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Time History Analysis of Truss Bridge

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Abstract: this study is going to emphasize the importance role of time history analysis for the performance of truss bridge. Truss bridge has been a popular type for long lasting in our country and comes in a wide variety of sizes, shapes and forms. However, many of these bridges are not constructed according to the design for seismic loads as now for current American Association of State Highway and Transportation Officials (AASHTO) provisions. Nowadays, our government concentrates to construct as well as to consider seismic retrofit for existing structures as a major project. This study aims towards analysis and design of Truss Bridge located in high seismic zone. For case study, the behaviour of seismic retrofitting is determined by performance levels. But it is difficult to standardize the seismic analysis and evaluation procedure for truss bridge due to their complexity of size, shape and form. Therefore, the aim of the present paper is to carry out seismic evaluation case study for an existing steel truss bridge with Time History Analysis (THA) to determine as a part of seismic performance categories. The analysis is used by the guidelines of AASHTO-LRFD 2007. Type of plastic hinge for seismic design is reviewed by California Department of Transportation (CALTRANS) approved consensus group. Earthquake loads are based on International Building Code (IBC 2006). SAP 2000 software is used as a tool for structural analysing. A hypothetical bridge model is 1050 ft long, 48 ft wide and 58 ft high. This includes three lanes, two of which are applied for vehicles and one for train, and sidewalk at each. HS 20-44 is considered as truck loading and 1929 Meter Gauge Standard Heavy Mineral is used for train loading. Load combinations of bridge are considered for strength limit state-III, extreme event limit state-I and service limit state-I according to AASHTO specifications. Maximum displacements, rotations and accelerations occurred at different points varying with different times and different damping ratios are discussed in this study. Self mass of this bridge model is 667 kip-sec2/ft and its self weight is 21451 kips. The fundamental mode is occurred at 0.576705seconds. Type of modes is used as Ritz vectors acceleration type.

Keywords: Time History Analysis, Truss, Seismic Zones, Performance Levels, Ritz Vectors.

I. INTRODUCTION

Myanmar is an earthquake-prone region which has four active seismic faults namely Sagaing fault, Kabaw fault, Gangaw fault and Pha-pon fault. These faults are very active and damageable. It is unexpected natural disaster. There is a nation-wide attention to the seismic vulnerability assessment of existing structures. The proposed model for this project is based on the case study of Thanlwin Bridge (Mawlamyine), which is a part of a Union Roadway. This is the longest main spaned truss in Myanmar before 2012. Seismic zones of Myanmar are classified by the magnitude of the earthquake. The bridge is locating in seismic zone IIB now, but it may be transformed to high seismic zone IV in one day. So, it was considered in zone IV and this study is special of THA for seismic evaluation.

II. CONSIDERATION OF SEISMIC ANALYSIS

A. Seismic Evaluation Levels

There are three levels to perform seismic evaluation. They are classified as levels.

Level1: A simple screening using flowcharts based on bridge characteristics previously known to be vulnerable to seismic activity.

Level2: Evaluation is a schematic assessment. Simple and approximate models are used to evaluate the applied seismic demand against the capacity of the components of the structure.

Level3: Evaluation is an indepth seismic evaluation. This is usually employed for bridges that cannot be conservatively and for bridges that serve as very critical links in the transportation system.

B. Modelling Techniques

The requirement for all seismic evaluation levels is computer modelling. Three different types of computer models have been used for truss bridges engineering practice:

- Equivalent Beam Model (EBM)
- Truss Action Model (TAM)
- Finite Element Model (FEM)

All are three dimensional models and require a structural analysis program. Among these models, FEM is more appropriate method for seismic evaluation because it accounts for both axial and bending stresses in truss members.

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C. Methods for Seismic Analysis

There are four methods used for seismic analysis are:

- Single Mode response Spectrum Analysis
- Multi-Mode Response Spectrum Analysis
- Push-Over (Nonlinear Static) Analysis
- Nonlinear Time History Analysis

Method should be used for seismic evaluation must be determined according to the seismic zone where the bridge will be situated, the importance of the bridge and types of the bridge. Classification of these methods can be found in Fig.1. The proposed model in this study is located in seismic zone 4 and critical bridge for publicity. Therefore, time history analysis should be performed.

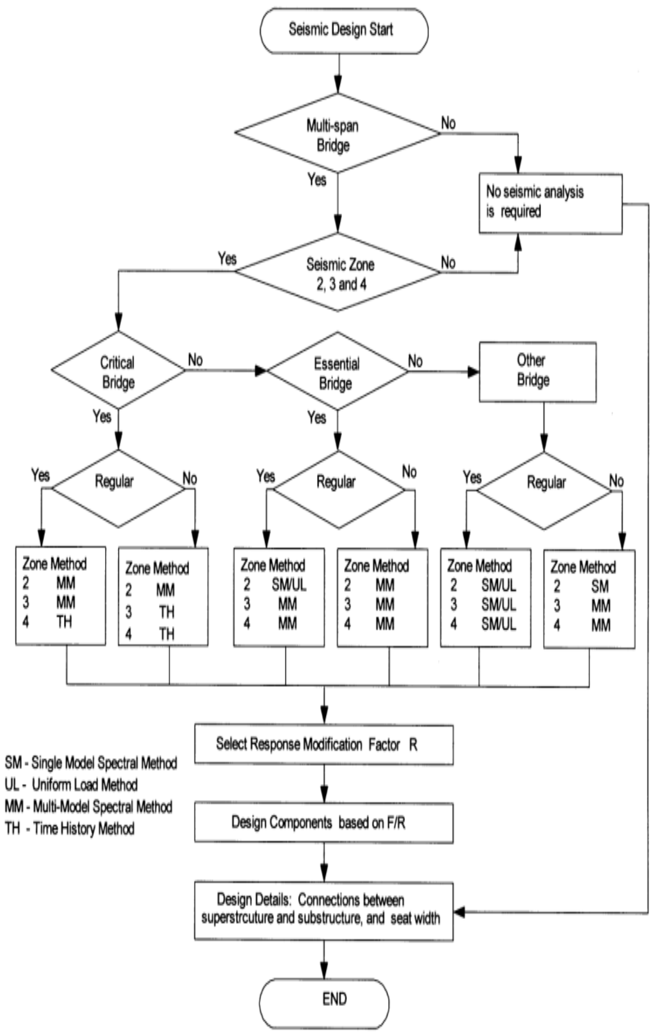

Fig1. Seismic Design Procedure.

THA method differs from response spectrum analysis because the effect of "time" is considered. Results are realistic and not conservative because this method does not assume a specific method for mode combination. A direct-integration time-history analysis solves equations for the entire structure at each time step, a compared with a model time history load case, which uses the method of mode superposition.

III. CLASSIFICATION AND SELECTION OF BRIDGE TYPES

Bridges can be classified in various types and can be selected from the different types of structures. Types of truss and framework of lateral bracing can be observed.

A. Classification of Bridge Types

Types of bridges can be classified in seven ways, which are expressed as:

- Classification by function
- Classification by material
- Classification by relative position of floor
- Classification by method of providing clearance for navigation
- Classification by structural system
- Classification by support condition
- Classification depending on the life of the bridge

According to these classifications, a proposed bridge model is a continuously supported through truss bridge.

B. Selection of Bridge Types

There are many factors affecting on the selection of bridge type. Special factors for selection of superstructure are:

- Material function and availability
- Construction cost
- Speed of construction and constructability
- Design complexity
- Maintenance cost and life expectancy
- Environmental concerns
- Aesthetics

C. Types of Bridge Truss

There are many mainly used simple-span types for truss bridge. They are composed of top chords, bottom chords, struts and diagonal members. These truss types are mainly as Pratt, Warren-without verticals, Warren-with verticals, Parker, and K truss as shown in Fig. 2. Truss type of warren-with verticals is used in this proposed model as main truss.

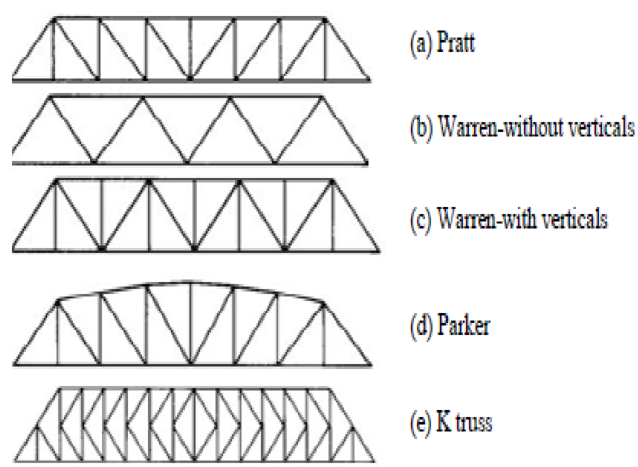

Fig2. Types of simple-span truss bridge.

D. Framework of Lateral Bracing

Frameworks in truss bridge commonly used for lateral bracings are diamond truss, double warren and K truss, which are illustrated in Fig. 3. Double warren types of lateral bracing frameworks are used to tie for the whole truss in this study.

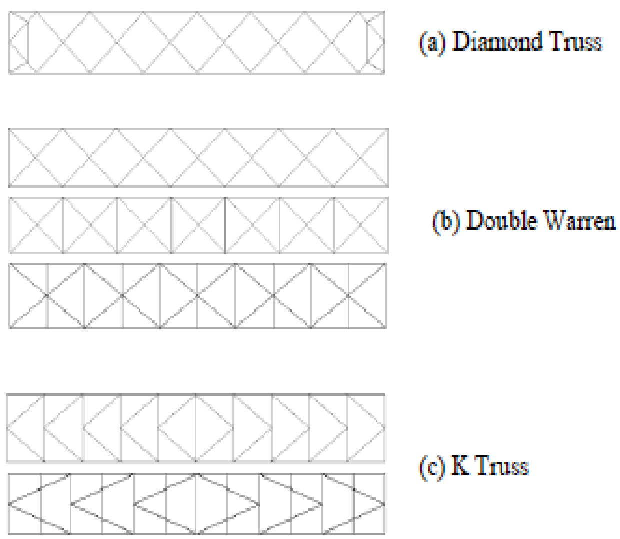

Fig3. Types of framework of lateral bracing.

IV. DESIGN CONSIDERATION OF TRUSS BRIDGE

A hypothetical three- span bridge model is 1050 ft long, 48ft wide and 58 ft high from supports. This includes two lanes for vehicles, one for railroad beside and a sidewalk each side. Shapes of section used for steel truss are H-sections, box sections and tee sections. Steel used are the yield strength (fy) of 50ksi and tensile strength (fu) of 65ksi. Compressive strength of concrete (f'c) used for this design is 3500psi. Grade 50 Structural steel is also used. This proposed bridge model is shown in Fig. 4. Bridge loads can be classified in two categories. They are permanent load and transient load. Permanent load includes dead load and superimposed dead load. Dead load includes the rail weight of 200lb/ft and superimposed dead load of 9lb/ft for 1in. thickness of asphalt. Transient load includes all types of live loads. Construction live load of 1200lb/ft and pedestrian live load of 85lb/ft2 are considered. HS 20-44 is used as truck loading and lane loadings according to AASHTO LRFD 2007 as shown in Fig. 5. 1929 Meter Gauge Standard Heavy Mineral as shown in Fig. 6.is used as a train of 3.87 tonnes per linear foot behind the engine, which is according to manual of 1941 India Bridge Rule. Wind load on structure is considered. The exposure type is D, the load value of 150 lb/ft and important factor is 1.15 in all direction. Basic wind speed is 100mph according to AASHTO. Earthquake load is considered as the code of IBC 2006. The seismic category lies under Category III and the site class is B. The important factor used for seismic loading is 1.25. Specification of temperature for metal is 120°F which is used in this analysis determined based on monthly records for two years. Braking force is also considered.

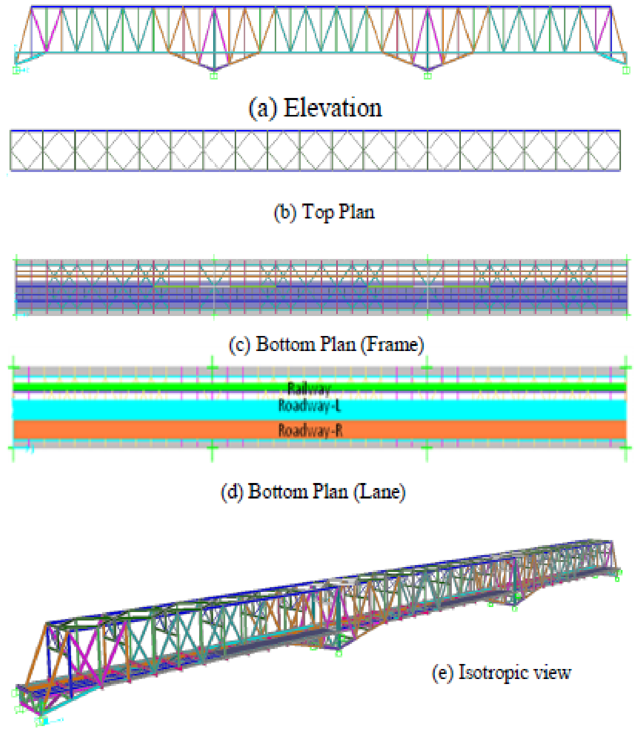

Fig4. Proposed bridge model.

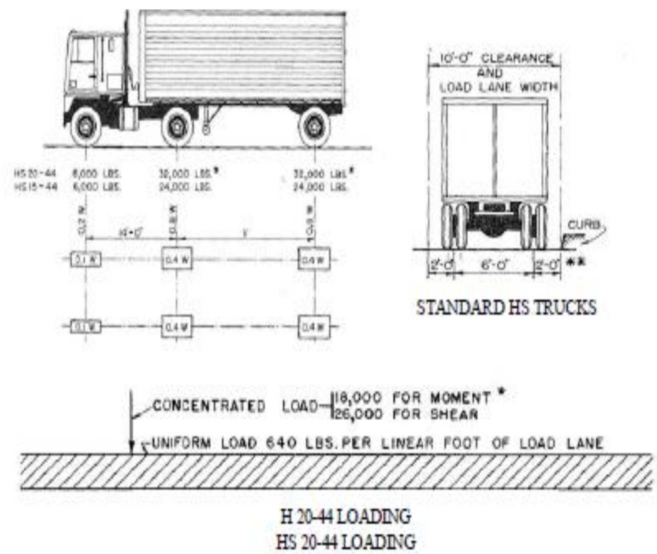

Fig5. Standard HS 20-44 Truck Loading and Lane Loading.

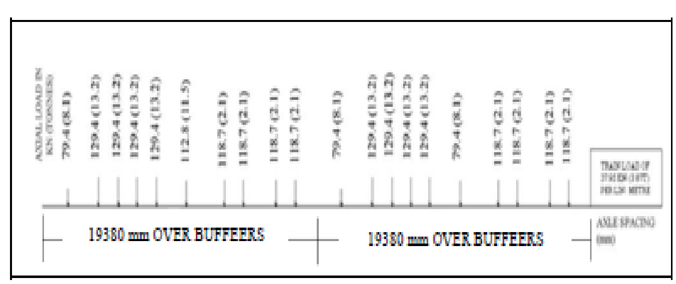

Fig6. 1929 Meter Gauge Standard Heavy Mineral Loading.

TABLE I: Load Combination and Load Factors Used In the AASHTO LRFD 2007 Code

Load Combo Limit State	DC DD DW EH EV ES EL PS CR SH	LL IM CE BR PL LS	WA	WS	WL	FR	TU	TG	SE	EQ	IC	CT	CV
Str I	γ_P	1.75	1.00	-	-	1.00	0.5/1.20	γ_{TG}	γ_{SE}	-	-	-	-
Str II	γ_P	1.35	1.00	-	-	1.00	0.5/1.20	γ_{TG}	γ_{SE}	-	-	-	-
Str III	γ_P	-	1.00	1.40	-	1.00	0.5/1.20	γ_{TG}	γ_{SE}	-	-	-	-
Str IV	γ_P	-	1.00	-	-	1.00	0.5/1.20	-		-	-	-	-
Str V	γ_P	1.35	1.00	0.40	1.00	1.00	0.5/1.20	γ_{TG}	γ_{SE}	-	-	-	-
Ext Ev I	γ_P	γ_{EQ}	1.00	-	-	1.00	-	-		1.00	-	-	-
Ext Ev II	γ_P	0.5	1.00	-	-	1.00	-	-		-	1.00	1.00	1.00
Serv I	1.00	1.00	1.00	0.30	1.00	1.00	0.5/1.20	γ_{TG}	γ_{SE}	-	-	-	-
Serv II	1.00	1.00	1.00	-	-	1.00	0.5/1.20	-		-	-	-	-
Serv III	1.00	1.00	1.00	-	-	1.00	0.5/1.20	γ_{TG}	γ_{SE}	-	-	-	-
Serv IV	1.00	1.00	1.00	0.70	-	1.00	0.5/1.20	-	1.00	-	-	-	-
Fatigue-LL, IM & CE Only	-	0.75	-	-	-	-	-	-	-	-	-	-	-

TABLE II: Load Factors for Permanent Loads, Γp Used In the AASHTO LRFD 2007 Code

Type of Load	Load Factor Maximum	Load Factor Minimum
DC	1.25	0.90
DC: Strength IV only	1.50	0.90
DD: Downdrag	1.40	0.25
DW: Wearing Surfaces and Utilities	1.50	0.65
EH: Horizontal Earth Pressure	1.50	0.90
EL: Locked in Construction Stresses	1.00	1.00
EV: Vertical Earth Pressure	1.35	1.00
ES: Earth Surcharge	1.50	0.75

Loading combinations used for this bridge are: structural limit state III, extremely limit state I and serviceability limit state I. These are chosen from AASHTO LRFD 2007 bridge load combination as shown in Table 1 and factors used for these load combinations can be received from Table 2 according to the conditions of load applications. Effective damping ratios of 0, 0.05 and 0.1 have been considered and different effects on six different joints are also investigated.

V. ANALYTICAL RESULTS

Time history sine function with Ritz vectors mode was performed. Number of total output time steps is 500.After simulating the proposed bridge model under all loading conditions and loading combinations, the results including axial loads (P), torsion (T), shear about vertical axis (V2) and shear about horizontal axis (V3), moment about vertical axis (M2) and moment about horizontal axis (M3) are observed and maximum only is displayed in this paper. Some of the results are illustrated in the following diagrams. Fig. 7 to Fig.12 show maximum value of axial load, torsion, shears, moments and longitudinal stress -top and bottom centre (S11) for the entire bridge section is shown in Fig. 13. From THA, axial load is about 93000 kip, vertical shear is about 730 kip, horizontal shear is about 18000 kip, torsion force is about 4700 kip-ft, moment about vertical axis is about 105000 kip-ft, and moment about horizontal axis is about7600 kip-ft. All are maximum value encountered the entire bridge section. Maximum longitudinal stress at top and bottom- center is about 27.5 ksi. Maximum results of axial loads (P), torsion (T), shear about vertical axis (V2) and shear about horizontal axis (V3), moment about vertical axis (M2) and moment about horizontal axis (M3) are observed around the exterior supports and interior supports.

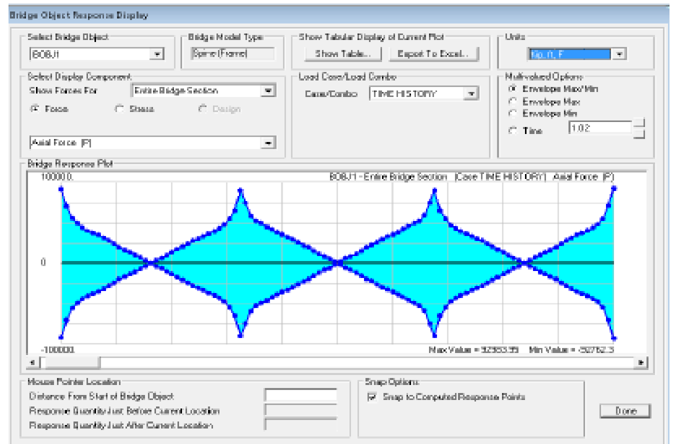

Fig7. Axial load (P).

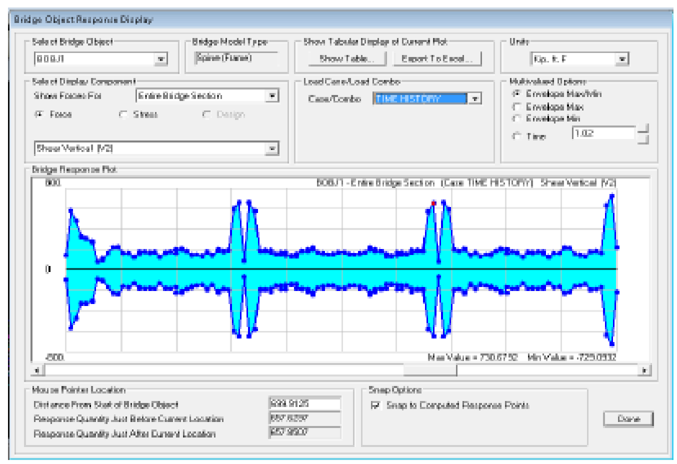

Fig8. Vertical shear (V2).

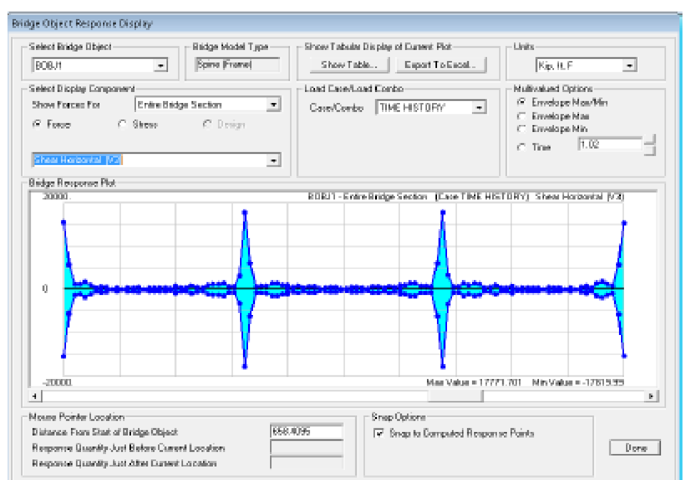

Fig9. Horizontal shear (V3).

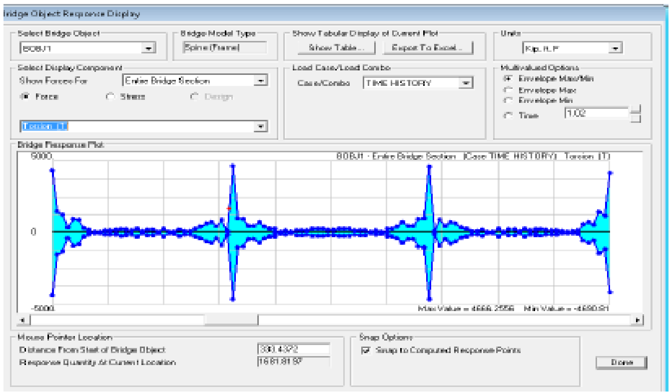

Fig10. Torsion (T).

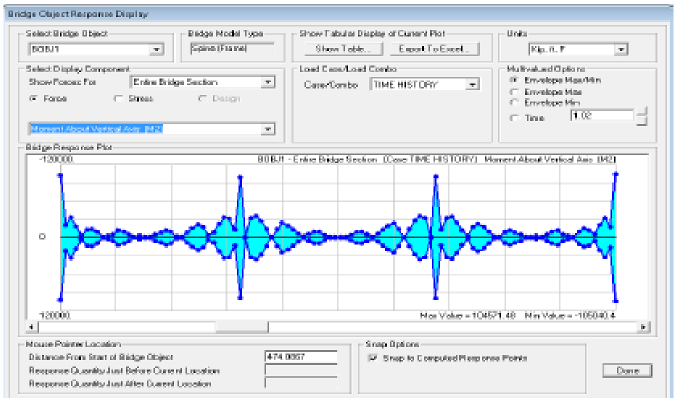

Fig11. Moment about vertical axis (M2).

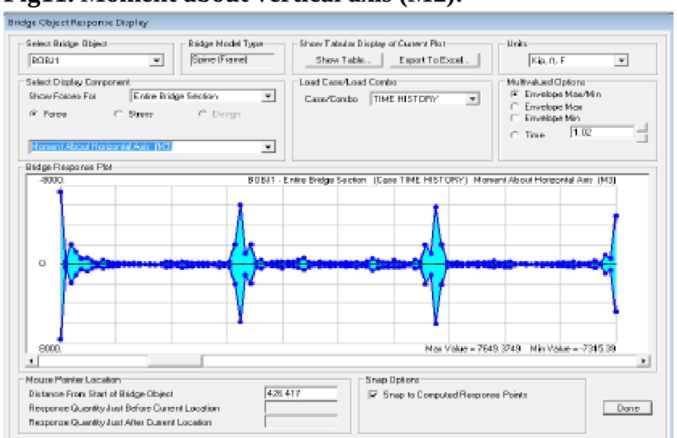

Fig12. Moment about horizontal axis (M3).

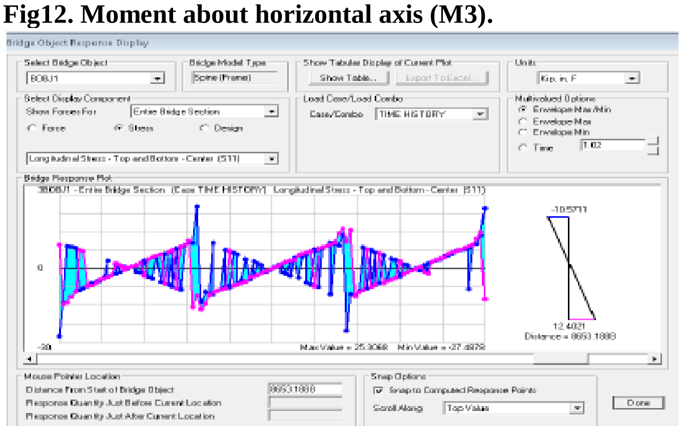

Fig13. Longitudinal Stress–Top and Bottom Centre (S11).

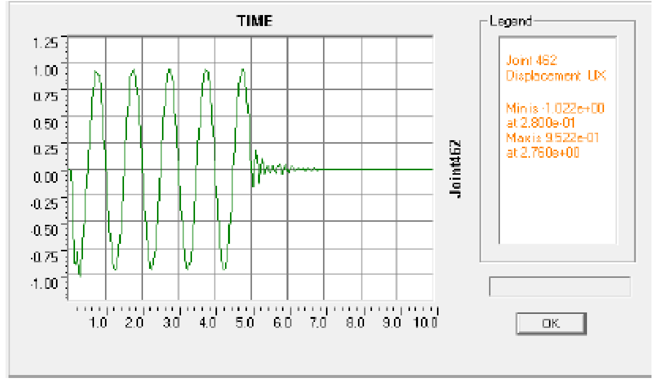

Fig14. Displacement plot function in X-direction (ft).

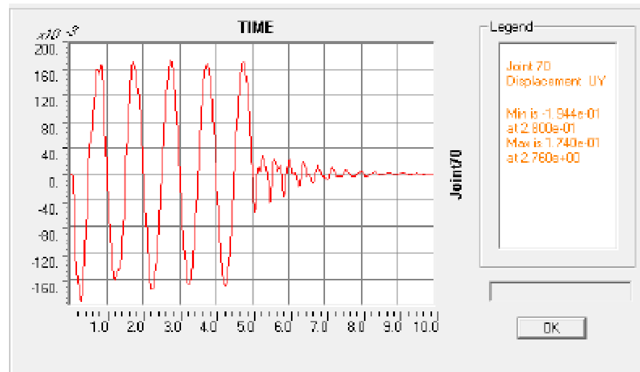

Fig15. Displacement plot function in Y-direction (ft).

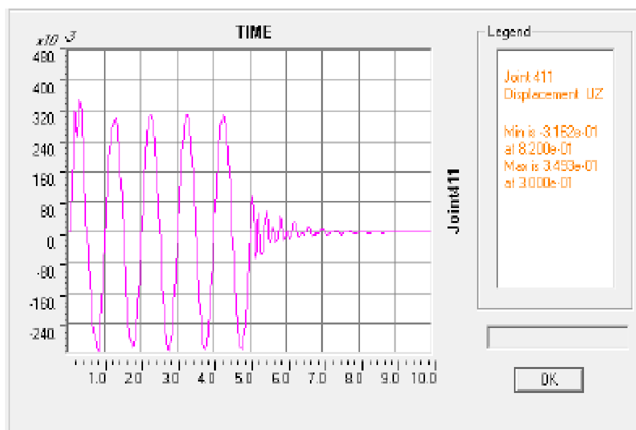

Fig16. Displacement plot function in Z-direction (ft).

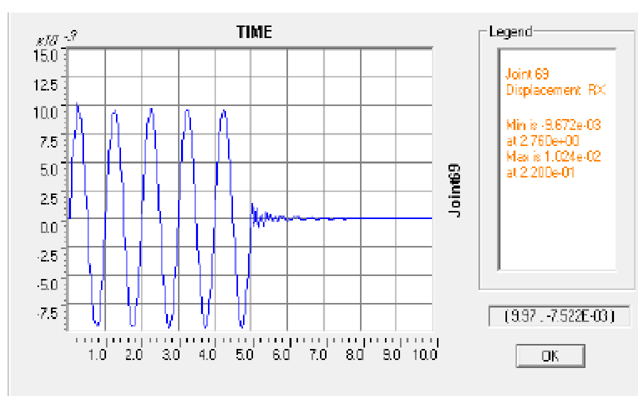

Fig17. Rotation plot function in X-direction (rad).

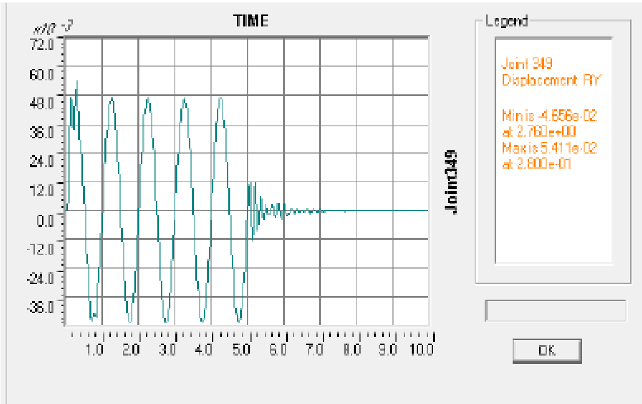

Fig18. Rotation plot function in Y-direction (rad).

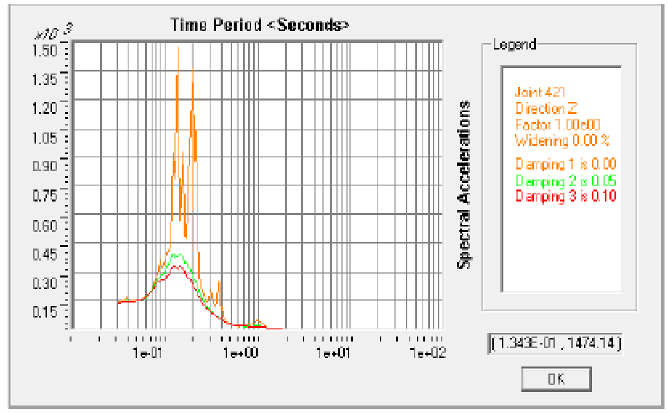

Fig22. Spectral acceleration in Z-direction (Uz, ft/sec).

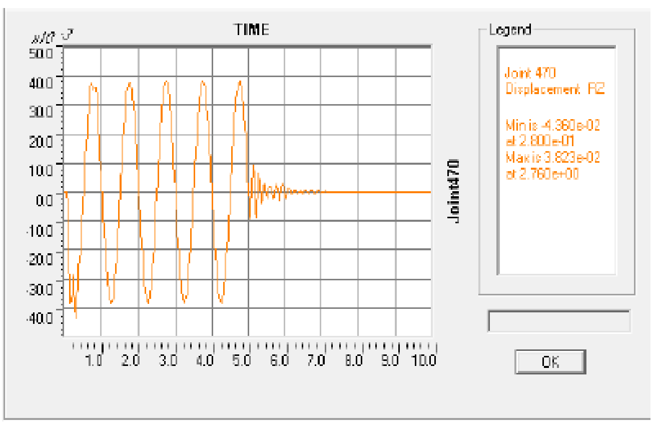

Fig19. Rotation plot function in Z-direction (rad).

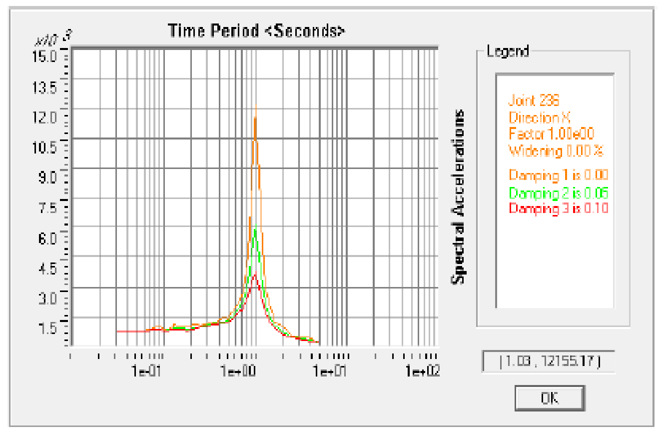

Fig23. Spectral acceleration in X-direction (Rx, rad/sec).

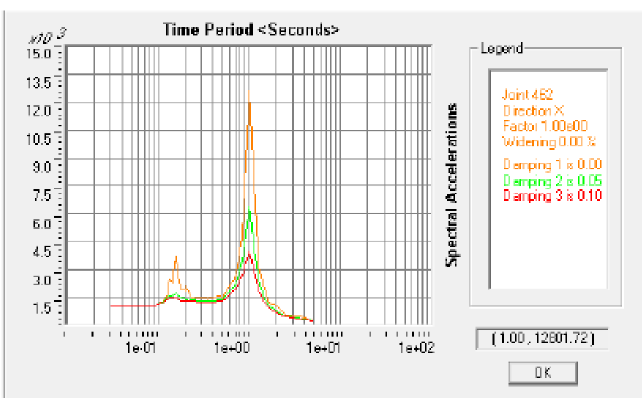

Fig20. Spectral acceleration in X-direction (Ux, ft/sec).

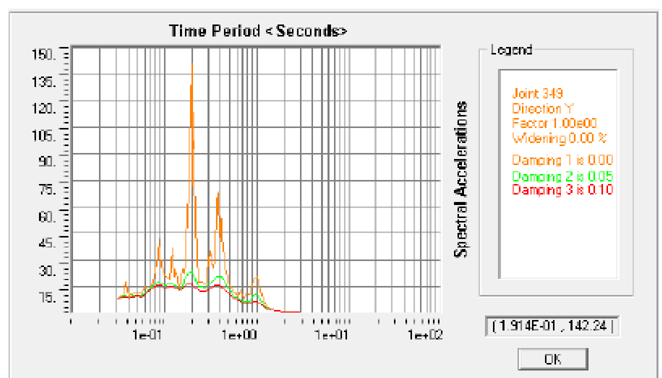

Fig24. Spectral acceleration in Y-direction (Ry, rad/sec).

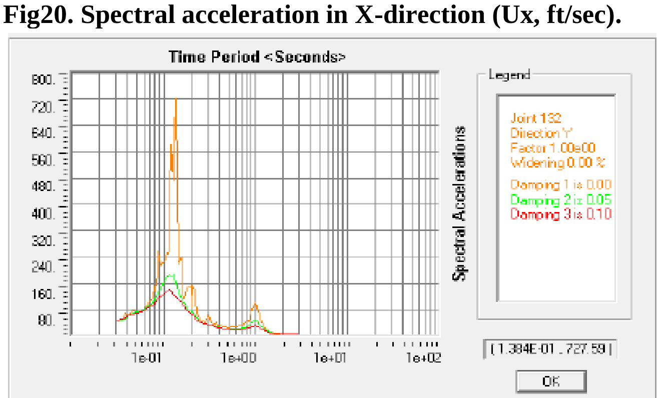

Fig21. Spectral acceleration in Y-direction (Uy, ft/sec).

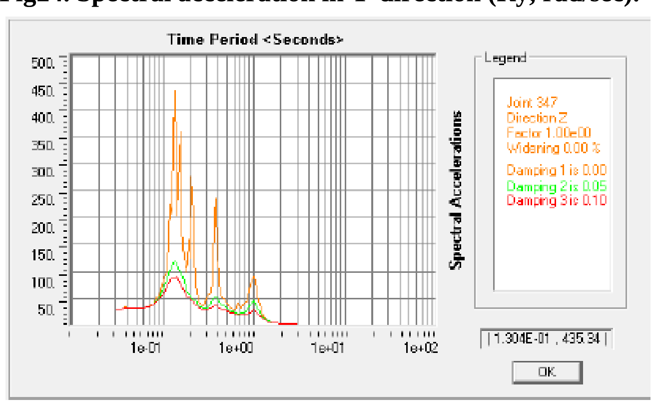

Fig.25 Spectral acceleration in Z-direction (Rz, rad/sec).

After performing THA during 10 seconds, there are various deformations and rotation about the joints along the entire bridge. Maximum displacement in longitudinal direction is 1.022 ft at joint 462 to opposite direction, which is occurred at 2.8 sec. In transverse direction, joint 70 is displaced with the magnitude of 0.19441 ft at 2.8 sec. In vertical direction, joint 411 is deformed with the value of 0.35 ft upward at 3 sec. Maximum rotations about X- direction is 0.01 rad, maximum rotatiion about Y-direction is 0.054 rad and maximum rotatiion about Z-direction is 0.044 rad, which are found at joint 69, 349, and 470 respectively at 2.8 sec. Fig. 14 to Fig. 19 show maximum values of displacement and rotation about X, Y, and Z direction respectively. Fig. 20 to Fig. 25 show different responses under three different damping ratios:0, 0.05, and 0.1. The fundamental mode is occurred at 0.576705seconds and the fundamental frequency is 2.1421 cycle/sec and the peak frequency is 4.0053 cycles/sec. Maximum joint acceleration are 268.1 ft/sec, 54.8 ft/sec, 143.6 ft/sec, 3.8 rad/sec, 19.2 rad/sec and 15.2 rad/sec, which are occurred at joint 462, 132, 421, 236, 349 and 347 respectively.

VI. CONCLUSION

This paper is aiming only for the study on behaviour of steel truss bridge under high seismic zone with THA. This analysis is a method for seismic evaluation to calculate the target displacement based on the maximum displacement of the main frame. Almost all loads and stresses are the most affected on this bridge object under the load case of earthquake occurrence. Displacements are fluctuated and after the peak value, they have been decreased. Finally, they are stable. Although THA is performing during 10 sec, maximum responses are investigated about 3 sec. With varying damping ratios, displacements and rotations are varied. We can observe that damping ratio and structural responses are not directly proportional. Therefore, minimum damping ratio gives maximum structural responses among three damping ratios.

VII. ACKNOWLEDGMENT

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