Long Span Cable-Stayed Bridge with H-Shaped Tower

Aye Nyein Thu, Dr. San Yu Khaing, Dr. Kyaw Lin Htat

Abstract— **A bridge is a structure that across over a river, bay, or other obstruction, permitting the smooth and safe passage of vehicles, trains, and pedestrians. In the family of bridge systems, the cable supported bridges are distinguished by their ability to overcome large spans. The different types of cable supported bridges are distinctively characterized by the configuration of the cable system. The cable-stayed system contains straight cables connecting the stiffening girder to the pylons. This study intends to describe the structural behaviors of long span cable-stayed bridge with H-shaped tower. 2400 ft main span superstructure of long span cable-stayed bridge with H-shaped tower is analyzed and designed by using SAP 2000 software in this study. This study provides the results of cable tension forces, axial forces, vertical shear and horizontal shear, vertical moment and horizontal moment, torsion, truss girder displacement, support reactions and so on. Necessary design and checking are done according to the specifications of AASHTO.**

Index Terms— **Long span cable-stayed bridge, H-shaped tower, SAP 2000 software, AASHTO.**

I. INTRODUCTION

The cable-stayed bridge has been developing rapidly since World War II, and becomes one of the most competitive types of bridges for main spans ranging from 300 to 600 meters. Nowadays, cable-stayed bridges are increasingly built because they can span distance far longer than any other kinds of bridges. The structural configurations of superstructure long span cable-stayed bridge are cables, cable system, tower or pylon, stiffening girder or truss, cable anchorage and connection. The structural systems can be varied by changing the tower shapes and the cable arrangement. Because of their aesthetic appearance, efficient utilization of structural materials and other notable advantages, cable-stayed bridges have gained popularity in recent decades. This fact is, due to advent of efficient construction techniques apart from the rapid progress in analysis and designs of this type of bridges.

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II. STRUCTURAL SPECIFICATIONS AND STRUCTURAL TECHNIQUES

A. Structural Specifications

The basic structure form of a cable-stayed bridge is a series of overlapping triangles comprising the pylon or tower, the cable and the girder or truss. Its structural type is regarded as one of the continuous girder types. In the superstructure of cable-stayed bridges, there are five components that must consider. They are cables, cable systems, tower or pylon and stiffening girder. Cables are the most important elements of a cable-stayed bridge. They carry the load of the girder and transfer it to the tower and the back-stay cable anchorage. Three basic cable arrangements are radial system, harp system, fan system. This study is proposed as a long span cable-stayed bridge with double plane fan type. There are three basic span types. They are two spans (asymmetrical or symmetrical), three spans, and multiple spans. And then, the role of tower or pylon is also very important in cable-stayed bridge. The towers are the most visible elements of a cable-stayed bridge. The primary function of the pylon is to transmit the force arising from anchoring the stay and these forces will dominate the design of the pylon. Many varied types of the pylon have developed to support both the vertical and inclined stay layouts. These include H-frame, A -frame, inverted frame or λ-frame and so on. In this cable-stayed bridge, H-shaped tower is used. H towers are the most logical shape structurally for two plane cable-stayed bridges.

B. Structural Techniques

This study proposed a long span cable-stayed bridge with double plane fan type and its span type is also three spans type. The type of the cable is new parallel-wire strands. New PWS cable with an outer diameter of 17 mm has a metallic cross-section of 16202mm^2 corresponding to a void ratio of 0.33. Its tensile strength is 1770 MPa and the size range is from 7 No. 7mm wires to 421 No. 7mm wires. Long-span cable-stayed bridge is designed and analyzed by using SAP-2000 Software. The cable-stayed bridge with H shape tower is analyzed under own weight condition by using required programming and analytical results are investigated in detail. Designing procedure and checking process will be carried out according to the specifications of American Association of State Highway and Transportation Officials.

III. PREPARING DESIGN DATA AND MODELLING

To achieve safe and successful design of long span cable-stayed bridge, it is needed to know the material properties defined in the studied bridge. In addition, design

ISSN: 2278 – 7798

specifications, tension forces of cables are also taken into account.

A. *Material Properties*

The material properties defined in the studied bridge are shown in Table I.

Table.I Material Properties

Structural Steel (Grade 50, ASTM A 992)	Minimum tensile strength	F_u = 65 ksi
	Minimum yield strength	F_y =50 ksi
	Modulus of elasticity	E =29,000 ksi
	Shear Modulus	G = 1154 ksi
	Poisson's ratio	ν = 0.3
	Coeff: of linear expansion	$\alpha = 6.5 \times 10^{-6}$ (°C)
	Unit Weight	W = 490 (lb/ft^3)

B. *Design Data*

In preparing design data, tension forces are initially assigned in the cables. Preparing design data used in the proposed bridge are described in Table II.

Table.II Design Data Used in Proposed Bridge

Name	Description
Type of Bridge	Cable-Stayed Bridge
Total length of Bridge	4800 ft
Span arrangement	3-spans arrangement
Main span, L_m	2400 ft
Side span	1200 ft (each)
Height of Pylon	550 ft
Pylon	H-type
Cable system	Fan type
Cable plane	Double plane
Height of truss	30 ft
Traffic	HS 20-44, four lanes
Girder width	56 ft
Type of truss	Warren truss

Tension forces of each cable for side span are also displayed in tTable III.

Table.III Tension Forces of Each Cable for Side Span

Cable No.	Tension Force (lb)
Cable 1	3.04E+13
Cable 2	151560.26
Cable 3	120742.79
Cable 4	140684.03
Cable 5	112400.37
Cable 6	127208.49
Cable 7	102057.4
Cable 8	116379.8
Cable 9	93692.70
Cable 10	107521.66
Cable 11	84791.34
Cable 12	95944.44
Cable 13	74822.32
Cable 14	85734.03
Cable 15	66613.24
Cable 16	75287.49
Cable 17	58922.87
Cable 18	66997.91
Cable 19	53085.13
Cable 20	62277.99

Tension forces of each cable for mid span are also displayed in Table IV.

Table.IV Tension Forces of Each Cable for Mid Span

Cable 21	62277.99
Cable 22	53085.13
Cable 23	66997.91
Cable 24	58922.87
Cable 25	75287.49
Cable 26	66613.24
Cable 27	85734.03
Cable 28	74822.32
Cable 29	95944.44
Cable 30	84791.34
Cable 31	107521.68
Cable 32	93692.70
Cable 33	116379.8
Cable 34	102057.4
Cable 35	127208.49
Cable 36	112400.37
Cable 37	140684.21
Cable 38	120744.19
Cable 39	151626.12
Cable 40	130597.99

C. *Modelling*

Elevation view and 3D view of proposed bridge can be seen in Fig 1, and 2.

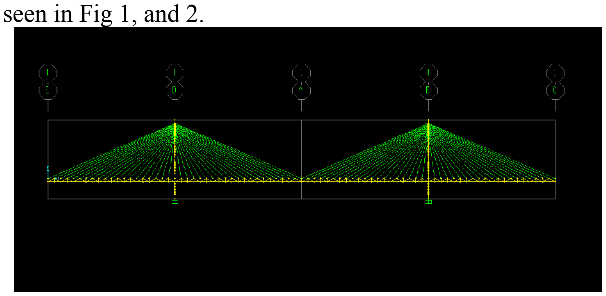

Fig.1 Elevation view of proposed bridge

ISSN: 2278 – 7798

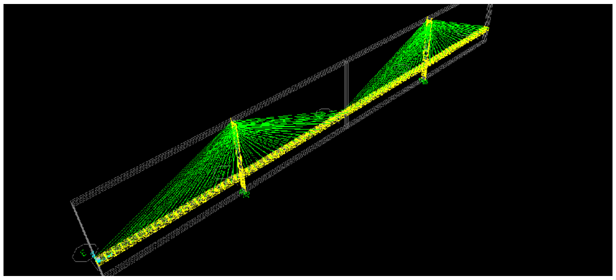

Fig.2 3D view of proposed bridge

IV. Analytical Results of Proposed Bridge

A. *Girder Displacement due to Self Weight*

Deformation such as displacements and rotations of steel bridge is important to consider in design. If a bridge is too flexible, the public often complains about vibration. So the generation of the deflection is checked according to the limitation of AASHTO specifications. The displacements about x- axis are shown in Fig.3.We can seen that the displacement about x- axis is exactly zero at mid span. The displacements about y-axis are also shown in Fig.4 and the displacements about y-axis are symmetric.

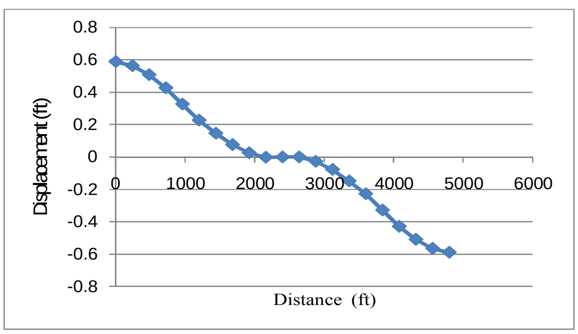

Fig.3 Girder Displacement about x-axis

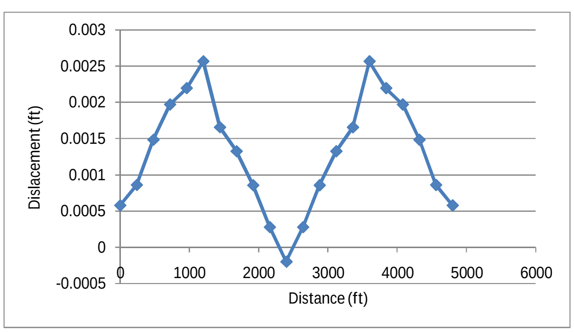

Fig.4 Girder Displacement about y-axis

Fig. 5 illustrates the vertical girder displacements due to self weight. The maximum vertical displacement (2.613ft) occurs at mid span.

Allowable deflection, δ_{all} = L/400

=731.52/400=1.83m

= 6 ft

Maximum deflection due to self weight = 2.613 ft < 6 ft

So, it is satisfied.

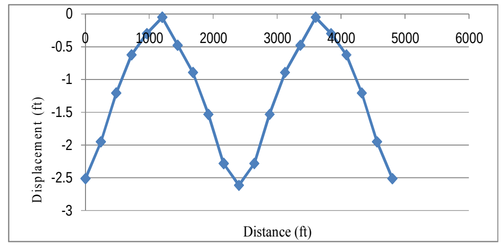

Fig.5 Girder Displacement about z-axis

B. *Reactions at Fixed Support*

It is necessary to know the support reactions. The support reaction can be obtained from the fixed support node points which are specified at the base end of each tower. The support reactions are described in Table V.

Table.V Joint Reactions at Fixed Support

Node	**F1 (lb)**	**F2 (lb)**	**F3 (lb)**	**M1** (lb-ft)	**M2** (lb-ft)	**M3** (lb-ft)
8	-1.43×10^6	1.10×10^5	160×10^7	-5.86×10^6	-1.87×10^8	-8.8×10^3
12	1.43×10^6	1.10×10^5	1.60×10^7	-5.86×10^6	1.87×10^8	8.8×10^3
16	-1.43×10^6	-1.10×10^5	1.60×10^7	5.86×10^6	$--1.87 \times 10^8$	8.8×10^3
20	1.43×10^6	-1.10×10^5	1.60×10^7	5.86×10^6	1.87×10^8	-8.8×10^3

C. *Analysis Results due to Self Weight*

As the output results, the maximum values of bridge forces such as axial forces, vertical and horizontal shear, vertical and horizontal moment, values of torsion are also to be known from their respective figures. The maximum values of axial forces are shown in Fig.6.

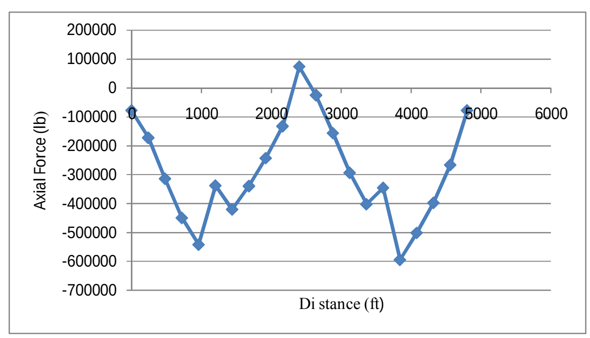

Fig.6 Maximum Values of Axial Forces under Self Weight

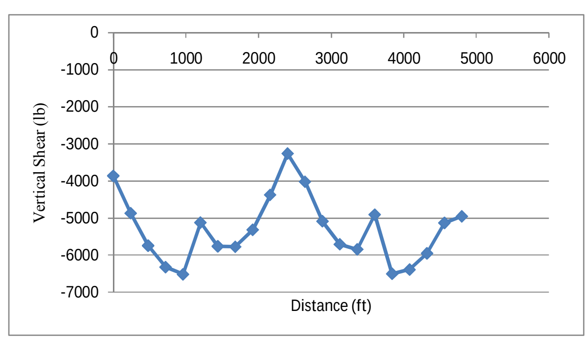

Fig.7 Maximum Values of Vertical Shear under Self Weight

ISSN: 2278 – 7798

Fig.7 is shown the maximum values of vertical shear for self weight condition. The maximum values of horizontal shear are shown in Fig.8.Maximum values of torsion are also shown in Fig. 9.

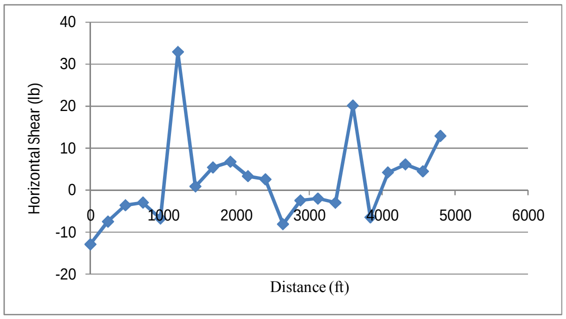

Fig.8 Maximum Values of Horizontal Shear under Self Weight

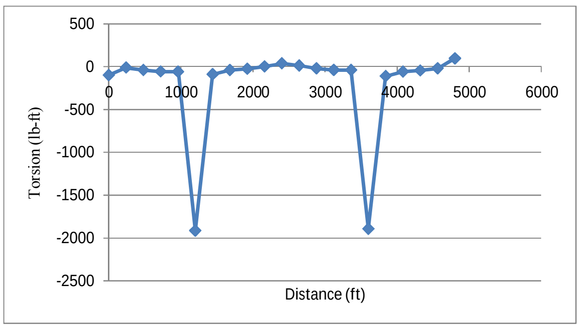

Fig.9 Maximum Values of Torsion under Self Weight

In Fig. 10, the values of vertical moment are expressed. Fig. 11 is shown the values of horizontal moment.

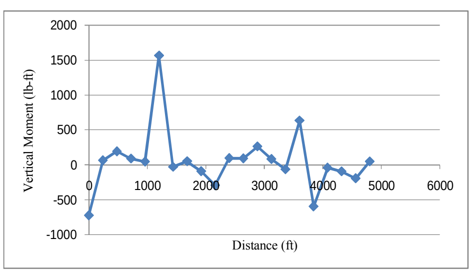

Fig.10 Maximum Values of Vertical Moment under Self Weight

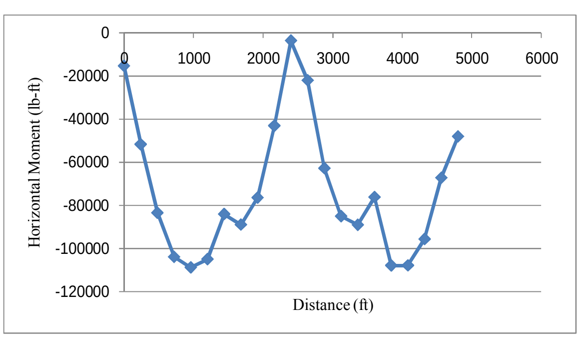

Fig.11 Maximum Values of Horizontal Moment under Self Weight

V. Conclusion

In this study, 2400 ft main span cable stayed bridge is analyzed by using SAP 2000 software. It can be said that this study would give some knowledge of analysis and design of three-span cable-stayed bridge and for the way how to use SAP 2000 software. From the output results, maximum deflection due to self weight is 2.613 ft and it is within the acceptable limit 6 ft and it can be concluded that the result is in the satisfactory condition. According to analytical results, all of bridge forces diagrams are nearly symmetrical. And then, maximum value of axial force is 73398.92 lb and occurs at mid span. Moreover, maximum values of vertical shear and torsion occur at mid span and maximum values of horizontal shear and vertical moment are found at tower support. In this way, superstructure of long span cable-stayed bridge with H-shaped tower can be analyzed and designed safely.

Acknowledgment

This study is the achievement of invaluable help from teachers and many other persons. The author would like to express her deep gratitude to Dr. Kyaw Moe Aung, Associate Professor and Head of Civil Department, Mandalay Technology University, for his invaluable supports and managements. The author would like to special thank to her supervisor and co-supervisor, Dr. San Yu Khaing and Dr. Kyaw Lin Htat, Associate Professors of Civil Department, Mandalay Technological University, for their invaluable guidance, kind consideration and knowledge. The author wishes to thank all who kindly helped directly and indirectly to ward the successful completion of this study

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ISSN: 2278 – 7798