Investigation on the Behaviours of Long-Span Suspension Bridge with Self Anchorage System

Ni Ni Moe Kyaw, Dr. Kyaw Lin Htat, Dr. San Yu Khaing

Abstract— **Our country, Myanmar is a developing country. There are many construction works for the progression of the country to be done. . Transportation development can give a nation's political, economical and social advancement. For this reason, role of transportation plays an important sector for the development of the country. Role of transportation is mainly composed of roads and bridges. These services are concerned with the engineering viewpoint and many civil engineers become to emphasis the analysis and design of roads and bridges. Moreover, our country possesses rich areas of lands and water resources. In addition, bridges are structures which give the communications and the ways to move over the obstacles and carry safety of the necessary traffic volumes and loads. Among the various types of bridges, for longer spans, suspension bridges should be considered and actually represent 20 percent or more of all the longest span bridges all over the world. The function of a suspension bridge is that parabolic-shaped main cables suspended from the tops of the two towers support the traffic carrying deck which exists on the stiffening girder by hanging the suspenders and transfer their loading by direct tension force to the supporting towers and anchorages. Loading of suspension bridge may be come from its own weight, traffic live load and other environmental loads such as temperature, wind and earthquake loads, etc. The proposed long-span suspension bridge will be modelled with self anchorage system. The proposed bridge will be designed and analysed by using Multi Integrated Design and Analysis (MIDA) Software with American Association of State Highway and Transportation Officials (AASHTO) Standard, Indian Railway Standard (IRS) and Japan Road Association (JRA) Standard. This study offers the behaviours such as deflections, reactions of supports, forces of members of long span suspension bridge under its own weight condition.**

Index Terms— **Suspension bridge, MIDAS, AASHTO and JRA.**

I. Introduction

The essential points of evolution era of civil engineering are bridges. Besides, a viable structural solution to spanning long distances is suspension bridge. When suspension bridges are well designed and proportioned, they are very aesthetic and attractive structures in overall bridges. The structural arrangement of this kind of bridge combines with the graceful curve of the main cables, the suspended deck and vertical towers, to produce a naturally beautiful structure. Suspension bridges are used for the longest spans across river estuaries where intermediate piers are not feasible. A suspension bridge consists of the structural parts: main cables, suspenders or hangers, traffic carrying deck structure or stiffening girder, towers and anchorages. The cables form catenaries supporting both sides of the deck. Cables are either a compacted bundle of parallel high tensile steel strands (commonly 5 mm diameter) installed progressively by 'spinning' or may be formed from a group of wire ropes. Deck hangers are wire ropes clamped to the cable and connected to the deck at spacing equal to the length of each deck unit erected, typically 18 m. Towers are usually twin steel or concrete box members which are braced together above the roadway level. This study emphasises on the behaviours of long-span suspension bridge with self anchorage system under its self weight condition.

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II. Structural Configuration and Strategies

A. Structural Configuration

The structural system of a suspension bridge can be divided into four main parts.

1) The cable system: In the cable system of a suspension bridge, parabolic main cable and vertical hanger cables connecting the deck to the main cable are comprised. The basic element for all cables to be found in modern suspension bridges is the steel wire characterized by a considerably larger tensile strength than that of ordinary structural steel. In most cases, the steel wire is of cylindrical shape with a diameter between 3 and 7 mm. Typically, a wire with a diameter of 5–5.5 mm is used in the main cables of suspension bridges. In the transverse direction of the bridge, a number of different arrangements of the main cable plan can be found. The arrangement used traditionally in suspension bridges comprises two vertical main cable planes supporting the deck along the edges of the bridge deck. In this arrangement, the deck is supported both vertically and torsionally and the loads are transferred to the towers by the cable systems.

2) The deck or stiffening girder: In cases where the bridge deck can be divided into three separated traffic areas, e.g. a central railway or tramway area flanked by roadway areas on either side. So, the deck is the structural element subjected to the major part of the external load on a suspension bridge. This is because the total traffic load is applied directly to the deck, and in most cases both the dead load and the wind area

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are larger for the deck than for the cable system. Immediately the deck must be able to transfer the load locally whereas it will receive strong decisive assistance from the cable system in the global transmission of the (vertical) load to the supporting points at the main piers.

3) The pylons or towers: The pylons or towers of a suspension may be made up of concrete or steel material. The pylon is a tower structure, but in contrast to a free-standing tower, where the moment induced by the horizontal loading (drag) from wind dominates the design, the most decisive load on a regular pylon will be the axial force originating from the vertical components of the forces in the cables attached to the pylon. And, it transfer the bridge loads to the foundation.

4) The anchor blocks or anchor piers: The anchored system in a suspension bridge can be divided into self anchored and external anchored systems. In the self-anchored system, the horizontal component of the cable force in the anchor cable is transferred as compression in the deck, whereas the vertical component is taken by the anchor pier. In the external anchored system, also called earth anchored systems, both the vertical and the horizontal components of the cable force are transferred to the anchor block.

In this paper, the proposed suspension bridge uses two vertical main cable plans with vertical suspenders which are attached to the traffic carrying deck. The pylon of the bridge uses steel materials and self anchored type is terminated at the bridge ends.

B. Strategies

The proposed bridge is modelled with self anchored type and analysed and designed by using MIDA Software with AASHTO Standard specifications and IRS specifications. As the general, linear responses and other design considerations constitute the essence of the study on the structural behaviours of the bridges. In longer spans, the deflections may be substantial, so the design of the proposed structure should be emphasies on the deflection of the bridge. Deflection is the vertical displacement of a member due to loading. Girder should be cambered to compensate for dead load deflection. The allowable deflection is shown in Table I. So, in this study, displacements of the proposed bridge according to the JRA specifications are taken into account.

III. Design Approach and Modelling

A. Design Approach

Before the modelling of the proposed bridge, it is necessary to satisfy the initial design specifications. In the tentative design of the suspension bridge, the side span length must be proportioned to the 0.2 to 0.5 of the main span length. Besides, in the early applications of the deflection theory, the authorities recommended a minimum depth of the stiffening girder in the interval from one sixtieth (1/60) to one ninetieth (1/90) of the span length. For conceptual designs, the height of suspension bridge towers above the deck depend on the sag-to-span ratio which can vary from about 1:8 to 1:12. A good preliminary value is about 1:10. To this value must be added the structural depth of the deck and the clearance to the foundations to obtain the approximate total tower height.

Table I. Allowable Deflection

<table>
<tr><th rowspan="2" colspan="3">Kind of bridge</th><th colspan="2">Maximum deflection</th></tr>
<tr><th>Simply supported girder and continuous girder</th><th>Cantilever arms</th></tr>
<tr><td rowspan="4">Plate girder bridge</td><td rowspan="3">Plate girder bridge with reinforced concrete slabs</td><td>L≤ 10</td><td>L / 2000</td><td>L / 1200</td></tr>
<tr><td>10 < L ≤ 40</td><td>L / (20000 / L)</td><td>L / (12000 / L)</td></tr>
<tr><td>L > 40</td><td>L / 500</td><td>L / 300</td></tr>
<tr><td colspan="2">Plate girder bridge with other type of floor bridge</td><td>L / 500</td><td>L / 300</td></tr>
<tr><td colspan="3">Suspension bridge</td><td colspan="2">L / 350</td></tr>
<tr><td colspan="3">Cable stayed bridge</td><td colspan="2">L / 400</td></tr>
<tr><td colspan="3">Other types of bridge</td><td>L / 600</td><td>L / 400</td></tr>
</table>

B. Modelling

According to the design specifications, the design data used in proposed suspension bridge are shown in Table II.

Table II. Design Data used in Proposed Bridge

Name	Description
Bridge type	Suspension bridge
Total length	2.16 km
Span arrangement	3 span arrangement
Main span	1.2 km, 60@20 m
Side span	0.48 km (each), 24@20 m
Height of pylon	0.18 km
Tower type	Truss type
Girder type	Warren truss type
Girder height	10 m
Girder width	70 m
Traffic lane	5 lanes

In the modelling of the proposed bridge, the properties of materials used are displayed in Table III.

Table III. Properties of Materials used in Proposed Bridge

Material property	Main cable & hanger	Girder & tower	Concrete slab
Modulus of elasticity (kN/m^2)	2×10^8	1.9995×10^8	2.5126×10^7
Poisson's ratio	0.3	0.3	0.2
Thermal	1.17×10^{-5}	1.17×10^{-5}	1.08 ×

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Coefficient (per °C)			10^{-5}
Weight Density (kN/m^3)	82	77.09	23.56

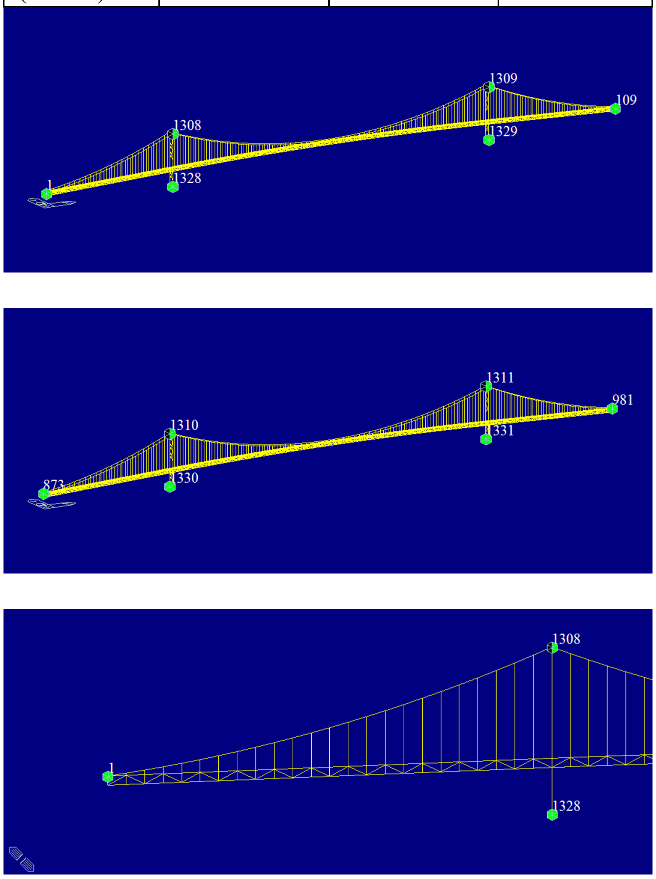

Fig. 1 Proposed Suspension Bridge Model

Table IV. Design Data used in Proposed Bridge

Type	Name	Weight of applied load
Dead load	Steel or cast steel	77.09 kN/m^3
	Concrete, plain or reinforced	23.56 kN/m^3
	Guard rails and fastenings	2.919 kN/m
	Railway rails	1.313 kN/m
	Asphalt plank, 1 in thick	0.86 kN/m^2

Fig. 1 shows the proposed suspension bridge model and Table IV describes the dead load specifications used in this bridge.

IV. Results of the Analysis

After simulating the proposed model under dead load with static analysis, the results of the forces of the member along the bridge length of the proposed self anchored bridge can be obtained. The reactions at fixed supports in proposed self anchored bridge are displayed in Table V. Moreover, axial force, shear and moment about horizontal axis (z axis) and about vertical axis (y axis) can be obtained. These values are described in figures which show as the result values of the members via the bridge length. The axial force of members along the bridge length is shown in Fig. 2. The shear force about the z axis is shown in Fig. 3. In addition, the moment about the y axis is shown in Fig. 4. The deflections or the vertical displacement along the bridge length of the proposed long-span suspension bridge is also shown in Fig. 5.

Table V. Reaction at Fixed Supports in Proposed Bridge

Node	FX (kN)	FY (kN)	FZ (kN)	MX (kN . m)	MY (kN . m)	MZ (kN . m)
1	-1.3×10^5	2.4	-1.6×10^4	60.1	-1.9×10^3	-2.6×10^2
109	1.3×10^5	2.4	-1.6×10^4	60.1	1.9×10^3	2.6×10^2
873	-1.3×10^5	-2.4	-1.6×10^4	60.1	-1.9×10^3	2.6×10^2
981	1.3×10^5	-2.4	-1.6×10^4	-60.1	1.9×10^3	-2.6×10^2
1308	-1.5×10^4	-8.9×10^2	1.2×10^5	0	0	0
1309	1.5×10^4	-8.9×10^2	1.2×10^5	0	0	0
1310	-1.5×10^4	8.9×10^2	1.2×10^5	0	0	0
1311	1.5×10^4	8.9×10^2	1.2×10^5	0	0	0
1328	-1.5×10^2	49.1	6.7×10^3	-4.7×10^2	1.5×10^3	-88.2
1329	1.5×10^2	49.1	6.7×10^3	-4.7×10^2	-1.5×10^3	88.2
1330	-1.5×10^2	-49.1	6.7×10^3	4.7×10^2	1.5×10^3	88.2
1331	1.5×10^2	-49.1	6.7×10^3	4.7×10^2	-1.5×10^3	-88.2

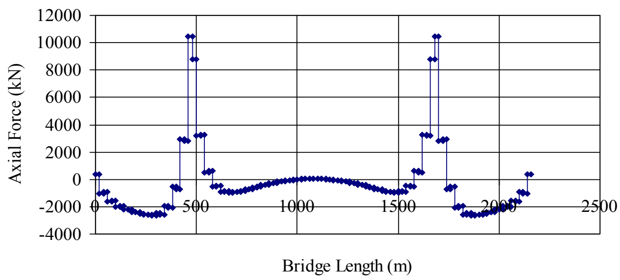

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Fig. 2 Axial Force of the Proposed Bridge

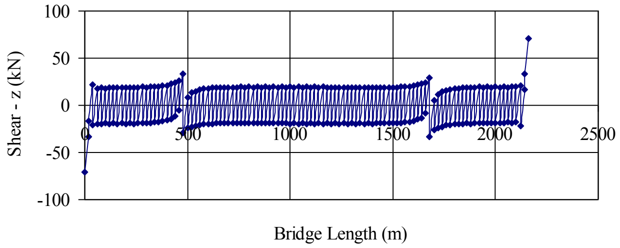

Fig. 3 Shear Force about z- axis of the Proposed Bridge

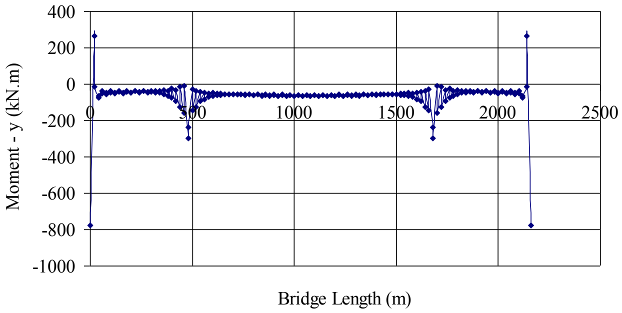

Fig. 4 Moment about y-axis of the Proposed Bridge

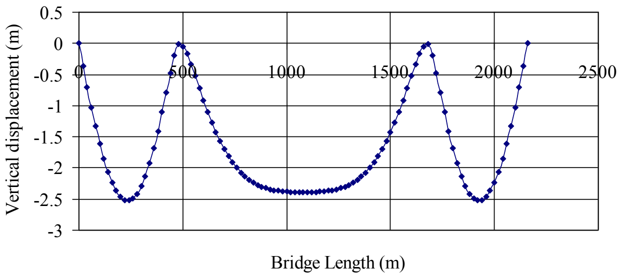

Fig. 5 Vertical Displacement of the Proposed Bridge

V. Checking of Deflection

From Fig. 5,
Maximum deflection = 2.52 m.
From Table I.
Allowable deflection = L/350
= 1200/350
= 3.4 m > max deflection = 2.52 m
Therefore, it is satisfied.

VI. Conclusion

In this study, 2.16 km span suspension bridge is analysed and designed with self anchorage system. The proposed model is analysed and designed with MIDA software. From the output results, maximum deflection due to own weight is 2.52 m which is less than the allowable deflection, 3.4 m, so the result indicates the satisfied section. Besides, from the fig, it can be concluded that the results of the proposed bridge are symmetrical and the maximum deflection occurs at mid span. Moreover, maximum axial force and shear force of the proposed bridge occurs near the tower and the maximum moment occurs at the end of the cable which is joined with the girder. By investigating this behaviours , long-span suspension bridge with self anchorage system can be analysed and designed satisfyingly.

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