radius of curvature ratio increases responses parameter longitudinal stresses at the very top and bottom, shear, torsion, moment and deflection are increases for 3 kinds of box girder bridges. Because the span length towards the radius of curvature ratio increases fundamental frequency decreases for 3 kinds of box girder bridges.

Vivek Gajera et.al (2019) the research paper depicted the study of seismic analysis of reinforced concrete bridge piers as per provisions of Indian Road Congress (IRC) guidelines. Seismic analysis of Reinforced Cement Concrete (RCC) bridge pier was carried out as per provisions of prevailing guideline IRC:6-2017. The base shear value of IRC:6-2017 was compared with IRC SP:114-2018 which now supersedes seismic provisions of IRC:6-2017. For analysis, different span lengths of 25 m, 30 m and 36 m were used. To assess the impact of the height of piers in earthquake analysis, various pier heights such as 10 m, 20 m and 30 m are assumed. The analysis was carried out as per Elastic Seismic Acceleration Method with consideration of different zones and importance of the bridge as per IRC guidelines. The effect of vertical ground motion was further considered in the analysis. The results stated that in the case of the bridge crossing more than two railway lines, change in importance was clearly visible as base shear values were increased to 25% for 10 m and 20 m height of pier. The base shear value for 30 m height in IRC SP:114-2018 is 97.84 % higher than IRC:6- 2017 in the longitudinal direction and 102 % in the transverse direction. As per new provisions IRC SP:114-2018, the vertical component is independent of the horizontal component and now the vertical component depends on the time period of the superstructure. Hence, results summarized base shear and vertical forces have increased remarkably as per IRC SP:114-2018 compared to IRC:6-2017.

Reshma Babu and Jobil Varghese (2018) This study presents a numerical study of the response of metro rail supporting structure that is the metro pillars under lateral impact load, seismic load and blast load using, finite element techniques and recommend some retrofitting methods based on a comparative analysis of FRP rib and concrete rib to overcome the adverse effect of impact loads. FRP rib is quite effective, so it can be preferred as a retrofitting method for columns. Also, analyse the structure with a damper to retrofit the pillar subjected to seismic loads. Also compared the results of impact loading obtained from static structural and explicit dynamics. The effects of various load parameters on the metro rail supporting structure were analysed in ANSYS 16.0.

Metro rail supporting structures were analysed for various accidental load cases that may happen and different retrofitting methods were suggested. Metro pillars are safe to some extent against impact loading, and earthquakes. But if a vehicle has a weight and speed of more than 30 tons and 150 km/hrs respectively in the case of impact loading the deformation will exceed the permissible limit. As the impact area decreases deformation will also increase.If either the mass or the speed of the vehicle increases, there may be a chance of excess deformation. If an additional structure in the form of FRP rib is provided beneath the pillar, it will reduce the deformation to

50% in the case of vehicular impact. Considering the economical factor and cost of material it is found that FRP rib is more economical. It will be more effective to withstand the impact load. In the case of seismic load, if any strong earthquake occurs, it will cause more vibrations and the provision of a damper will reduce the effect to some extent by absorbing the vibration and thereby reducing the deformation.

Parimal A. Godse (2013) in the research paper, typical short and medium span bridges structure like a mono-pier, bent beam-pier frame (typical flyover) with and without elastic-foundation in the urban area was considered. Nonlinear pushover analysis procedure as recommended by ATC-40 is adopted under various seismic demands. The hinge formation for expected performance level is recorded, and compared for different boundary conditions in terms of different soil types using soil-structure interaction, ground acceleration input, and various values of ductility factors. The response parameters like base shear and roof (top) displacement for each case are studied. Evaluation of performance points for the given structure is considered (important parameter) as per capacity-demand methodology.

Consideration of Mono pier–pile as flexible foundation system has more ductile behavior than that of fixed base system provided proper reinforcement detailing is adopted. Also the hinge formations are more liable to occur near ground level in the pile system than fixed base pier. This highlights the need of modeling soil with bridges. In case of bent beam–pier frame model the results indicate that in transverse mode case, the bridge has to carry large amounts of shear forces for comparatively small roof displacement as compared to mono-pier system. However, for the longitudinal mode case, the first hinge formation is observed at intermediate pier suggesting this to be possible weakest part in this case. For multi-span bridge, under longitudinal push over, the exterior columns were observed to be weak as hinges were formed first.

Leping Ren et al (2019) a typical three-span V-shaped continuous girder bridge was analyzed in the research paper. The total length of the three-span bridge is 200 meters, consisting of two sides span (55 meters) and a middle span (90 m). The 22.5 m wide deck is supported by V-shaped beams, and the height of these beams from the bottom to the top is 22.7 m. Hollow thin-walled box girder is adopted in the section of V-shaped beams to reduce weight and improve stress. The middle beam connects the top of the V-shaped beam with the main beam and the V-shaped beams intersect at the top of the main pier to form an arch abutment. The V-angle is about 80° . The support occurs underneath the arch abutment. An alternative system fragility framework based on a new improved PCM method. Compared with PCM and I-PCM, this framework can provide an efficient and accurate approach to developing system fragility functions.

The results show that when the seismic demand parameters are the curvature and displacement of the structural section, the fragility curve risks of the components with different membership functions are different. By comparing the fragility curves of the bridge system under four damage states, the failure probability of the bridge system obtained by the seminormal membership function was higher than that obtained without considering the fuzzy failure criterion.

Vijay Bhushan Gupta and Dr. M.P.Jakhanwal (2015) research paper mentioned

detailed design loading as adopted for the planning of Metro Tunnels by Delhi Metro Rail and it can be worked out either by considering the direct loading method or by considering soil/rock mass structure interaction method. Seismic analysis of underground tunnels has also become important in India in areas that are in high seismic zones.

The authors have worked out the design criteria for the safe design checking of radial joints in the tunnel segment as adopted in Delhi Metro Rail with detailed calculations.

Meghashree T N et al (2017) the research paper presented comparative studies of metro railway stations under different loading conditions for the different seismic zones . The station comprises nine stores such as stilt parking level, first-floor level, second floor which is link bridge level, the third floor which is platform level, fourth, fifth, sixth floor for commercial activity and a terrace. The analysis of this building was done using ETABS version-15.0 for different load cases such as time history cases and response spectrum cases. Finally, responses of the building such as maximum displacement, natural period and base shear etc were done.

The results stated that the displacement in zone II was less when compared to zone III and zone V. The displacement was comparatively less in the present area of the metro than compared to the proposed area of the metro because zone III and zone V are highly prone to earthquakes compared to zone II. The base shear in zone II is less when compared to zone III and zone V because zone III and zone V are highly prone to earthquakes than compared to zone II. The building in zone II is stiffer compared to buildings in zone III and zone V because zone III and zone V are highly seismic prone areas compared to zone II.

Basavana Gowda G.M et al (2019) research paper discussed the site-specific seismic response analysis of Metro Rail Bridge situated in Bengaluru, India. For this purpose, it was necessary to consider the local site effects with Soil-Structure Interaction (SSI) for the analysis of structure during seismic excitation. Site Response analysis was done using RSPMatch2005 and SHAKE2000. The wavelet-based spectrum compatibility approach was used to generate synthetic earthquake motion for the study area. The effect of soil deposits on the propagation of seismic wave motion was investigated based on the equivalent linear approach. Static and Dynamic analysis was done using STAAD(V8i) in order to find the variation in Natural Period, Bending Moment and Deflection of the structure, by incorporating soil flexibility as compared to structures with conventional fixed-base. Site-Specific Response analysis for the site shows a Peak Ground Acceleration at the ground surface was 0.485g against 0.1g for the Bengaluru region (As per IS 1893:2002) with an amplification factor 3.17. The increase in the time period of vibration is 18% and 31% in the longitudinal direction and 11% and 16% in transverse vibration of Bridge structure for Box support and Pile support respectively compared to conventional Fixed base support. Variation in Pier Bending Moment in the longitudinal direction (20%) and transverse direction (13.6%) of the Bridge was less for the Pile support compared to the conventional fixed base support (Equivalent Static Analysis). The Deflection has increased by 74.35% in the longitudinal direction and 34.5% in the transverse direction for the pile support (Time History Analysis) compared to conventional Fixed support (Equivalent Static Analysis).

Desai Vishal and Vyas Vipul (2019) research paper conducted seismic design of metro reinforced concrete (RC) bridge Pier using direct displacement-based design (DDBD) confirming IS provisions and strength-based traditional method. Structural analysis of the pier was done by both the procedures and design carried out as per Indian railway standards for different configurations. Forced Based and Direct Displacement Based analysis procedure was carried out for Single Degree of freedom (SDOF) systems. Seismic analysis is carried out using STAAD pro software and analytical design results are obtained from FBD compared with DDBD.

Results stated that the difference in the base shear was significant for circular sections for the seismic region. However, pier heights increasing the difference in the base shear comparatively decrease & similar observations were found. In few cases, height increases the Base shear obtained from DDBD is slightly higher than that for FBD. Hence results concluded that as the base shear obtained is less, the resulting moment will be also comparatively lesser & hence the corresponding Percentage of steel (Pt %) to be provided will be less.

Prabhat kumar and Kapil soni (2019) the research paper focused 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 and conducted the performance assessment of selected designed pier showed that the Force Based Design Method may not always guarantee the performance parameter required and at the present case the pier just achieved the target required.In case of Direct Displacement Based Design Method, selected pier achieved the behaviour factors more than targeted Values.

The parametric study on behaviour of box girder bridges showed 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 frequency of three types of box girder bridges due to the constant span length.As the span length 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 fundamental frequency decreases for three types of box girder bridges.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.

Bhagirath Joshi et al (2017) research paper contained the design of metro bridge pier using direct displacement based design (DDBD) method confirming to IS provisions and traditional strength based method. Parametric analysis of the pier is considered different circular and square cross sections having different heights of 8m, 10m, 12m and 15m were carried out using FBD and DDBD procedure. The seismic assessment obtains from the analysis of the pier design using both methods were compared.

And the reinforced bridge pier of 8m, 10m, 12m and 15m height with 25m and 31m span were analysed using direct displacement based design (DDBD) and traditional forced based design (FBD) method as per RDSO: 2015. It was observed that the difference in the design loading is significant for both square as well as for the circular section for all seismic zones, when pier height increases lateral load decreases. The seismic shear of pier by DDBD is less compared to FBD. As DDBD method for pier attracts lesser seismic force compared to FBD, Which results in saving of material.

Kammari Swetha and Kn. Usha Kiran (2017) the research focused 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 and 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.

Analysis and plan of the lifted Metro Bridge according to IRC codes can be effectively done by E-TABS regarding ETABS. pier just achieved the target required. In case of Direct Displacement Based Design Method, selected pier achieved the behaviour factors more than targeted Values. 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 frequency of three types of box girder bridges due to the constant span length. As the span length increases, response parameter longitudinal stresses at the top and bottom, shear, torsion, moment and deflection are increased for three types of box girder bridges and fundamental frequency decreases for three types of box girder bridges. 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.

Harish M K et al (2017) this research discussed the Analysis of Box girder bridges under IRC loading of two different types Single cell and Multi cell with IRC standard codes followed superstructures subjected to load of heavy vehicles using CSi Bridge software 2015 version to know its structural behaviour and to decide which standard code is better when comparing the results in determining the economical section in all aspects for the assumed problem statement. Also to know about the modelling pattern using CSi bridge and to know the structural behaviour considering the bridge object responses and horizontal moments of both single cell and multi cell box girders under IRC loading conditions.

According to results obtained, the bending moment was found to be maximum for the Single cell box girder while compared with Four cell girder. It was found that the deflection obtained thanks to varied loading conditions and at service condition is well at intervals permissible limits as per IRC. The utmost vertical deflection is found to occur close to the mid-span location of the beam.

Results of bending moment and stress for self-weight and superimposed weight are same, however those are totally different for the moving load though, as a result of IRC codes offers style for the significant loading. Finally supporting this comparative study it's clear that Single cell girder bridge is economical than Four cell girder bridge.

Ravikant and Jagdish Chand (2019) the research study considers the design of bridge girders both longitudinal girders and cross girders and the span of the bridge was taken as 25m in which girders were constructed. The size of longitudinal girders was taken as 2000x500 mm and cross girders was 1500x250 mm. There were three longitudinal girders considered to have spacing 2600 mm c/c and cross girders were considered as 5000mm c/c. The design of girders was carried out using the software STAAD Pro. In the study of bridge girder design, three same models were prepared in the STAAD pro and then their loadings were changed according to IRC codes, Euro codes and AASHTO specifications respectively. According to these different loading we found the shear force, bending moment and area of steel in longitudinal girder as well as cross girder. The analysis is conducted in STAAD Pro and analysis results are compared with tables and graphs.

In comparison of all three codes, Euro code designs are over reinforced as compare to the other two i.e.

IRC codes and AASHTO specification In design of bridge girders with Euro codes shear forces, bending moment and deflection are almost double as compare to the other two i.e. IRC codes and AASHTO specifications. Design of bridge girders (up to 25m) using IRC codes are most economical and safer as compare to the other two i.e. AASHTO specifications and Euro codes. IRC codes have the best combination of loading and design methods as compare to the other two i.e. AASHTO specifications and Euro codes. Since the design of bridge girder using IRC codes acquire minimum value of deflection and bending moment so therefore IRC Class A loading is the most economical and optimum loading for the design of bridge girder in INDIA.

Hitesh Bhure et al (2018) the research paper investigated the dynamic response of a metro rail over-bridge, subjected to moving loads without considering track irregularity and train inertia effects. Bridge superstructure, piers and substructure was modelled using shell elements, rails were modelled with frame elements and the interaction between bridge deck and piers was simulated using link supports (bearings) in SAP2000 (2014). Moving load analysis was performed for two models namely the fixed base model and complete pile model. For a complete pile model, the piles are modelled using frame elements. IS 2911: 2010 was considered to evaluate the soil stiffness properties. A modal damping ratio of 5% is adopted. The finite element method was used to perform the dynamic analysis and the Newmark-β method was considered to solve the equations of motion.

Results stated that the natural frequency of a multi-span simply supported bridge plays a vital role in identifying its vertical resonance response. The maximum vertical resonant speed of the bridge deck (under single train loading) corresponds to the fundamental frequency of the bridge structure. The dynamic behaviour of the bridge structure is governed by the soil–bridge interaction under moving loads. The vertical acceleration response of the mid-span of the bridge deck is obtained at lower speeds under moving loads when SSI is considered for both the loading conditions. The fixed base model does not represent the actual dynamic behaviour of the bridge structure.

Yanling Leng et al (2020) a model bridge with a scale of 1:2 (half size) was built based on the prototype design drawings for 10-meter adjacent box beam bridges in China. The model bridge consisted of four 5-meter long reinforced concrete beams that were designed so that their stresses were equivalent to those of a full-scale beam. The compressive strength of concrete was 51.85 MPa, and the yield strength and the ultimate strength of reinforcement were 450 MPa and 580 MPa, respectively. The live-load distribution factor of the exterior beam was 0.4, which was calculated according to the design code.

Results stated that the System performance of a bridge varies with its structural conditions; for the model bridge, the redundancy factor is 0.73 for the originally intact system, 0.56 for the damaged system with a seriously cracked edge hinge joint, and 0.47 when the "Single Plate Load Effect" appears. Bridges with this type of hinge joints do not have adequate levels of redundancy and robustness. Deflection distribution factors can be used in the inelastic analysis for the system performance distribution of adjacent beam bridges. +e new framework for redundancy rate calculation based on deflection distribution factors agrees well with the existing approaches with less computing complexity.

III. CONCLUSION

Here authors illustrated that bridge structures require special analysis considering vehicular loading and lateral loads. These forces examined were not yet analysed by and research scholar till date.

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