AIJREAS VOLUME 2, ISSUE 1 (2017, JAN) (ISSN-2455-6300) ONLINE
ANVESHANA'S INTERNATIONAL JOURNAL OF RESEARCH IN ENGINEERING AND APPLIED SCIENCES

STUDIES ON MAJOR ELEMENTS OF AN ELEVATED METRO BRIDGE BY USING BY USING STAAD PRO

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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. 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.

Bridges are the lifelines and supporters for the improvisation of the road network. Not only do the bridges help in traffic flow without any interference but also maintain the safety of roads. Due to this reason the bridges design has gained much importance. This project is basically concerned about the analysis and design of elevated metro bridge by STAAD Pro using IRC Loading. which contains a span of 100m X 16m and has a 4-girder system. The objective is to check the result for particular input design, properties and parameters and the approach has been taken from AASHTO standard design. The nodal displacement, beam property, vehicle loading details, concrete design can be easily found out performing the analysis and design method.

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

INTRODUCTION

A metro system is an electric passenger railway in an urban area. Characteristics of a metro system are the high capacity and frequency at which it transports people and the grade separation from other traffic. The grade separation allows the metro to move freely, with fewer interruptions and at higher overall speeds. Furthermore, there are fewer conflicts between traffic movements, which reduce the number of accidents, making it a safer way to travel. Grade separation for metro systems is realised by placing it in underground tunnels, elevated above street level or grade separated at ground level. Often a metro system is a combination of these three options. Beside the traditional metro using electric multiple units on rails, nowadays one can find also some systems using magnetic levitation or monorails. By changing the capacity of the trains, the frequency and the distance between the stations, variations on traditional metros like people movers and light metros have appeared. At the same time, technological improvements have allowed new driverless lines and systems. With all these variations in metro systems it is sometimes difficult to determine to what type a system belongs. Despite all these variations, they have in common that they are executed more and more as elevated railways in dense urban areas.

An elevated metro system has two major components pier and box girder. A typical elevated metro bridge model is shown in Figure. Viaduct or box girder of a metro bridge requires pier to support the 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. A typical pier considered for the present study is shown in Figure.

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 torsional and warping effects induced by curvatures. The torsional 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. Box girder cross sections may take the form of single cell, multi spine or multi cell as shown in Figure.

Bridges

The structure of an elevated metro railway is similar to that of a bridge. A bridge is a structure that crosses over a river, valley or other obstruction. In this way it permits a safe and smooth passage of vehicles, trains and pedestrians. For an elevated metro railway obstructions are for instance roads, buildings and rivers. By elevation of the railway it will be grade separated from other modes of traffic. This enables the metros to drive fast and safe without hindrance. A bridge structure can be divided into an upper part (the superstructure), which consists of the deck, the floor system and the main trusses or girders, and a lower part (the substructure), which consists of piers, columns, footings, piles and abutments. The superstructure provides horizontal spans and carries traffic load directly. The substructure supports the horizontal spans elevating above the ground surface.

For the type of structure of an elevated railway there are many possibilities. The type of bridge is usually determined by factors such as loads, surrounding features, soil properties, bridge dimensions, aesthetics, transportation of construction materials, erection procedures, construction cost and construction time. The choice for a bridge type is thus dependant of many factors and besides, it is integrally related to the chosen material. The different bridge types all have their own advantages and disadvantages. These qualities together determine the appropriate span range for a certain bridge type.

Span range for common bridge types

The span ranges given in Table 1 are very wide and overlap each other. This table does thus not give information about which bridge type should be chosen. In order to choose the desired bridge type the most common bridge types are briefly described in this chapter. This will also result in a more refined overview of the span range of the bridge types. Together with information about the construction methods and maintenance this should give a better understanding of bridge types and its possibilities.

Analysis bridge types

The bridge types above are the most common bridge types. They all have their own advantages and disadvantages as briefly described. In Appendix 4: Span range for bridge types, the appropriate span ranges for the above described bridge types are given. This gives a clear overview and easily shows the possible bridge types for a specific span. There is a division between the small-span and long span bridge types as the span range between the bridge types is too large in order to give a clear overview.

The maximum span for the different bridge types is deducted from straight highway bridges. Because the load for a metro bridge is less it can be noticed that the curvature of the elevated structure/torsional resistance is important to determine the span length. It can be concluded that the choice of the bridge type is not only determined by span range but is among other things also determined by the application within the city. The final decision for a certain bridge type can be made by taking everything into consideration and not only the largest span as this for instance creates a smaller physical barrier

Incremental launching

For bridge decks greater than 250 metres in length, the incremental launching method can be considered. With this method of construction the bridge deck is built in sections by pushing the structure outwards from an abutment towards the pier. The sections are cast contiguously, one after another, and are then stressed together. The superstructure is launched over temporary sliding bearings on the piers until the bridge is completed. In order to keep the bending moment low in the superstructure during the extrusion phases, a launching nose made of steel is attached to the front of the bridge deck. In-situ deck segments range in length from 5 to 30 metres. The spans should not exceed approximately 60 metres and the bridge sections must be constant. Furthermore the superstructure of the bridge has to be continuous over the whole length and straight or have a constant curvature.

Arch construction

Nowadays arch bridges are mostly built of reinforced or precast concrete. Arch construction often uses expensive formwork and scaffolding. The development of modern construction methods has made it possible to construct without the need of this traditional supporting system. However, the abutments still must be well founded on rock or solid ground. Arch bridges are often the most economical choice for bridges which cross over inaccessible landscape. Two construction methods which are most commonly used are:

 Cast-in-situ free cantilever method

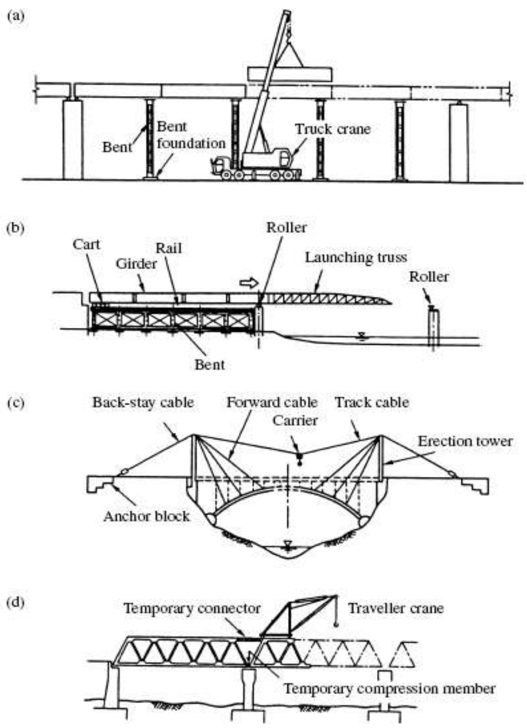
This involves the partially built arch being tied back to rock anchors in the valley slopes.

 Slip formed sections

This involves half arch section being held vertically over each abutment and then rotating each arch section into position.

Steel bridge construction

Steel bridge components are fabricated into members in the workplace and are then transported to the construction site for assembly. Ideally all constructional work should be completed in the workplace to get the highest quality in the minimum construction time. Maximum length and size are preferred for the members of the bridge. However, the size of the elements is limited by transportation and erection restrictions. Common construction methods for steel bridges are crane erection, launching truss erection, cable erection and cantilever erection. The best way to connect the members is by bolting as welding on site is more complicated and expensive.



In Past, advanced mathematical methods were used for the analysis of the large structures such as Bridges, buildings etc. Those methods are elaborated techniques. So it takes too much time for designer to concentrate on the calculations. Now a days, STAAD. Pro Software is being widely used for the analysis and design of buildings, towers etc. In this project, STAAD Pro. has been used for the analysis and design of a elevated metro bridge in connection with STAAD beava. It becomes much more easier to assign the properties and other specifications in creating elevated metro bridge by the STAAD Pro. software.

The various properties are to be considered in the analysis and design of the elevated metroof a bridge which include section property, plate thickness, dead load, live load etc. Dead Load consists of its own weight and portion of weight of superstructure and fixed loads also. Live loads are caused by vehicle moving over the bridge

OBJECTIVE

The project gives an idea about the analysis and design of Elevated metro Bridge using IRC Loading 70R by STAAD.Pro V8i. Here the model is being designed as per IRC 70R loading which is applicable on all roads on which the permanent bridges and culverts can be constructed. Analysis and Design process by STAAD Pro determines the performance of Structures. The designing by the software saves the design time and by this way we can check the safety of the structure very easily.

LITERATURE REVIEW

In the past three decades, the finite element method of analysis has rapidly become popular and effective technique for the analysis of box girder bridges. So many researchers conducted studies on Box girder bridges by using finite element method. Khaled et al. (2001, 2002) have conducted detailed literature review on analysis of box girder bridges. Based on Khaled et al.(2001, 2002), the following literature review has been done and presented. Malcolm and Redwood (1970) and Moffatt and Dowling (1975) studied the shear lag phenomena in steel box-girder bridges. Sisodiya et al. (1970) approximated the curvilinear boundaries of finite elements used to model the curved box-girder bridges by a series of straight boundaries using parallelogram elements. This approximation would require a large number of elements to achieve a satisfactory solution. Such an approach is impractical, especially for highly curved box bridges. Komatsu and Nakai (1966,

1970) presented several studies on the free vibration and forced vibration of horizontally curved single, and twin box-girder bridges using the fundamental equation of motion along with Vlasov's thin-walled beam theory. Field tests on bridges excited either by a shaker or by a truck travelling at various speeds showed reasonable agreement between the theory and experimental results.

Chu and Pinjarkar (1971) proposed a finite element formulation of curved box-girder bridges, consisting of horizontal sector plates and vertical cylindrical shell elements. The method can be applied only to simply supported bridges without intermediate diaphragms.

Chapman et al. (1971) carried out a finite element analysis on steel and concrete box-girder bridges to study the effect of intermediate diaphragms on the warping and distortional stresses.

Lim et al. (1971) proposed an element that has a beam-like-in-plane displacement field. The element is trapezoidal in shape, and hence, can be used to analyse right, skew, or curved box-girder bridges with constant depth and width.

William and Scordelis (1972) presented an elastic analysis of cellular structures of constant depth with arbitrary geometry in the plane using quadrilateral elements.

Cheung and Cheung (1972) described the application of the finite-strip method for the determination of the natural frequencies and mode shapes of vibration of straight and curved beam-slab or box-girder bridges.

Tabba (1972) utilized the thin-walled beam theory to estimate the natural modes and frequencies of a curved simply supported girder of asymmetric multi cell section. Results from testing two curved cellular plexiglass models were used to verify the proposed method.

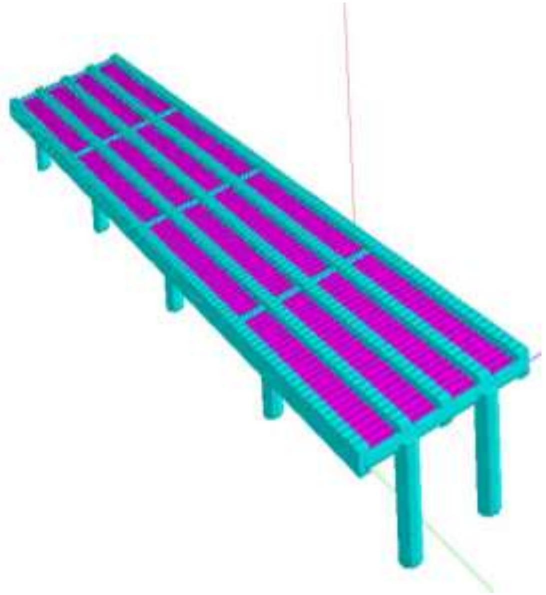
Fam (1973) studied the behaviour of curved box-girder bridges using the finite-element method for applied dynamic loads. Results from testing a single-cell plexiglass model having high curvature were used to verify the proposed method.

Armstrong and Landon (1973) and Greig and Armstrong (1973) reported the results of a field study of a curved twin-spine composite box-girder bridge in Springfield, Mass.

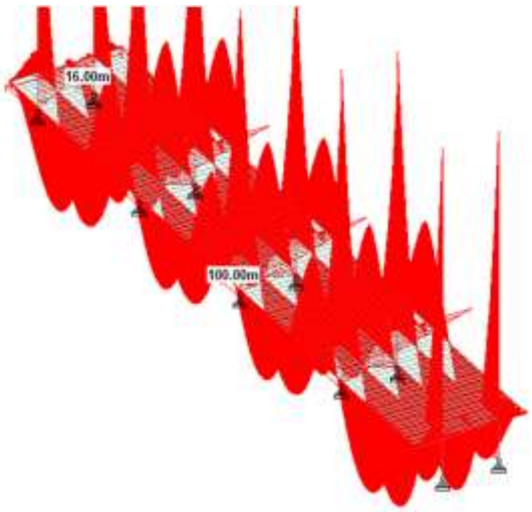
METHODOLOGY

DESIGN OF PIER USING FORCE BASED DESIGN

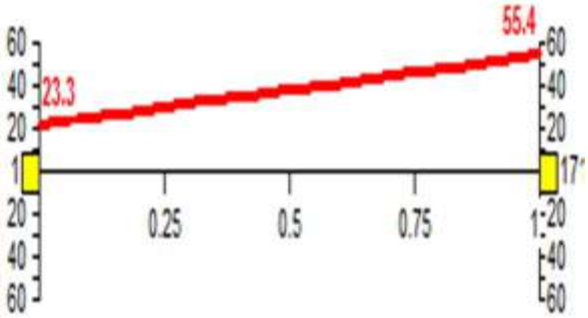
STAAD. Pro. in space is Operated with units Metre and Kilo Newton. The geometry is drawn and the section properties are assigned. Fixed Supports are taken. Quadrilateral meshing is done followed by assigning of plate thickness.3D rendering can be viewed for the geometry. Loads are defined by the loads and definitions. By Post Processing mode, Nodal displacement, Max. Absolute Stress distribution for the bridge can be viewed. Run analysis is operated. Max. Response by the IRC Class 70R loading is done by STAAD.beava. The deck is created in bridge deck processor, this being the first step of STAAD.beava. In STAAD.beava, roadways, curbs, vehicular parameters are provided. Lastly transfer of load is done into STAAD Pro. For further analysis and design. All the Max response criteria are checked Mx,My,Mz stresses etc for different members elements. The load positions and reactions, beam forces and moments,etc. are determined. The concrete is designed as per IS Code.



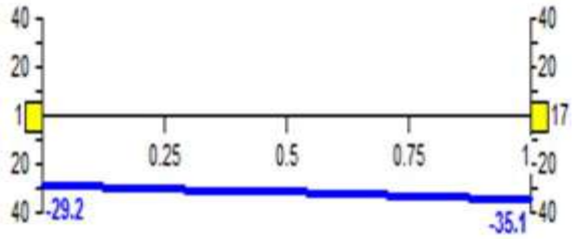
3D Rendering View



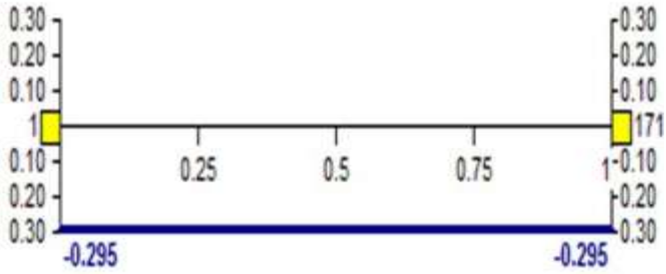
Bending Z



Mz(kNm) Beam Graph



Fy(kN) Beam Graph



Fx(kN) Beam Graph

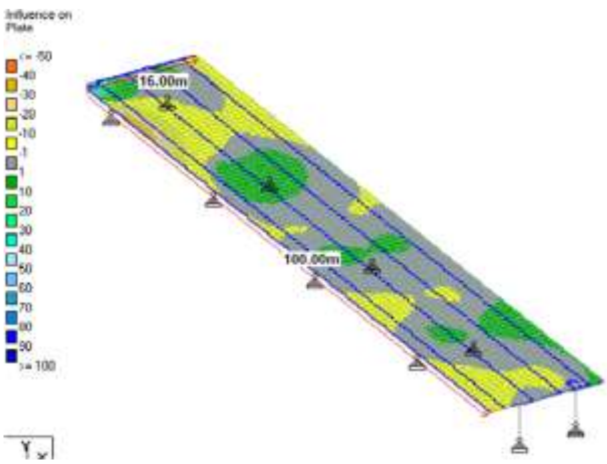


Plate Stresses

RESULTS AND DISCUSSIONS

The output data for the IRC Class 70R bogie loadings are considered which include nodal displacement, nodal displacement summary, beam forces, beam end displacements, beam end displacement summary, reactions, reaction summary, axial forces, beam moments, live load effect and many more by STAAD. Pro V8i. As all of them cannot be described in this project, the data result tables being very large, some of the glimpse of the output results in the tabular forms is provided in this below

Vehicle Loading

The loading vehicle details are given:
Design Code = IRC Chapter 3
Loading Class = Class 70R Loading
Max. Effect = 9.39626m
Unit of Length = m
Unit of Force = kN
Combination Factor =1
No. of Traffic Lanes = 6

Traffic Lane number 1

Lane Factor = 1
The loading vehicle details are
Width = 2900
Front Clearance = 31675
Rear Clearance = 31675
No. of Axles = 3

Vehicles travel in the roadway direction

Vehicle No.	Position x	Position y	Orientation
1	17.171	0.05	0

End Lane
Traffic Lane No. 2
End Lane
Traffic Lane No. 3
Lane Factor 1
The loading vehicle details are
Width = 2900
Front Clearance = 31675
Rear Clearance = 31675
No. of Axles = 3
Vehicles travel in the roadway direction

Vehicle No.	Position x	Position y	Orientation
1	11.9501	88.219	1.5708
2	11.9501	49.689	1.5708
1	12.05	-4.35305	1.5708

End Lane
Traffic Lane No. 4
Lane Factor 1
The loading vehicle details are
Width = 2900
Front Clearance = 31675
Rear Clearance = 31675
No. of Axles = 3
Vehicles travel in the roadway direction

Vehicle No.	Position x	Position y	Orientation
1	8.0501	97.7264	1.5708
2	8.05005	50.1894	1.5708
1	7.95	-2.85188	1.5708

End Lane

Traffic Lane No. 5

Lane Factor 1
The loading vehicle details are
Width = 2900
Front Clearance = 31675
Rear Clearance = 31675
No. of Axles = 3
Vehicles travel in the roadway direction
End Lane

Traffic Lane No. 6

Lane Factor 1

Vehicle No.	Position x	Position y	Orientation
1	3.95	99.72	1.5708
2	3.95	49.689	1.5708
1	4.05	0.65	1.5708

It cuts time and gives safe values required for its design.

By this approach of design, maximum loads created by STAAD. behava are transferred into STAAD Pro. and the analysis and design is then carried out.

The loading vehicle details are
Width = 2900
Front Clearance = 31675
Rear Clearance = 31675
No. of Axles = 3
Vehicles travel in the roadway direction

Vehicle No.	Position x	Position y	Orientation
1	-1.74	88.71	1.5708
2	-1.74	50.18	1.5708
1	-4.43	-4.35305	1.5708

End Lane

Concrete Design Details

The concrete is designed for element no. 61 which gives the following result:

For

FY: 413.682MPA;

FC: 27.579MPA;

Cover (top):19.05mm;

Cover (bottom): 19.05mm

Longitudinal Direction-only minimum steel required;

Transverse Direction – only minimum steel required;

LONG.REINF Sq.mm/mm	MOM-X/LOAD Kn-mm/mm	Trans.reinf Sq.mm/mm	OM-Y/LOAD Kn-mm/mm
TOP-0.540	24.16/2	0.540	0
BOTTOM-0.545	54.76/1	0.782	1

CONCLUSIONS

1. Analysis and design of the elevated Metro Bridge as per IRC codes (here IRC 70R loading) can be easily done by STAAD.Pro. in connection with STAAD.beava. mechanism is well understood.
2. The maximum resultant nodal displacement is for node 1529; 0..015mm in x, -51.203mm in y and -.287mm in x.
3. The maximum resultant beam end displacement is for beam 1930 and node 1529 equivalent to 51.204.
4. The maximum and minimum values for beam maximum forces by section property are computed for axial, shear and bending.
5. The effect of vertical loading for 6 traffic lanes showing width, front clearance, rear clearance, no. of axles, positon in x, position in y with orientation can be determined. The orientation varies from 0 to 1.5708.
6. The concrete design for element 61 gives the top and bottom longitudinal reinforcement is 0.540 and 0.545. The top and bottom transverse reinforcement are 0.540 and 0.780 for element 61. Similarly, for other element, it can be found out.
7. It is must for today's engineers, designers, research scholars to make an effective contribution to what is the purpose of each high quality design and for the improvement of quality of environment in which we all are residing. Thus evolution of software must be properly used so that it meets the beneficiary needs.

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