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HORIZONTAL LAYOUT BEND OF BRIDGES STRUCTURE EFFECTS ON THE STATIC DESIGN INTERNAL FORCES: EVALUATION AND OPTIMIZATION STUDY

Ali Fadhil Naser and Hussam Ali Mohammed
Department of Building and Construction Engineering Techniques, Al-Mussaib Technical College,
Al-Furat Al-Awsat Technical University, Iraq
E-Mail: ali_hu73@yahoo.com

ABSTRACT

Horizontal layout bend was an important factor in the design of bridges structure depending on nature of bridge location within construction area. The aim of this study was to evaluate and optimize the different designs of bridge horizontal layout bends and compare the results with horizontal layout straight of bridge by depending on the application of static analysis according to finite element analysis method. Static analysis results showed that the straight model had the minimum values of static internal forces. Therefore, this model gave higher resistance to effects of applied loads and the horizontal layout straight of this type of bridges was suitable for design.

Keywords: horizontal layout, box girder, bridge, finite element, static, dynamic.

1. INTRODUCTION

Bridges constitute a critical link in the highway network and require a large capital investment for construction and maintenance. The bridge is a civil structure which is constructed to cross a dell, highways, rails of trains, waterway, and others barriers [1], [2] [3].

Bridges can be designed to carry and allow the loads to cross the obstacles. These loads include vehicles loads, trains, peoples, and animals. There are four types of bridges can be used. These types include beam bridges, arch bridges, cantilever bridges and suspension bridges. Bridges can deflect when subjected to different types of loads. Bridges must have enough stiffness to resist the effects of loads. Each member of bridge must be strong enough [4].

The layout and position of the bridge structure depends on the traffic volumes and conditions, therefore, the bridge must be located to serve the traffic movement between two sides of bridge structure. Generally, different traffic situations and site state will influence the selection of bridge position and layout. The most important factor is layout of bridge with respect to topographic crossing when the position of bridge is decided to select [5].

The pre-stress scheme of concrete is known as the application of pre-tension loads of concrete structure before subjected to service loads. It is a type of concrete that internal stresses are introduced by means of high strength pre-strained steel tendons. The purpose of this scheme is to develop the structural performance in particular ways. The pre-stressing concrete consist of two categories of pre-stressing, pre-tensioned pre-stressed and post-tensioned pre-stressed [6], [7], [8], [9], [10].

Box girders is widely used in the construction of the highway and city pre-stressing concrete bridges and it has a good structural performance, stiffness, bending resistance, high employment of section, and good economic income [11].

The most important points of structural analysis is to review the static responses of a structure and to get the distribution of internal forces system by determining vertical displacement (vertical deflection), tension stress, axial force, bending moment, torsion moment, and compressive stresses. According to different types of applied loads, a linear elastic model is assumed in the structural analysis. The finite element method (FEM) is a appropriate employment to find solution of differential equations for the structural engineering functions [12], [13], [14]

Analysis of bridge includes engineering software models, which are using suitable material properties, boundary situations, and different types of loads. Parts and bonds joints of bridges are designed to carry all possible loads such as structure dead load, prestressed load, vehicles load, wind load, and temperature load [15], [16].

There are two methods of bridge analysis. These methods are static method and dynamic method. The selection of suitable analysis method depends on a number of factors. These factors include the objective of analysis, significance of bridge structure, methods obtainable for analysis, type of bridge, and soil conditions. Most engineering software are using finite element in the analysis. The finite element method is known instrument for the answer of complex structural engineering problems. In this method, the real range is replaced by an equivalent idealized structure composed of separate elements, referred to as finite elements, connected together at a number of nodes [17], [18].

The aim of this study is to evaluate and optimize the different designs of bridge horizontal layout bends and compare the results with horizontal layout straight of bridge by depending on the application of static analysis according to finite element analysis method.

2. DESCRIPTION OF BRIDGES MODELS

In this study, continuous box girder with two cells bridge is used. Nine models of bridges are selected according to horizontal layout bend type. All models have same span length, width, and depth which is equivalent to

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20m, 10m, and 1.8m respectively. The total length of bridges models is 120m which is distributed by six spans. Table-1 lists horizontal layout bend type. Figure-1 shows the models of box girder bridge.

3. CONCRETE AND REINFORCED STEEL PROPERTIES

The strength grade of concrete is C40 and the modulus of elasticity is 24855MPA. The mass per unit volume is 2.4 kN/m^3 and the poison ratio is 0.2. The shear modulus is 10357MPa. For pre-stressing tendons, the types of tendon is A416 Gr270 and the modulus of elasticity is 196500MPA. The mass per unit volume is 7.84 kN/m^3. The minimum yield stress is 1690MPa and the minimum tensile stress is 1861.5MPa.

4. STATIC ANALYSIS RESULTS AND DISCUSSION

Sap2000 is used in the analysis of bridges models by adopting finite element method. Static analysis is used to determine the downward vertical deflection, tension stress, compression stress, positive bending moment, and negative bending moment.

4.1 Downward vertical deflection

Figure-2 illustrates the maximum values of downward vertical deflection due to static analysis results of bridges models. From this figure, it can be shown that the horizontal layout bend No. i model (straight-curve right-straight-curve left- straight) gives the maximum value of downward vertical deflection which is 16mm, and the minimum value of downward deflection which is appeared within horizontal layout bend No. a model (straight) and it is equivalent to 12mm, indicating that the straight model is suitable for bridge design according to downward vertical deflection factor because of the resistance of external loads is enough.

4.2 Tension and compression stresses

Tension and compression stress is important factor in evaluation of structural performance of bridges structure because of it can be determined the structural cracks locations. The maximum values of tension stresses of bridges models can be shown in Figure-3. The model No. f (curve left-straight) is appeared the higher value of tension stress which is 5.69MPa, indicating that the cracks will be appeared in this model, and model No. a (straight) has the minimum value of tension stress which is 3.83MPa. For compression stress, the higher value is 9.98MPa which is appeared in model No. g (straight-curve left-straight) and the minimum value can be shown in model No. a (straight)) which is 7.97MPa. Therefore, the straight model is suitable for design according to tension and compression stresses.

Table-1. Horizontal layout bend type.

Horizontal Layout Bend No.	**a**	**b**	**c**	**d**	**E**	**f**	**G**	**h**	**i**
Horizontal Layout Bend Type	Straight	Straight - bend left	Straight -bend left-bend left	Curve left	Straight - curve left	Curve left-straight	Straight - curve left-straight	Straight - curve left-Straight - curve left-Straight	Straight - curve right-Straight - curve left-Straight

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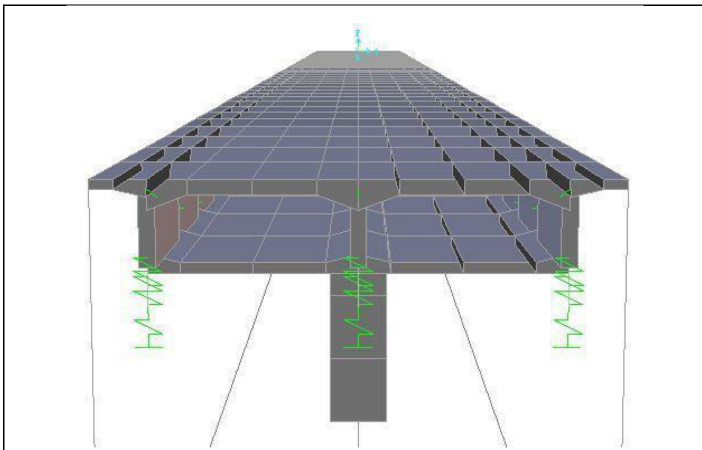
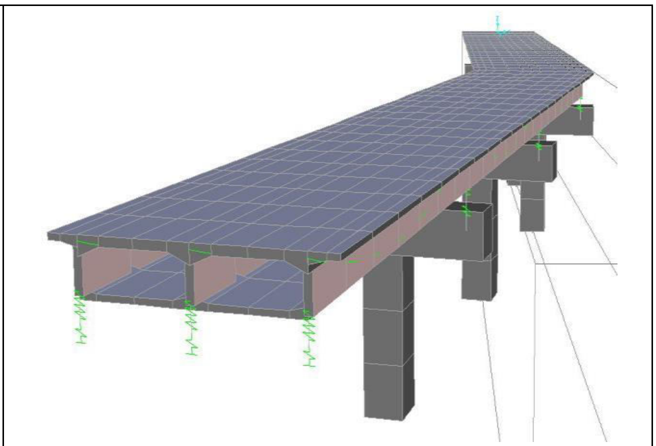
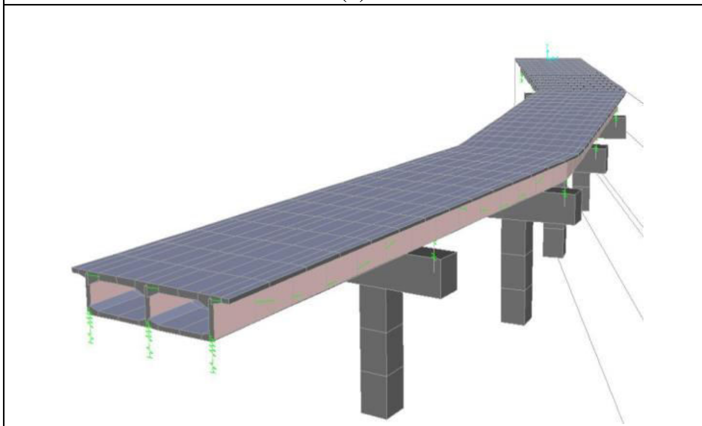


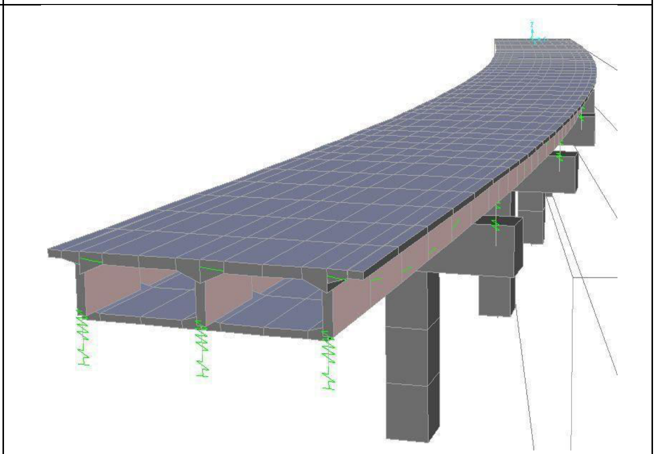
(a)



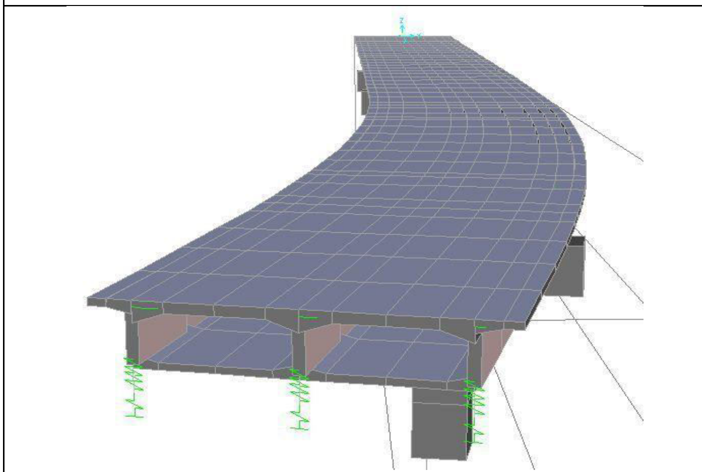
(b)



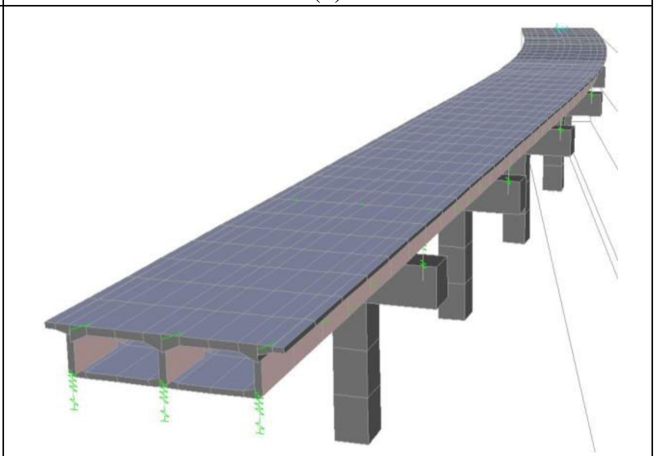
(c)



(d)



(e)



(f)

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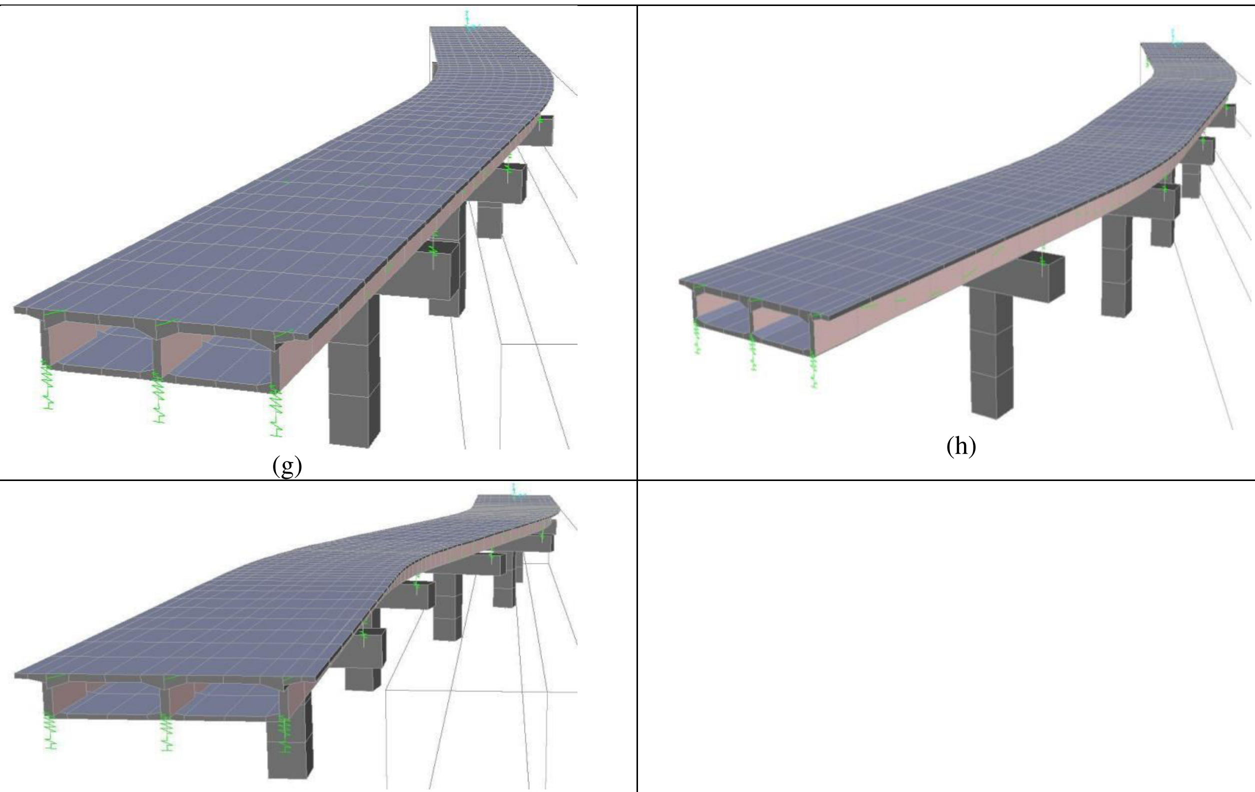

(g) (h)

(i)

Figure-1. Models of box girder bridge: (a) Straight, (b) Straight-bend left, (c) Straight-bend left-bend left, (d) Curve left, (e) Straight-curve left, (f) Curve left-straight, (g) Straight-curve left-straight, (h) Straight-curve left- Straight-curve left-straight, (i) Straight - curve right- straight-curve left- straight.

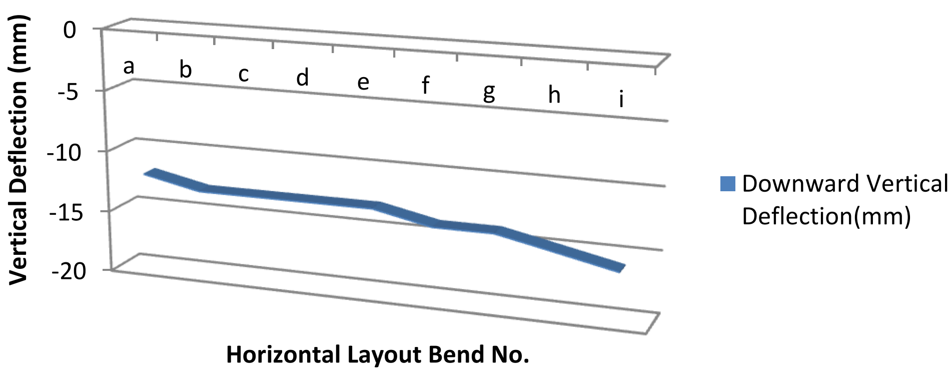

Figure-2. Maximum values of downward vertical deflection.

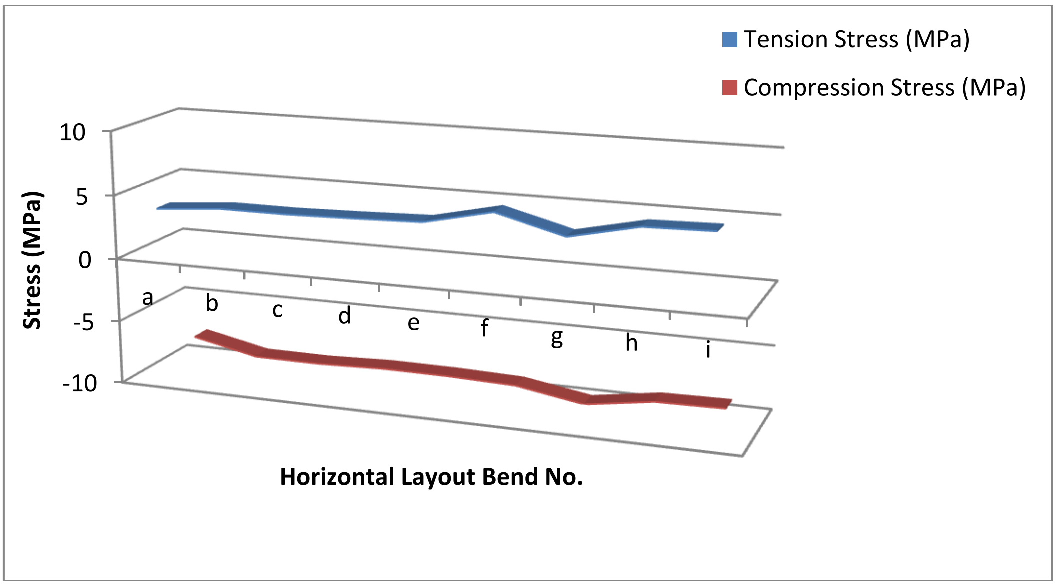

Figure-3. Maximum values of tension and compression stresses.

4.3 Positive and negative bending moment

The maximum value of positive and negative bending moment is 21930kN.m and 20983kN.m within model (No. i) respectively. Model (No. a) is appeared minimum values of positive and negative bending moment which are 15737kN.m and 18567kN.m respectively. Figure-4 shows the maximum values of positive and negative bending moment of bridges models for different types of horizontal layout bends.

The above results indicate that the model No. a (straight model) has the minimum values of static internal forces. Therefore, this model gives higher resistance to effects of applied loads and the horizontal layout straight of this type of bridges is suitable for design because of the structural parts of bridge has enough elasticity and resistance for internal and external loads. Therefore, the designer can be avoided the various horizontal layout bend designs as much as possible and select straight line for bridge length.

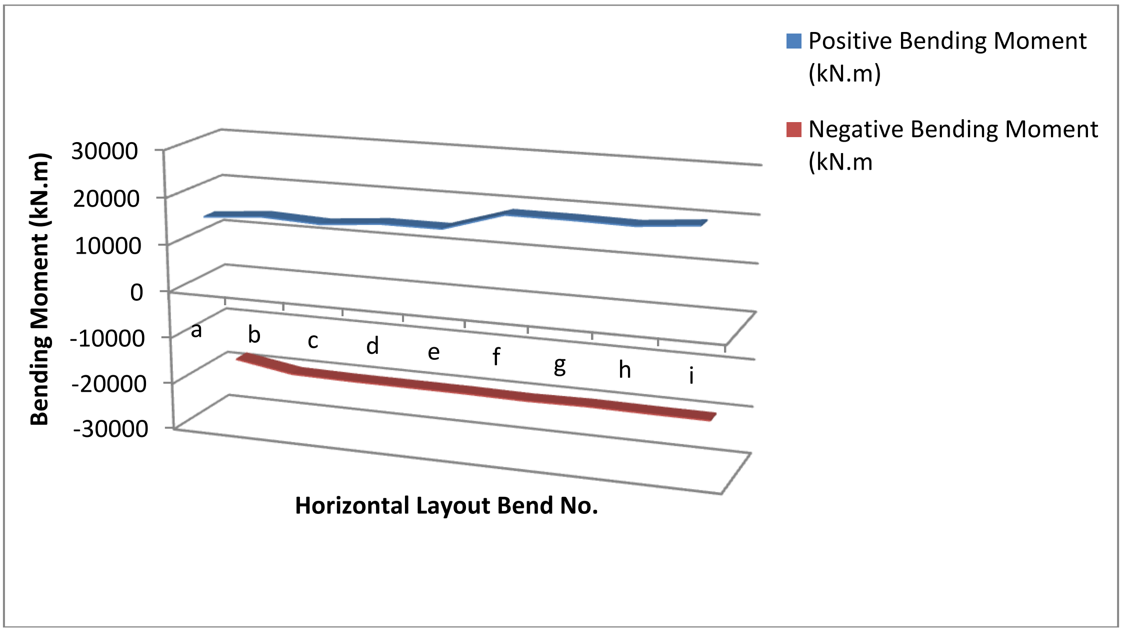

Figure-4. Maximum values of positive and negative bending moment.

5. CONCLUSIONS

Prestressed concrete box girder bridge model were selected as a model to study the effects of using different types of horizontal layout bends on the static design internal forces. There are nine types of horizontal layout bends were used in this study. All models had same span length, width, and depth which is equivalent to 20m, 10m, and 1.8m respectively. The total length of bridges models is 120m which is distributed by six spans. The results of static analysis shown that horizontal layout bend No. i model (straight–curve right-straight-curve left-straight) gave maximum value of downward vertical deflection which was 16mm, and the minimum value of downward deflection which was appeared within horizontal layout bend No. a model (straight) and it was equivalent to 12mm. The others results of internal forces shown that the model No. a (straight) had the minimum values of static internal forces. Therefore, this model gave higher resistance to effects of applied loads and the horizontal layout straight of this type of bridges was suitable for design.

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