VIVA-Tech International Journal for Research and Innovation
ISSN(Online): 2581-7280

Volume 1, Issue 4 (2021)
Article No. X
PP XX-XX

VIVA Institute of Technology
9thNational Conference onRole of Engineers in Nation Building – 2021 (NCRENB-2021)

VIVA-TECH INTERNATIONAL JOURNAL FOR RESEARCH AND INNOVATION
ANNUAL RESEARCH JOURNAL
ISSN(ONLINE): 2581-7280

Analyze and Design of Suspension Bridge Using SAP2000

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Abstract: *Structural design requires a full understanding and knowledge of all the components comprising the structure. A suspension bridge is a type of bridge in which the deck (the load-bearing portion) is hung below suspension cables on vertical suspenders. The design of modern suspension bridges allows them to cover longer distances than other types of bridges. The main element of a cable suspended bridge is the cable system. Bridges are normally designed for dead load, live load and other occasional loads. All loading and unloading conditions in analysis and design are provided as per IRC codal specifications. The whole modeling of the suspension parts of the bridge was done by using SAP2000. Suspension cable bridge having 1km span with single lane road, the intensity of road is given has 20 numbers of vehicles each loaded with 350KN (heavy loading class A-A track load) is analyzed by SAP2000. The output of the software presents results including moments, axial loads, shear force and displacements. Moreover, moments and axial load at each node and at any point within the element can be easily obtained from the software output. This thesis examines issues analysis and design calculation in over a structure will safe under all conditions.*

Keywords - *Suspension Cable, SAP2000, Software Output, Design Calculations.*

I. Introduction

A type of bridge where deck is hung below the suspension cable in vertical suspenders is known as suspension Cable Bridge. The main element of a cable suspended bridge is a cable system. The main forces are tension in cable and compression in towers. The cable is anchored at each end of bridge to maintain tension in this cable. The design of modern suspension bridge allows them to cover longer distance than other types of bridge. The model analysis is perform by analysis software SAP2000.

II. Headings

1.1 History of Bridge

The Manhattan Bridge, connecting Manhattan and Brooklyn in New York City, opened in 1909 and is considered to be the forerunner of modern suspension bridges; its design served as the model for many of the long span suspension bridges around the world. For bridges where the deck follows the suspenders, see simple suspension bridge. The earliest suspension bridges were ropes slung across a chasm, with a deck possibly at the same level or hung below the ropes such that the rope had a catenary shape.

The Tibetan saint and bridge-builder than tong Gallop originated the use of iron chains in his version of simple suspension bridges. In 1433, Gallop built eight bridges in eastern Bhutan. The last surviving chain-linked bridge of Gallop's was the than tong Gallop Bridge in Dustmen route to TrashyYangtze, which was finally washed away in 2004. Gallop's iron chain bridges did not include a bridge which is the standard on all modern suspension bridges today. Instead, both the railing and the walking layer of Gallop's bridges used wires. The stress points that carried the screed were reinforced by the iron chains. Before the use of 6 iron chains it is thought that Gallop used ropes from twisted willows or yak skins. He may have also used tightly bound cloth.

The first iron chain suspension bridge in the Western world was the Jacob's Creek Bridge (1801) in Westmoreland County, Pennsylvania, designed by inventor James Finley. Finley's bridge was the first to incorporate all of the

necessary components of a modern suspension bridge, including a suspended deck which hung by trusses. Finley patented his design in 1808, and published it in the Philadelphia journal, The Port Folio, in 1810.
An interesting variation is Wareham's Ferry Bridge in Burton-on-Trent, Staffordshire (1889), where the chains are not attached to abutments as is usual, but instead are attached to the main 7 girders, which are thus in compression. Here, the chains are made from flat wrought iron plates, eight inches (203 mm) wide by an inch and a half (38 mm) thick, riveted together.

1.2 Definition

It is called suspension bridge a structure that allows crossing, at different levels, an obstacle a deck supported by vertical or inclined wire hangers, which are the supporting structure, and hang flat on two towers.

1.3 Classification

The first and the main classification we will do it will be related with the number of spans of the bridge. In the following chapters we will classify different types of bridges according to more specific parameters as the continuity of the stiffening girders or the type of cable anchorages, but in general we can consider: single-span, three-span with two towers or multi-span with three or more towers.

1.4 General Characteristics

Thus, the general characteristics of a suspension bridge are:

- Central span of length L plus two lateral spans the length of which ranges from 0.2*L to 0.5*L.
- Two main cables formed from high strength steel wires with certain flexibility supporting the whole structure.
- Two towers, which can be made by metal or reinforced concrete, situated between the central span and the two lateral spans providing a support to the cables.
- The deck with the stiffening girder that distribute concentrated traffic loading on this one avoiding local deformations of the structure and providing the torsional and bending stiffness to avoid dangerous oscillations by windage.
- Anchorages to secure cables to the ground, usually resisting horizontal forces that transmit these cables thanks to the force of gravity.

1.5 Problem statement

The type of bridge to be adopted depends on the requirements of the location. Relevant Bridges as to be selected before proceeding for the Design and Construction. The structural analysis of bridges for dynamic loading conditions will give us deformations and shear force values. In the present study Suspension Cable Bridge is made to find out magnitude of deformations.

1.6 Summary

In this chapter, we have studied about suspension bridge, the need for study, what are the different objectives and the problem statement of our project is discussed. Details regarding the work carried out by different researchers for study of Suspension bridges are dealt in next chapter.

III. METHODOLOGY

3.1 Data Collection

A Suspension Cable bridge is to be analyzed. The bridge plan consists of span 500m along X direction. Placing tower at 100m from each end with height of tower 50m in Z direction. A main girder is placed at centre of tower. Such that, it coincide with centre of tower. Over main girder, cross girder is placed at spacing of 4m C/C distance. Hence, total number of cross girder is 125 along X direction. Placing deck over cross girder, width and depth of deck is 18m and 5m respectively along Y direction. The diameter of main cable is 0.35m and the dip of cable at mid span is 25m. Under reamed pile is placed at both ends of the bridge in order to anchor the main cable. From the main cable, the suspenders are connected to the deck having diameter 0.2m. The suspension cable bridge is designed and various results are compiled and analyzed.

3.2 Modeling in SAP2000

- Define Grid: After selecting a new model in SAP2000 we have to define the grid which has to be suitable of our structure model.
- Edit Grid Data: Selection of Grid is done then edit grid lines in three directions such as X plane for width, Y plane for length and Z plane for height.
- Define Material: In this case defining the material such as steel, rebar and concrete material properties has to be used in Structure.

- Define section properties: There are various types of sections are available. Such as concrete section, steel section, rebar section and other type of sections.
- Draw elements: Draw sections properties which construct the structure.
- Define Loads: Define the load are acts on the structure. There are three types of loads. Such as dead load, live load and load combination.
- Run Analysis: Run the structure analysis after drawing all the structure with elements, joint which has to be used and all the loads.

3.3 Define Models :

- **Main Cables:** Two main cables formed from high strength steel wires with certain flexibility supporting the whole structure. These cables drape in a parabolic curve between towers contributing to the overall visual impression. The problem appears in SAP2000, where doesn't exist a database of the different cables we can choose so we will have to put directly the exact properties of our cable choice. The diameter of main cable is 0.35m.
- **Tower/ Pylon:** Two towers, which can be made by reinforced concrete, situated between the central span and the two lateral spans providing a support to the cables. The towers are the primary responsible to provide supports to the ends of the main span with enough height to provide the required cable sag above the level of the Concrete girder and also to provide support to the deck. Height of the Pylon is 30m. And cross section is 2.5m x 2.5m.
- **Deck/ Girder:** The choice of the suspended deck is really important and the main reason is because the deck load is entirely supported by the cable, towers, and anchorages. From this point we have choose it trying to have the most economical deck with the best possible aerodynamic characteristics and with the highest tensional stiffness. The deck with the stiffening girder that distribute concentrated traffic loading on this one avoiding local deformations of the structure. The Properties of concrete is used for Precast Girder is M35 Grade of concrete.
- **Hangers/ Suspenders:** The main function of the hangers is to connect the deck and the stiffening girder to the main cables. The diameter of hangers is 0.2m. Spacing between these suspenders is about 3m C/C. The properties of steel are HYSD500.
- **Foundation:** The Foundation used for structure is Pile foundation. It consists of six helical shape foundation of 1m in Diameter. Its concrete properties are M35 grade of concrete. Steel are used for the foundation is 25mm Diameter bar. Provided Pile cap on top of the pile foundation.
- **Piers:** After the pile foundation is done piers are constructed on Pile cap. Height of the pier is 20m. M35 Grade of concrete to be used for constructing. Rectangular Piers are constructed of size 2.5m X 2.5m.
- **Anchorage:** Anchorages to secure cables to the ground, usually resisting horizontal forces that transmit these cables thanks to the force of gravity. We can have two different ways of connecting the main cable with the structure, so we can have externally anchored or self-anchored types. The second ones are fixed to the deck instead of an external anchorage and in consequence the axial the axial compression is carried into the girders.

IV. table no 1: loAD calculation

Load Calculation :

Left span length	100 m
Middle span length	300 m
Right span length	100 m
Deck width	18 m
Pier Height	20 m
Pylon Height	30 m
Minimum middle sag	25 m
Left number of Division	3

Middle number of Division		10
Right number of Division		3
Main Cables	Diameter	0.35 m
	Area	0.0962 m^2
Hangers	Diameter	0.2 m
	Area	0.0314 m^2

V. Conclusion

The analysis of the Composite cable bridge of 1000m span with double lane road, the intensity of road is given as 20 numbers of vehicle each loaded with 350 KN (Class A-A tack load) is carried out by using SAP2000. These results including Bending moments, shear force values at each node at every point within the element can be easily obtained from the software output. The maximum bending moment and shear force values are analyzed by software and compared with manual design of Composite Cable Bridge

Acknowledgements

We are using this opportunity to express our gratitude to everyone who has supported us throughout the completion of this project. We are thankful for their guidance, constructive criticism and friendly advice, during the project work. We express our gratitude to **Prof. Ashish Shetty** for giving us an opportunity to carry out project on ***"Analyze and Design of Suspension Bridge by Using SAP2000"***. We would also like to thank Prof. **Lissy Jose** , Head of Civil Department and **Dr. Arun Kumar**, the Principal for their whole hearted support. Lastly, we express our gratitude towards all those who directly or indirectly helped us in the completion of our studies.

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