Determination of Performance of Different Type of Bailey Bridge of Different Configurations

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Abstract

This paper provides a numerical determination of the performance of various type of Bailey bridge configurations, in which the main objective is to determine the maximum response of different configuration. Bailey bridges are modular steel structures made up of interlocking panels connected by pins, allowing them to be quickly assembled and easily adapted to different needs. These modular bridge systems are more susceptible to the effects of dynamic loading due to their flexibility. Four different configurations (Single Truss-Single Storey (SS), Double Truss-Single Storey (DS), Triple Truss-Single Storey (TS), Triple Truss-Double Storey (TD))for 30m span and Five different configuration(Single Truss-Single Storey (SS), Double Truss-Single Storey (DS), Triple Truss-Single Keywords Storey (TS), Triple Truss-Double Storey (TD), Double Truss-Double Story (DD))for 60m span were modeled in CSI Bridge and moving load analysis and buckling analysis has been conducted in order to determine the maximum response of bailey bridge members. In order to compare the maximum responses, moving load case is performed for all the structures considering IRC class A vehicle Load. The study shows that TD configuration has higher buckling resistance and increasing number of panels in vertical direction and horizontal direction maximum response mid-span deflection decreases significantly.

1. Introduction

A Bailey Bridge is a prefabricated truss bridge type whose symmetric bending moments varies from maximum to zero from the center span to the end posts [1]. These are bridge systems composed of steel panels connected by pins, which utilize a steel superstructure, are fabricated into module and can be quickly installed in the field. Bailey-type modular bridges were the first panel bridges ever developed. They were originally designed during World War II for easy transportation and quick assembly. Their strong and efficient design has allowed them to remain in use over time with only minor changes in shape, materials, and accessories. During their development, different panel designs were tested, including M, N, and K-shaped bracing between the top and bottom chords. The final design featured two rolled steel channels for the horizontal member, vertical members made from rolled steel joists, and diamond-shaped bracing for added strength.

The primary design parameters that need to be accurately predicted are the buckling behavior and the ultimate strength of the panel [2]. Panel bridges are commonly constructed to replace damaged bridges caused by earthquakes, floods, or hurricanes, and serve as temporary solutions during construction. However, today, they are also used as permanent structures. However, the Ultimate load-carrying capacity and performance of panel bridges are not readily available in public literature [3]. Since it is prefabricated in factories, no specific design adjustments are made based on site conditions. For various studies it is clear that if no proper layout of Bailey bridge configuration is installed according to site conditions, it may cause critical failure consequences. Lots of Bailey bridges collapses have been due to overloading, Lack of attention during construction and various other factors. Despite numerous failures and collapses, no new research literature is available. To mitigate these effects, it is essential to understand the load-carrying capacity of various Bailey bridge configurations and the behavior of each bridge component under real loading conditions. Various configurations of Bailey Bridges i.e., Single Truss-Single Storey (SS), Double Truss-Single Storey (DS), Triple Truss-Single Storey (TS), Triple Truss-Double Storey (TD), Double Truss-Double Storey (DD) are utilized here to determine maximum response of each member of   the bridge component on vehicle loading conditions. Hence, it is very much helpful and beneficial to understand and know the true behavior of the Bailey bridges for transportation.

2. Objective of the study

The main objective of this study is to determine the maximum response in different type of configuration of existing Bailey Bridge.

3. Methodology

A finite element analytical model representing the real bailey bridge has been prepared in CSI Bridge v25 i.e., Four different configurations (Single Truss-Single Storey (SS), Double Truss-Single Storey (DS), Triple Truss-Single Storey (TS), Triple Truss-Double Storey (TD) for 30m span and Five different configuration(Single Truss-Single Storey (SS), Double Truss-Single storey (DS), Triple Truss-Single (TS), Triple Truss-Double storey (TD), Double Truss-Double storey (DD) for 60m span were modeled. The bridge chosen for the study is based on the standard plan for Bailey bridge from department of public works and highways, republic of Philippines [4] which has been extracted from its official website. For study purpose, 30m and 60m single span with 4m lane width is considered. Moving Load analysis using IRC class A vehicle has been performed in order to determine the maximum response of different bailey bridge. Also, buckling analysis has been carried out to determine the buckling load factor for each configuration of Bailey bridge.

4. Modelling

Nine different types of Bailey bridge configuration i.e, four different configurations for 30m span and five different configurations for 60m span were modeled in CSi Bridge v25. All sections and their dimensions were taken from an actual Bailey bridge, following the standard plan for Bailey bridges provided by the Department of Public Works and Highways, Republic of the Philippines [4]. The bailey panels have its dimension 10 feet x 5 feet as shown in figure 1 and material used was steel of grade Fe345. The different bridge configuration as shown in figure 2 and figure 3 were of single span of carriageway width 4m. Details of sections used in modeling bridges are illustrated in table 1.

As CSi Bridge the most powerful finite element tool has some limitations to model tiny details which is required in modeling of bailey bridges. Hence, for modeling of inter-panel connections so as to represent as that in real scenario, rigid elastic link has been used and for the inter panel joints are considered as pin jointed connections and these connections are modeled using section designer has been done. Also, for connection with panel to transom rigid elastic link is used.

Table 14: Section Details

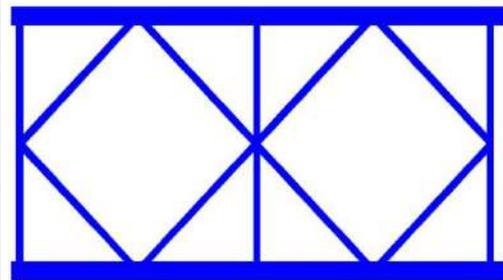| Member	Section	Size	Thickness(mm)
Horizontal	Channel	4"x2"	5x7
Vertical	Channel	3"x1.5"	5x7
Inclined	Channel	3"x1.5"	6x8
Rakers	Channel	3"x1.5"	6x8
Transom	I-section	12"x4.5"	9x9
Stringer	I-section	3.5"x2.5"	4x5
End post	Channel	4"x2"	5x5
Bracing angle	Angle	1"x1"	8x8
Sway brace bar	circular	25mm	25
Plate	thin shell		6.5

Figure 2: Bailey Panel

Here, for Moving load analysis IRC class A vehicle loading has been applied in all nine bailey bridge model with configuration as mentioned above. And for buckling factor calculation only dead load (i.e Self weight) has been considered with geometric non-linearity.
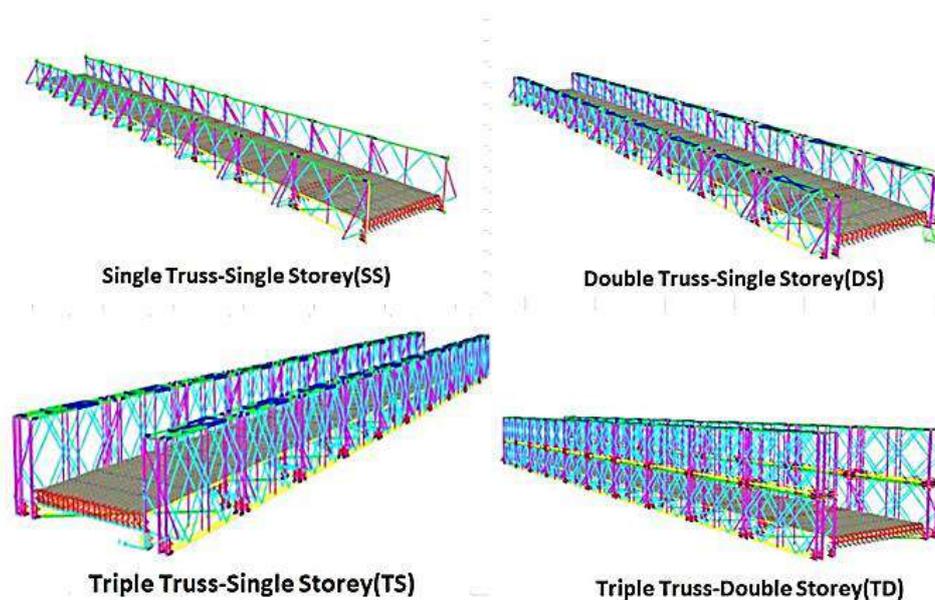

Single Truss-Single Storey(SS)

Double Truss-Single Storey(DS)

Triple Truss-Single Storey(TS)

Triple Truss-Double Storey(TD)

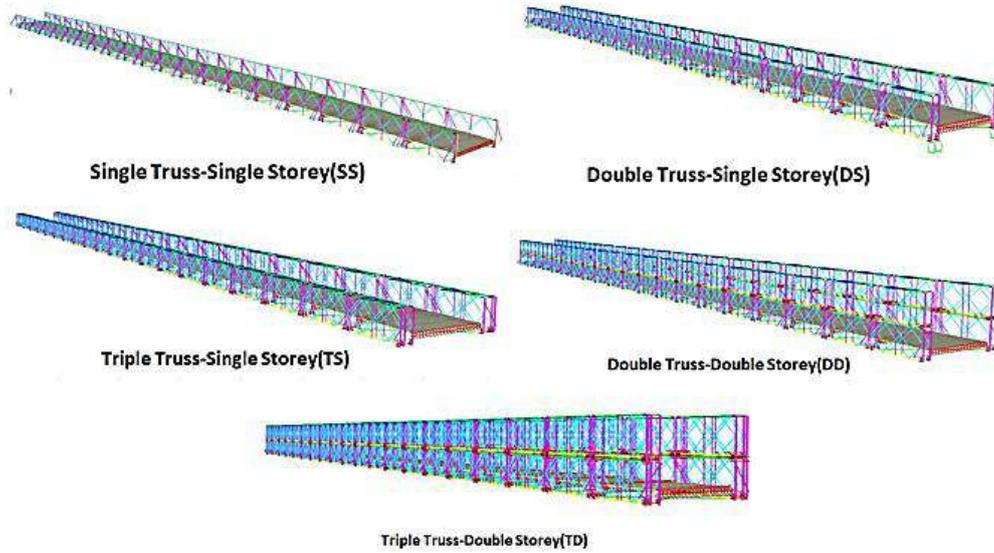*Figure 3: Different Configuration of Bailey Bride for 30m span*

Figure 4: Different Configuration of Bailey Bride for 60m span
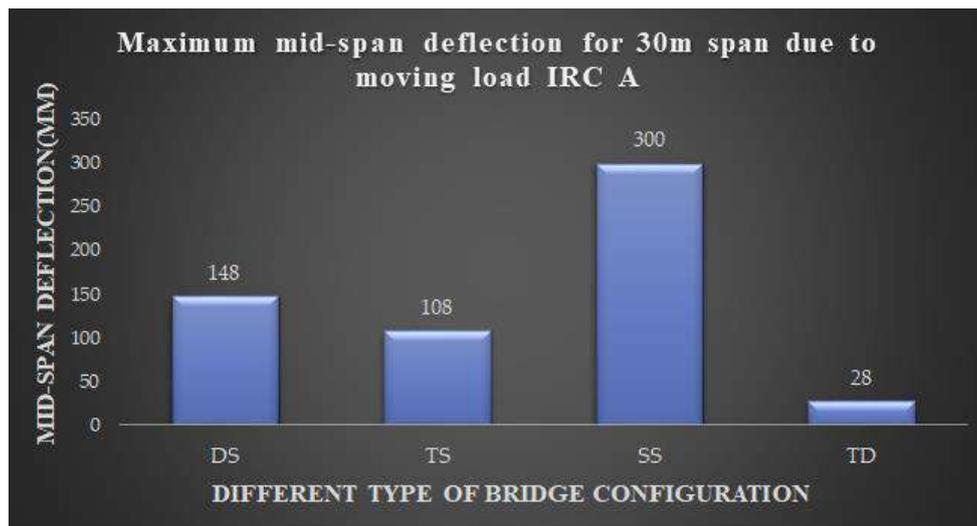
5. Results And Discussion

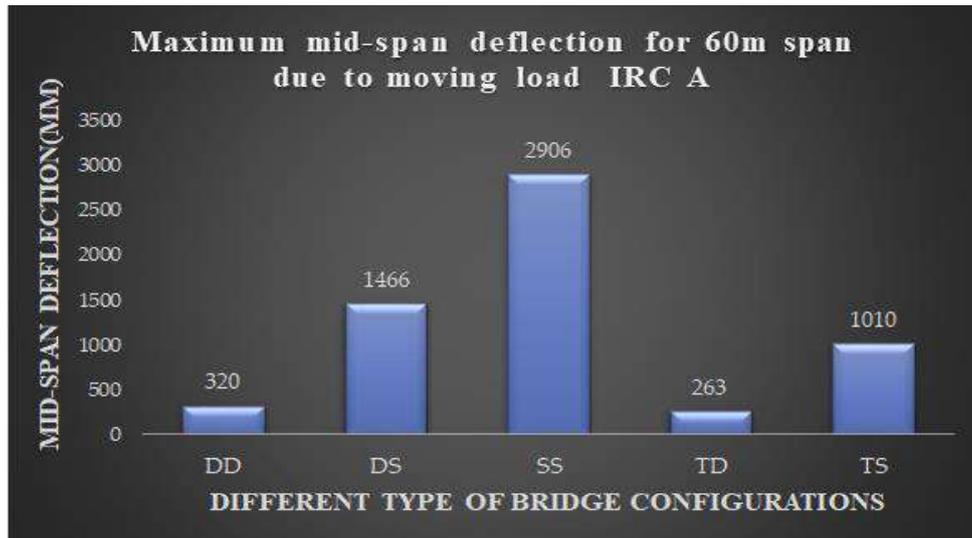*Figure 5: Maximum Mid-span Deflection for 30m*

Figure 6: Maximum Mid-span Deflection for 60m
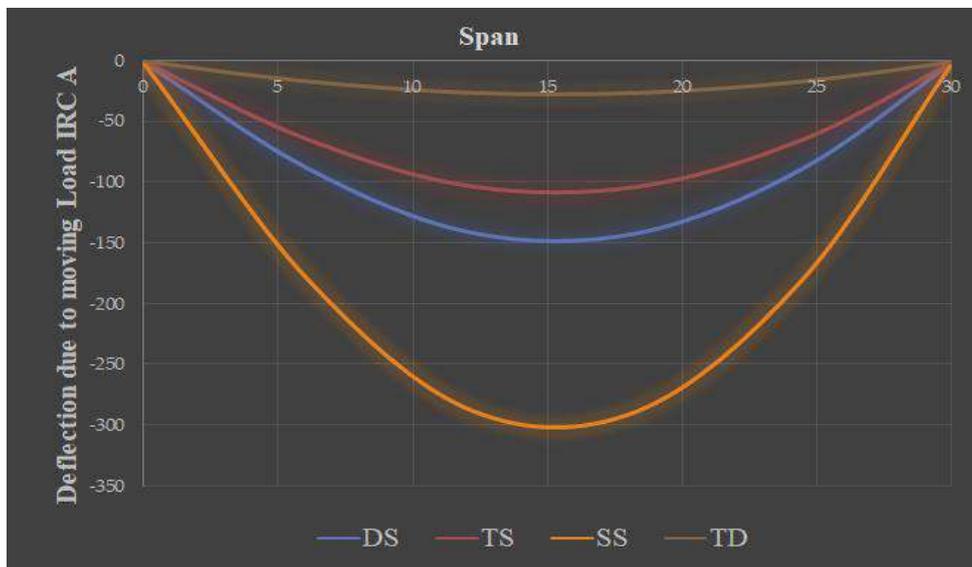

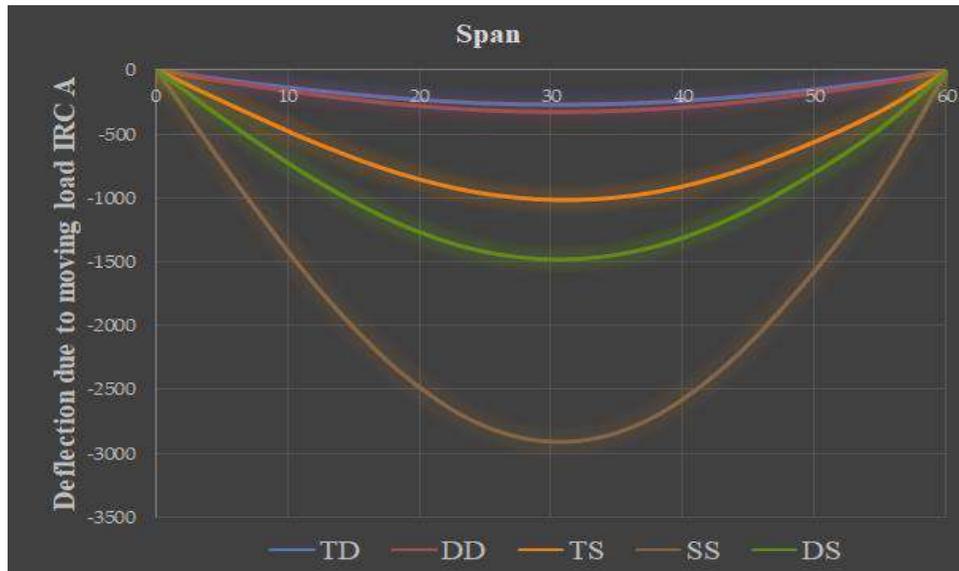*Figure 7: Deflected shape of different configuration of Bailey bridge for 30m*

Figure 8: Deflected shape of different configuration of Bailey bridge for 60m

Different type bridge configuration	SS	DS	TS	TD
Top Chord	1151	573	396	170
Bottom Chord	773	400	296	148
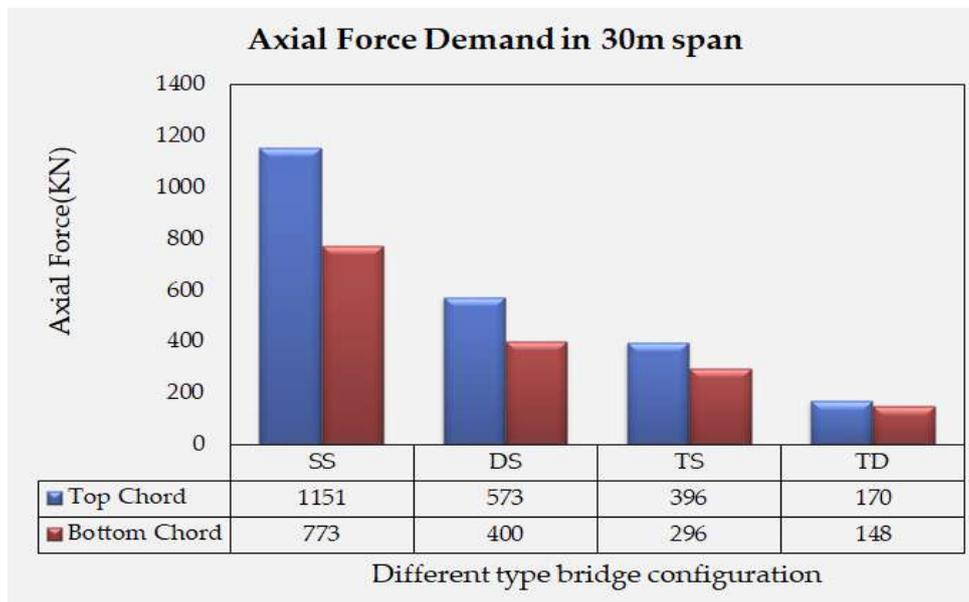
Figure 9: Axial Force in chord of different configuration for 30m

Axial Force Deman in 60m span

Different type of bridge configuration	SS	DS	TS	DD	TD
■ Top Chord	4141	2192	911	586	391
■ Bottom Chord	2220	1237	590	329	260
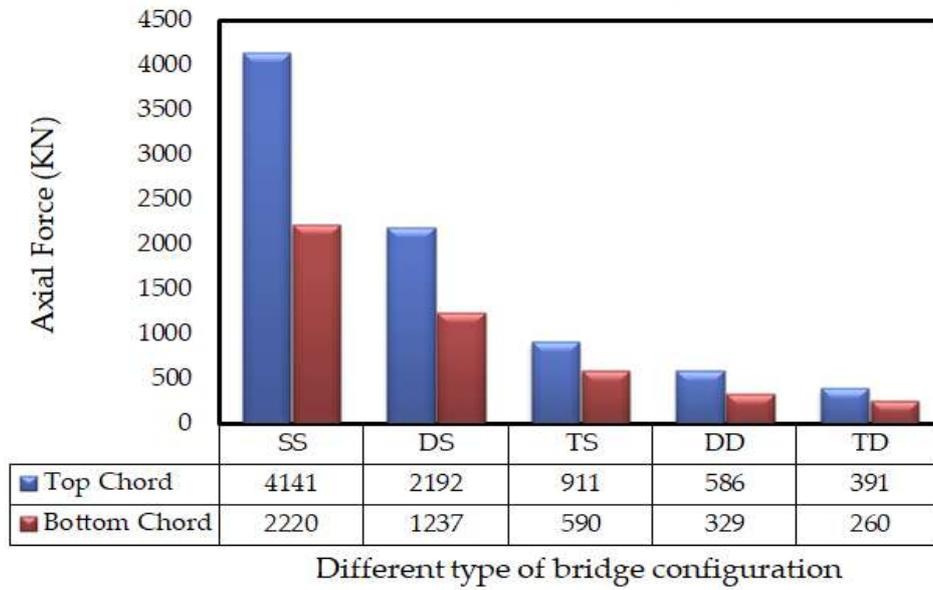
Figure 10: Axial Force in chord of different configuration for 60m

AXIAL FOCRE VARIATION IN HORIZONTAL MEMBER OF PANEL

DIFFERENT TYPE OF BRIDGE CONFIGURATION	SS	DS	TS	TD	DD
Top Chord (60m span)	4140	2192	911	586	391
Top Chord(30m span)	1151	573	396	170	
Bottom Chord (60m span)	2220	1237	590	329	260
Bottom Chord (30m span)	773	400	296	149	
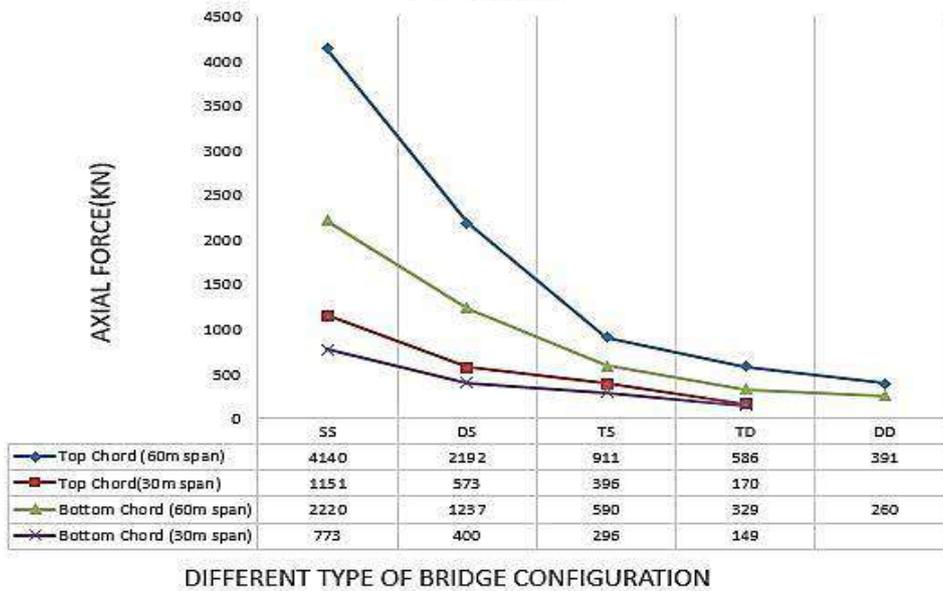
Figure 11: Variation of Axial Force in Horizontal Member

AXIAL FORCE VARIATION IN VERTICAL MEMBER OF PANEL

	SS	DS	TS	TD	DD
Tensile (60m)	184	160	96	343	273
Compressive (60m)	183	152	173	586	392
Tensile (30m)	132	77	57	53	
Compressive (30m)	132	69	52	47	

DIFFERENT TYPE OF BRIDGE CONFIGURATION
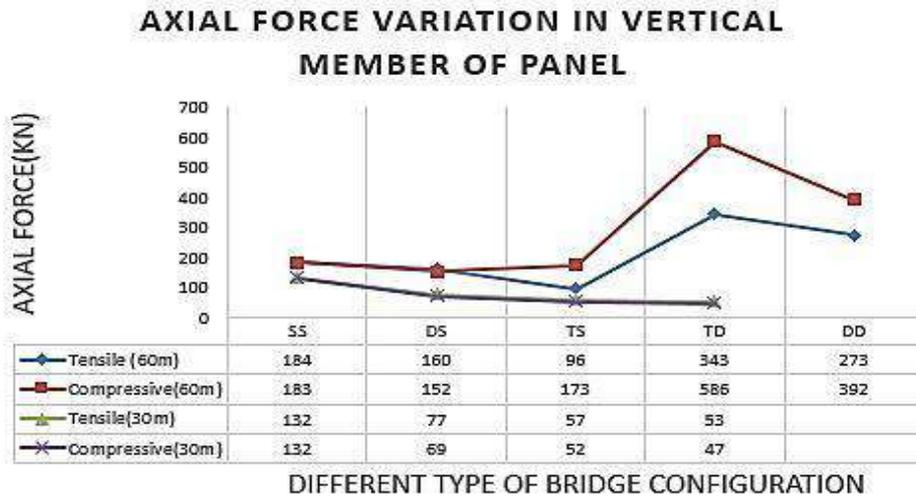
Figure 12: Variation of Axial Force in Vertical member

AXIAL FORCE VARIATION IN INCLINED MEMBER OF PANEL

	SS	DS	TS	TD	DD
Tensile (60m)	1605	162	590	47	62.5
Compressive (60m)	2868	172	912	47	62.5
Tensile (30m)	163	82	61	38	
Compressive (30m)	163	82	61	39	

DIFERENT TYPE OF BRIDGE CONFIGURATION
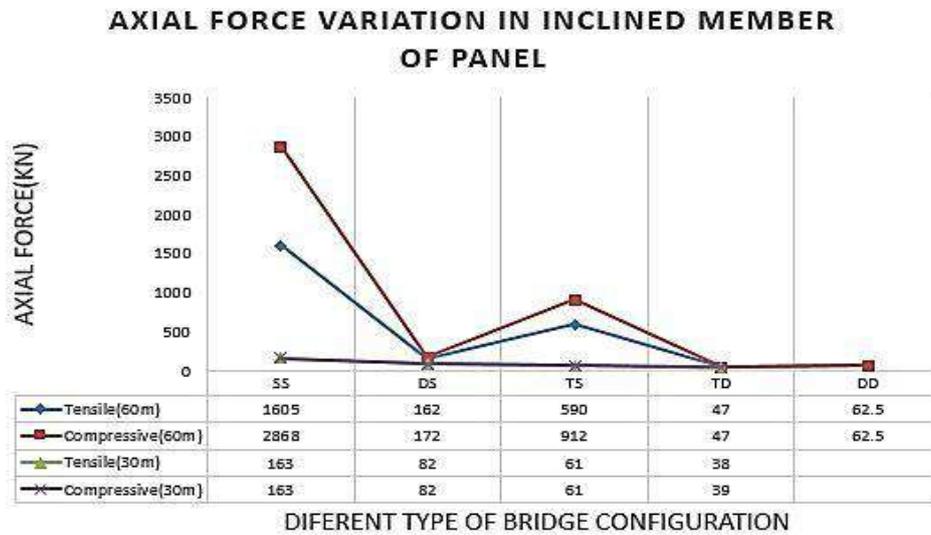
Figure 13: Variation of Axial Force in Inclined member

SHEAR FORCE VARIATION IN TRANSOM

	SS	DS	TS	TD	DD
Transom (60m)	101.25	98.51	96.42	95.64	95.37
Transom (30m)	98.55	100.41	96.36	95.20	

DIFFERENT TYPE OF BRIDGE CONFIGURATION
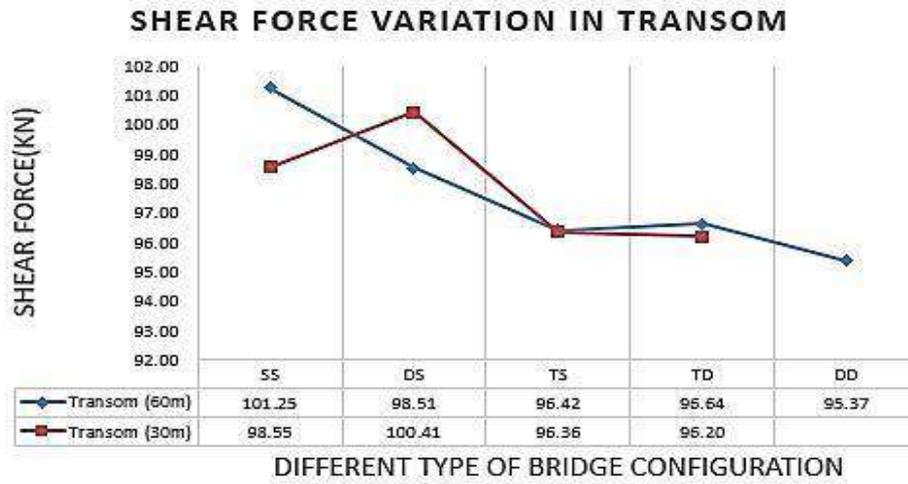
Figure 14: Variation of Shear Force in Transom

BENDING MOMENT VARIATION IN TRANSOM

	SS	DS	TS	TD	DD
Transom(60m)	40	30.5	36	30	27
Transom(30m)	30	28	27	26	

DIFFERENT TYPE OF BRIDGE CONFIGURATION
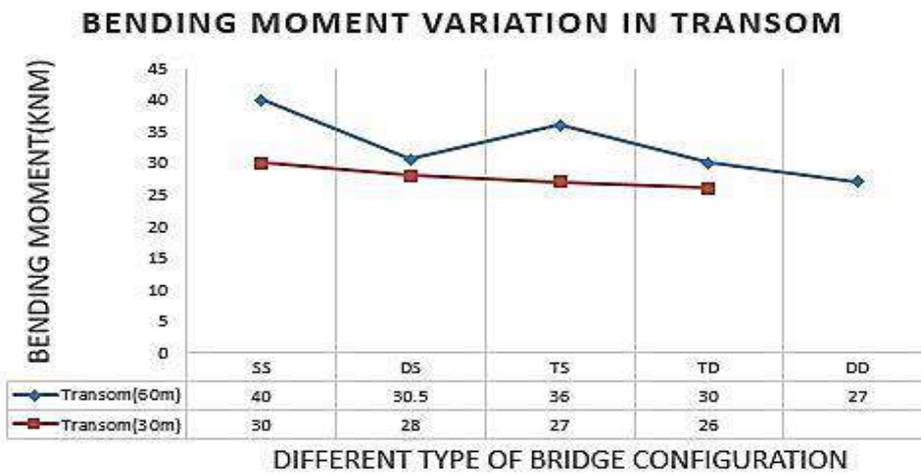
Figure 15: Variation of Bending Moment in Transom

TREND OF BUCKLING FACTOR FOR 30M SPAN

	1	2	3	4	5	6
TD	30.2	30.4	30.7	30.9	32.7	33.0
SS	5.9	5.9	7.8	7.8	10.1	10.2
TS	13.4	13.5	16.6	16.7	20.7	20.9
DS	10.2	10.2	12.9	13.0	16.4	16.6

MODE
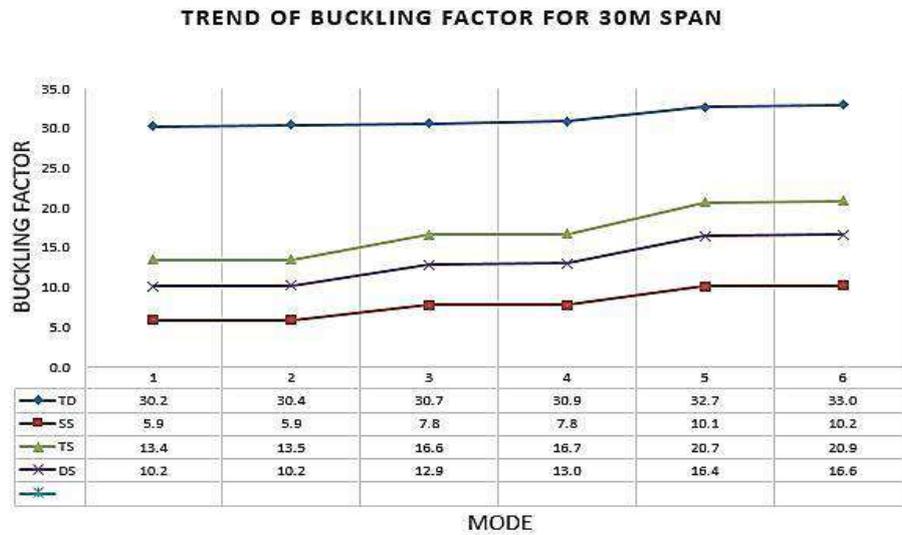
Figure 16: Trend line of Buckling Load Factor for 30m

TREND OF BUCKLING FACTOR FOR 60M SPAN

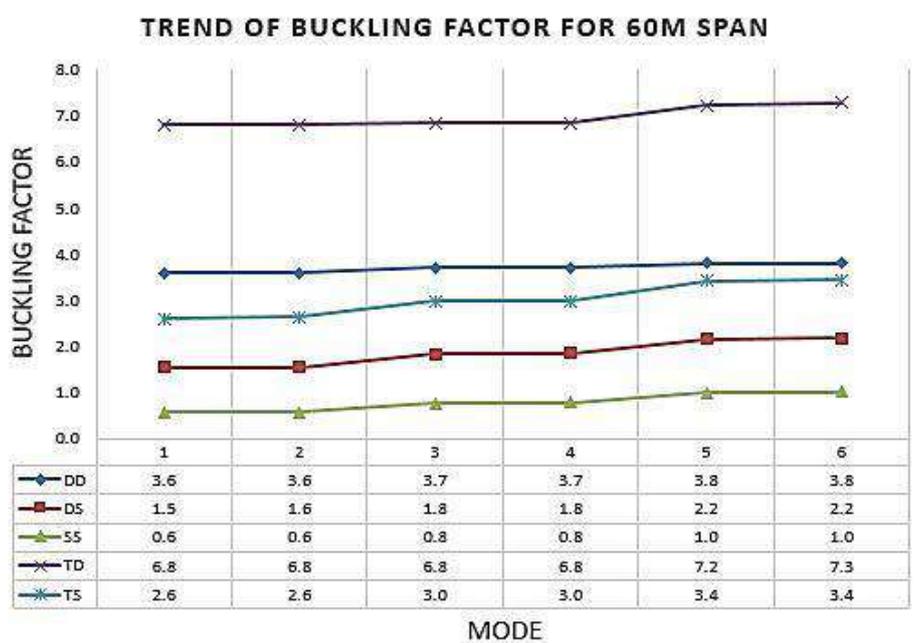|	1	2	3	4	5	6
DD	3.6	3.6	3.7	3.7	3.8	3.8
DS	1.5	1.6	1.8	1.8	2.2	2.2
SS	0.6	0.6	0.8	0.8	1.0	1.0
TD	6.8	6.8	6.8	6.8	7.2	7.3
TS	2.6	2.6	3.0	3.0	3.4	3.4

MODE

Figure 17: Trend line of Buckling Load Factor for 60m

For this study maximum response of the member of different configuration Bailey Bridges is observed. The figures obtained are developed through moving load analysis and buckling analysis. Graphs are obtained as Type of configuration in x-axis and maximum response value in y-axis. Figure4, Figure 5, Figure6 and Figure7 represents the maximum mid-span deflection of different configuration bridge

model which show that SS configuration experience highest deflection whereas TD Configuration experiences least. Similarly, Figure 8 and Figure 9 show the maximum axial force obtained in Top and Bottom chord which shows that Axial forces in bottom chord is always lesser than in top chord.

In Figure10, Figure 11 and Figure 12, variation of maximum axial force in horizontal, vertical and inclined member of the panel is shown which represents maximum axial force is in decreasing trend for both span bailey bridge configuration for horizontal member of panel ,maximum axial force for vertical member of panel is in rising trend for 60m span and decreasing trend also most similar for 30m span and maximum axial force in inclined member is in decreasing trend for 60m span and have almost same value of maximum force for 30m span.

Transom acting as cross girder, Figure 13 and Figure 14 shows the variation of the maximum Shear force and maximum bending moment. It shows for 30m span BM is almost similar, for 60m BM drop from SS to DS and rises from TS to DD. Similarly for 60m span SF is observed in decreasing manner but for 30m SF is observed random. Likewise, figure 15 and figure 16 shows the trend line of buckling factor for 30m and 60m respectively. Above results, shows that there is no any significant observation in the buckling factor. It is observed that buckling in mode 5 and mode 6 have higher values than other modes.

6. Conclusions

From the above study we can conclude that the Triple Truss-Triple Storey (TD) bailey bridge configuration can be used as the best configuration in terms of maximum resistance structural response compared to other configuration. Following conclusions are drawn:

1. Due to moving load, For 30m span, maximum mid-span deflection of TD (Triple Truss-Double Storey), TS (Triple Truss- Single Storey) and DS(Double Truss- Single Storey)DS configurations decreased by 90.6 %, 64 %, and 50.67 % respectively with respect to SS(Single Truss-Single deflection,
2. Due to moving load, For 60m, maximum mid-span deflection of TD(Triple Truss-Double Storey),TS(Triple Truss- Single Storey),DS(Double Truss- Single Storey) and DD(Double Truss-Double Storey) configuration decreased by 90.94 %, 65.24 %, 49.55 % and89.09 % respectively with respect to SS(Single Truss-Single Storey) configuration deflection,
3. For 30m span, maximum axial force in top chord for DS(Double Truss- Single Storey), TS(Triple Truss- Single Storey) and TD(Triple Truss-Double Storey) configuration decreased by 50.21 %, 65.59 % and 85.23 % respectively w.r.t SS configuration. Similarly, maximum axial force in bottom chord DS(Double Truss-Single Storey), TS(Triple Truss- Single Storey) and TD(Triple Truss-Double Storey) configuration decreased by 48.28 %,61.70 % and80.85 % respectively,
4. For 60m span, maximum axial force in top chord for DS(DoubleTruss-Single Storey), TS(Triple Truss-Single Storey), DD(Double Truss-Double Storey) and TD (Triple Truss-Double Storey) configuration decreased by 47.06 %, 78 %, 85.84 % and 90.57 % respectively w.r.t SS configuration. Similarly, maximum axial force in bottom chord DS(Double Truss-Single Storey), TS(Triple Truss- Single Storey), DD (Double Truss-Double Storey) and TD(Triple Truss-Double Storey) configuration decreased by 44.27 %, 73.42 %, 85.18 % and 88.28 % respectively,

5. For 30m span, maximum shear force in Transom for DS(DoubleTruss-Single Storey) increased by 2 % w.r.t SS(Single Truss-Single Storey) whereas TS(Triple Truss- Single Storey) and TD(TripleTruss-DoubleStorey) configuration decreased by 1.73 %, 1.83 % w.r.t SS(Single Truss-Single Storey) configuration,

6. For 30m span, maximum bending moment in Transom for DS (Double Truss-Single Storey), TS(Triple Truss-Single Storey) and TD(Triple Truss-Double Storey) configuration decreased by 6.51 %, 11.21 % and 13.33 % w.r.t SS(Single Truss-Single Storey) configuration,

7. For 60m maximum bending moment in transom decreased by DS (Double Truss-Single Storey), TS(Triple Truss-Single Storey) and TD(Triple Truss-Double Storey) configuration decreased by 25 %,10 %,25 % and 35% respectively w.r.t SS(Single Truss-Single Storey) configuration.

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