Exploring the Cable-Stayed Bridge with Shifting the Cable Arrangement at Deck Level

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Abstract - Cable stayed bridges are becoming a more and more viable option for lengthy spans with the development of computer-based optimisation techniques. Additionally, because they are suspended structures, they can be constructed with ease in locations where it would be challenging to provide several foundations or piers. The pre-tensioning forces of the cables on Sikkim's Akkar Bridge have been determined through this investigation. CSiBridge software is the programme utilised for the investigation. A analysis of the bridge's several parameters concludes this work. The parametric analysis looks at the deck moment, the bridge's span-wise reaction, the height of the pylon, and the length of the span in relation to the girder thickness. Also investigated is the impact of superstructure modifications on substructure. Due to a lack of resources, particularly steel, cable stayed bridges were initially created in Germany in the years following World War II. The effective introduction of cable stayed bridges is made feasible by the development of welding processes, advancements in structural analysis, the use of high strength steel, orthotropic type decking, and the previously noted shortage of steel in the years following World War II. Cable stayed bridges were extremely statically indeterminate structures. Electronic computers were essential in determining the precise solution to these extremely indeterminate systems and in analysing the cable stayed bridge. The software CSi Bridge is used to perform the analysis. Three distinct models of cable-stayed bridges have been constructed, each taking into account identical cable configurations under varying situations. Since the cables are arranged on the deck at various angles and attachment locations, their effects may be thoroughly investigated. IRC Class 70R Vehicle load was taken into consideration when taking live loads in accordance with IRC: 6-2017.

***Key Words*:** Cable-stayed Bridge, CSiBridge Software, IRC - 6, Analysis.

1. INTRODUCTION

1.1 General

Engineers are attempting to build bridges with even larger spans now that new materials and technologies have arrived. The suspension bridge is giving way to cable-stayed bridges, which are gaining a lot of popularity. Huge spans have been constructed, such as the 1988 feet (606 metres) Quingzhou Minjang, China, and the 2919 feet (890 metres) Tartara, Hiroshima, Japan, and Pont de Normandie, France.

Although inclined tension stays have been used to support bridge decks since the seventeenth century, cable stayed bridge analysis and construction have advanced significantly in the last fifty years. The introduction of new technologies, high strength steel, cables, orthotropic steel decking, and building techniques are primarily responsible for the swift advancement of these bridges. For medium to long span bridges with spans ranging from 200 to 1000 metres, the cable-stayed bridge is thought to be the most appropriate due to its visual attractiveness, economic benefits, and ease of building. However, far more material would be needed for a full steel truss bridge [1]. One of the first cable bridges built in India is the Akkar Joherthang Bridge in Sikkim. In this work, pretension forces are computed for every cable using software and the unit load approach. Every cable's cross section area is maintained constant. There are 34 cables in each plane of the current bridge, or 17 cables on each face of the tower in a single plane. Additionally, a zone for anchoring is given where the wires lie on the deck [2]. The idea behind a cable-stayed bridge was to support a beam or bridge using inclined cable stays. The inclined cables of the cable-stay bridge provide direct, reasonably taut cable support for the bridge deck. Though it was predated by two other well-known concrete cable-stayed bridges, Morandi's 1962 Lake Maracaibo Bridge in Venezuela is widely regarded as the first contemporary concrete cable-stayed bridge. Concrete cable-stayed bridges have evolved from the 1925 completion of Spain's Tempul Aqueduct by Torroja to the current design ideas [3]. Determining the time-dependent effects of prestressing tendon relaxation and concrete creep and shrinkage on stresses and deflections in segmentally erected, cable-stayed concrete bridges is the aim of the experiment reported. It is well known how important these time-dependent effects are in determining the girder cross-sectional stress redistribution that shear lag requires. Large displacements in girders and pylons, sag in cable stays, and anchorage slip loss are taken into consideration as time-independent effects. These consequences happen both when the structure is being built and when it is in use. It is plausible that permissible stress levels could be surpassed in one or both of the times. Consequently, the maximum stresses and deflections resulting from construction and service loads must be known by the designer as a function of time [4].

1.2 Software Used

Founded in 1975, Computers and Structures, Inc. (CSI) is a software company specialising in structural and earthquake engineering. Its main office is located in Walnut Creek, California, and it also has operations in New York.The structural analysis and design programme CSI is the source of CSiBridge.
CSiBridge is specialised analysis and design software for bridge system engineering. It is possible to model and construct suspension, cable-stay, elevated roadway, and other kinds of bridge systems for a variety of uses, including crossing water, joining locations in shear terrain, and expanding over pre-existing highway infrastructure. A robust object-based modelling framework is combined with personalised controls and functionalities to create a computational tool for bridge engineering that is easy to use, practical, and efficient. Complex analysis techniques and sophisticated modelling characteristics are used to account for dynamic effects, inelastic behaviour, and geometric nonlinearity. Code-based templates simplify the process of modelling, analysing, optimising designs, and producing comprehensive output reports in engineering. The best software for bridge engineering is called CSiBridge.

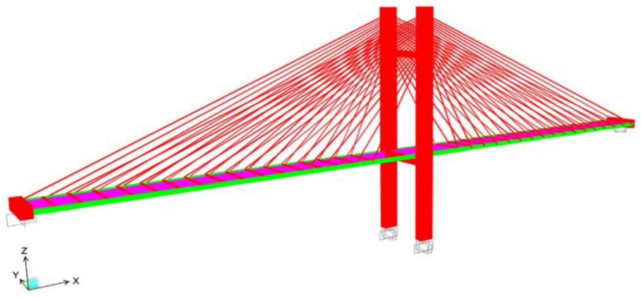

Figure 1. A model is created in CSIBridge Software

2. Cable-Stayed Bridge Configuration

In this study, "the Akkar Bridge at Jorethang, South Sikkim, over Rangit River"—a typical cable-stayed bridge—has been taken into consideration.

Project Planning Guidelines

1. Pylon

Pylon type = H type pylon
Pylon height total = 55 m
Pylon height above the deck = 35 m
Top cross-section = 1.6*1.6 m²
Bottom cross-section = 2.5*2.5 m²
Grade of Concrete = M45

2. Deck

Span of the bridge = 154 m
Total width of the deck = 10 m
Number of lanes = Two lanes of 7.5 m

3. Girder

Longitudinal Girder = 0.6*0.8 m²
Cross Girder = 0.45*0.8 m²

4. Cable

Cable Arrangement = fan type
Number of cable planes = 2
Number of cables in each plane = 34
Area of cable = 1423.9 mm²
37 H.T. E450 wires

3. Methodology

The research analysis used in this study uses the specific approach listed below:

3.1 Creating Model

Using the CSiBridge software, begin by building a 3D model of the cable-stayed bridge. Describe the bridge's geometry, taking into account the towers, deck, and cables. Enter the bridge elements' measurements, composition, and characteristics.

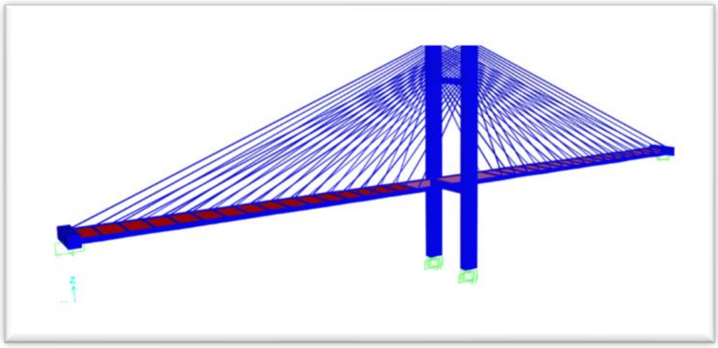

Figure 2. Bridge model creation

3.2 Cable Configuration

Specify the original cable configuration, encompassing the quantity of cables, the towers where they are attached, and the deck anchor points. This setup will function as the analysis's starting point.

3.3 Load Cases

Determine which load cases—such as dead loads, live loads, and other pertinent loads—will be taken into account during the study. Indicate the size and dispersion of these loads using IRC codes.

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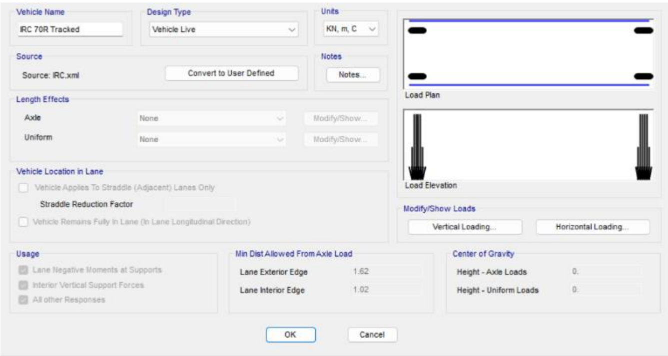

Figure 3. Vehicle load cases

3.4 Analysis Settings

CSiBridge software analysis settings should be set. Describe the sort of analysis (dynamic, nonlinear, linear static, etc.). Give the bridge elements' material qualities, section properties, and any pertinent details.

3.5 Cable Position Variation

Establish the range of deck-level cable positions you wish to look into. Selecting the variables that will change the cable positions, such as the distance between cables, the inclination angle, or other pertinent elements, will enable the creation of numerous cable combinations in various places for study.

3.6 Analysis Execution

For every possible cable position variation at the deck level, run the analysis in CSiBridge. Utilise the bridge model with the specified load situations. The structural reaction of the bridge, including deflections, bending moments, shear forces, cable forces, and other pertinent outputs, will be computed by the programme.

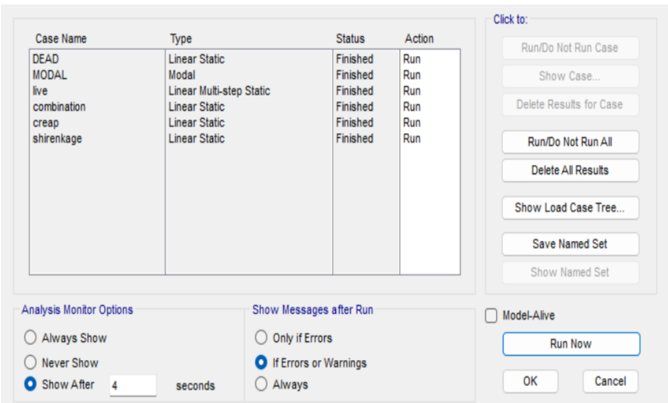

Figure 4. Run the analysis after analysis execution

4. Result and Discussion:

Following the examination of several cable-stayed bridge models, we will talk about the outcomes of various cable locations at the deck level. Analyse variables like stresses, cable forces, bridge deflections, and any other relevant performance indicators.

4.1 Shear force

When combining the dead and live loads, the original cable-stayed bridge has the largest shear force. The shear force of the original bridge is 14.91% larger under creep and shrinkage conditions when comparing the different cable positions of the cable-stayed bridge by increasing the number of cables. Furthermore, the original bridge's shear force is 9.58% greater than that of the cable-stayed bridge with additional cables and no creep or shrinkage. In order to validate the findings, we are comparing the pre-stressed concrete bridge to the original cable-stayed bridge under both creep and shrinkage conditions. In both cases, the pre-stressed concrete bridge has a greater shear force**.**

4.2 Bending Moment

When adjusting the cable locations by adding or removing cables, the bending moment of the original cable-stayed bridge is 13.75 percent more and fourteen percent less when taking into account the dead and live load combination with creep and shrinkage. When changing the cable placements by adding or removing cables, the original cable-stayed bridge's bending moment is 13.78% more and 15.08 percent less without creep and shrinkage. The original cable-stayed bridge has fewer bending moments under both situations when compared to the pre-stressed concrete bridge, with and without creep and shrinkage. This comparison is done to validate the results.

4.3 Vertical Deflection

When the number of cables is increased or decreased, the original cable-stayed bridge's deflection lowers by 28.66% and increases by 24.18%, respectively, taking into account the combination of dead and live load as well as creep and shrinkage. The initial cable-stayed bridge's deflection drops by 15.19% in the absence of creep and shrinkage, and increases by 19.46% when the cable placements are changed. We contrast the deflection of the original cable-stayed bridge with that of a pre-stressed concrete bridge under both creep and shrinkage-free conditions in order to verify the findings. Under both circumstances, the original cable-stayed bridge has greater deflections.

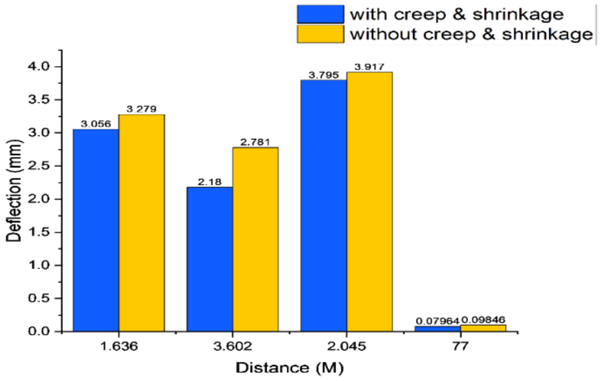

Figure 5. Comparison of Vertical deflection of different bridges

4.4 Shear stress

The analysis of a cable-stayed bridge has taken into account the effects of creep and shrinkage in addition to the combination of dead and live loads. It has been found that the shear stress of the original bridge falls by 7.44% and 9.85% when the cable placements are changed and the number of cables is increased or decreased. On the other hand, the shear stress of the original bridge drops by 4.86% and by 6.48% with equivalent alterations in cable placements when the effects of creep and shrinkage are ignored. A comparison between the original cable-stayed bridge and a pre-stressed concrete bridge—both with and without taking the effects of creep and shrinkage into account—has been undertaken in order to validate these findings.

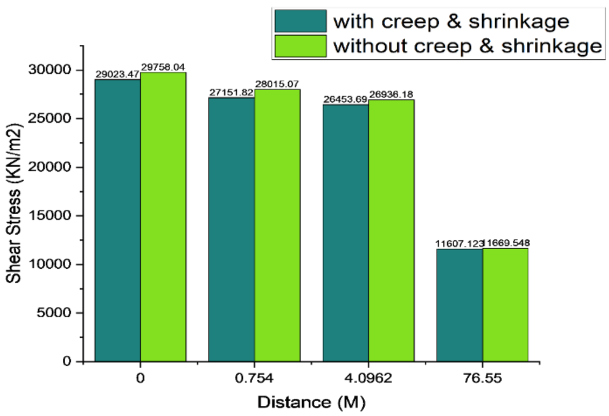

Figure 9. Comparison of Shear stress of different bridges

5. Conclusion

- By adjusting the cable placements in several bridge models, we were able to see a decrease in shear force, bending moment, vertical deflection, and shear stress with creep and shrinkage. We discovered that the pre-stressed concrete bridge is not as good as the original cable-stayed bridge and that the former will last longer. Thus, from an economic perspective, a cable-stayed bridge would be a good substitute for a pre-stressed concrete bridge.

- Through a comparison of fixed cable placements between precast concrete girder bridges and cable-stayed bridges, the study highlighted the distinct advantages of each design. The precast concrete girder bridge provided a contrasting point of reference in this comparison, highlighting the adaptability of cable-stayed bridges to various loading scenarios and aesthetic considerations.

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