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Dynamic Analysis of Scissor Bridge

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ABSTRACT: This study deals with the dynamic analysis of a new type of movable or foldable bridge called as scissor bridge. The main working principle of this type of bridge is scissor mechanism. This type of bridges can be used in military operations and also across the obstacle where there is restrictions in space to provide bascule, or vertical lift type movable bridge. This bridge expands and retracts on the plane parallel to the ground which makes it easy to store when not in working state. In this study a bridge of span 8m, width 5.5m and height 8m is modeled in STAAD Pro. software for the moving load analysis. IRC class AA tracked load is considered for the moving load analysis. The analysis of the structure was carried out for dead load and IRC class AA tracked load and it is observed results are within the permissible limits as per Indian design codes.

KEYWORDS: scissor bridge, X-links, connection shafts, moving load, cables, IRC class AA tracked load

I. INTRODUCTION

A bridge is a structure designed to span a physical obstacle, such as a body of water, a valley, or a road, without closing off the path beneath. It is built to provide passage over an obstacle, usually something that would be dangerous to cross otherwise. There are several designs, each of which serves a certain function and applies to different situations. Bridge designs differ based on the function of the bridge, the nature of the terrain where the bridge is built and anchored, the material used to create it, and the budget available to build it. Bridges are classified in a variety of ways. The sort of structural components utilized, what they carry, whether they are fixed or moveable, and the materials used are all common categories. In general, we can classify bridges in three groups i.e., fixed bridges, temporary bridges and movable bridges. The majority of bridges are fixed bridges, which have no moving sections and remain in place until they collapse or are removed. They are intended to remain in place until they are considered unfit for use or dismantled. Temporary bridges built of modular fundamental components that may be moved by medium or light machines. They are commonly utilized in military engineering or while repairing permanent bridges. A movable bridge is one of the types of bridges that may vary their location and sometimes even shape to allow vessels and boats to pass across the river. Because there are no high piers or long approaches, this form of bridge is less expensive to build. The use of this bridge halts road traffic, leaving it available for river traffic. Around the world, several types of moveable bridge systems are employed, such as draw bridges, folding bridges, and curling bridges. The benefits of this style of bridge are structural integrity, dependability, and cost-effective construction and operation.

Scissor Bridge is basically a collapsible bridge, made up of many links that form a scissor-like structure that may collapse and extend with a set ratio. The Collapsible Scissor Bridge is a movable bridge that may be used to access isolated locations damaged by disasters such as flooding. It gives a collateral force to the other link and widens the bridge by applying a force in the horizontal direction of the connection.

II. RELATED WORK

“Folding Bridge – a model unfolded for disaster management”^[1], *Published by -Int. Journal of Applied Sciences and Engineering Research, -2015*

In this paper the concept of folding bridge is discussed. A thought of folding bridge flashed the mind of researcher after a heavy rainstorm in Uttarkhand, India on June 16, 2013. Due to heavy rain, all the bridges that connected that states surrounding locations were swept away, due to which there was no one to help the injured and there was a difficulty in conducting the rescue operations. Mohd Akil Ustadis discussed the "Folding Bridge" concept, which is extremely effective in disaster management. This bridge is made up of a series of equilateral triangles of

varying sizes, and each smaller triangle folds into its next big size triangle. The deck is made of "Allied Foam Tech" and high strength "Steel" for triangular construction.

“Design and Analysis of Collapsible Scissor Bridge”^[2], *Published by - MATEC Web of Conferences 152-2018*

Collapsible Scissor Bridge is a movable bridge that may be used to access isolated locations devastated by disasters such as flooding. The goal of this project is to create a folding bridge that can be transported by a 4 vehicle and used to connect isolated regions. Here ANSYS is used for numerical analysis of structural strength. Due of the restricted library in ANSYS, the material employed in simulation is A36 structural steel. The recommended material, however, is Fiber Reinforced Polymer [FRP] composites, which have a high strength-to-weight ratio. FRP is extremely resistant to corrosion, which is advantageous in flooded areas.

“Analysis and Design of Deployable Bridge Based on Origami Skill”^[13], *Published by-International Journal of Engineering Development and Research, Volume 5, Issue 2, 2017*

This study deals with the analysis of a mobile foldable bridge. The bridge is analysed as single way two lane bridge for IRC class A loading. Two different spans of bridges are considered for analysis at different stages of opening for self-weight and full live load, the spans used for analysis are 10m and 15m. The software used for the analysis of the structure is STAAD Pro. and the materials considered in the analysis are titanium, steel and aluminium. Various geometric angles were assigned to the X-links to determine the most suitable one for the structure for particular span. After the analysis it was clear that best suitable angle was 45° for the span of 15m and it was found that titanium alloy would be the most economic material for the construction of such bridge.

III. METHODOLOGY

A. Software modelling and Analysis

The analysis of the structure is carried out using STAAD Pro. software. In this study the structure is analysed for its self weight and a moving load. Dimensions of the bridge are as follows: height- 3m, span- 8m and width of the deck is 5.5m. The bridge comprises of the following parts: X- links, deck frame, deck plates, connecting shafts, and high strength cables. The vehicular load considered in this study is IRC Class AA tracked load. This IRC load is of 700kN which is equally distributed to between two tracks i.e; 350 kN on each track and these tracks are separated by a clear space of 1.2m. Each track has a width of 0.85m and length of 3.6m. The figure below depicts the vehicle load used in this study.

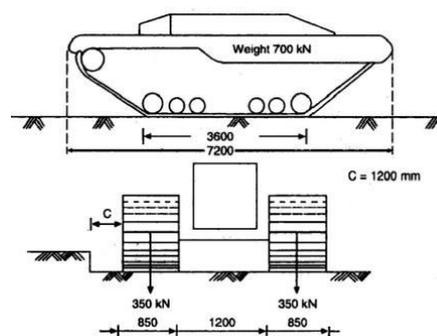


Fig 1. IRC class AA tracked load

This structure is basically analysed as a simply supported structure, but these support conditions are achieved only when the bridge is completely opened, until then it acts as cantilevered bridge. The figure below shows the software model of the structure.

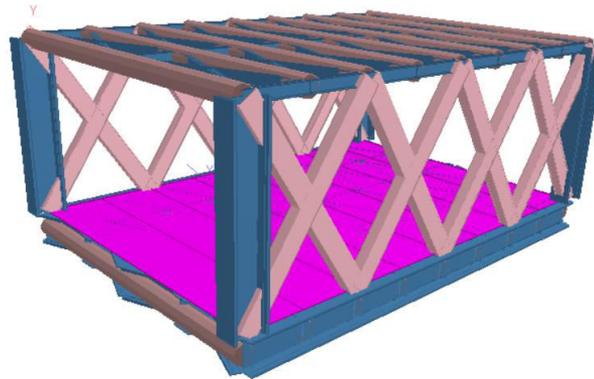


Fig 2. Scissor Bridge.

In this study we have used different types and sizes of the sections for various structural members of the bridge. The sections used are: 15mm thick steel plates for deck, ISHB450 with 40 mm top and bottom cover plates of width 400mm for bottom deck frame, rectangular tube section of size 300mmX175mmX15mm for X-links, ISMB150 and ISMB175 for top chord members, solid steel shaft of 300mm diameter for connecting shafts. The vehicular load considered in this study is IRC class AA tracked load, it has total load of 700kN which is equally distributed between two tracks as shown below.

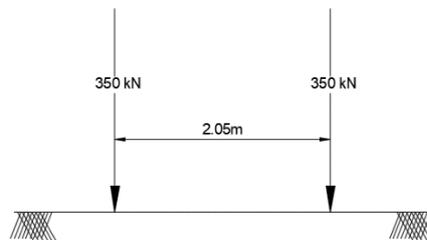


Fig 3. Tracked load line diagram.

The vehicular load is defined in the software considering above figure with load intensity of 350 kN separated by the width of 2.05m. Once the vehicle load is defined now we need to generate the moving loads, for this we have considered an interval of 0.25m for the generation of moving loads, i.e; each generated load will be placed/moving at the rate of 0.25m per meter length. Since the span on the bridge is 8m and we have taken the interval for load generation as 0.25m, therefore we need generate 33 load cases (i.e; $[8/0.25] + 1$). Now this defined moving load is applied on the bridge at the particular point at the starting of the bridge such that the two track loads are at equidistance from the center point of the width of the bridge. This structure is analysed as a simply supported bridge for the load combination of dead load and IRC class AA tracked moving load. The STAAD Pro. output of the analysis is as tabulated below:



Table 1. Beam displacement summary

	Beam	L/C	d (m)	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	151	14:LOAD GENERATION,	0.000	1.774	-0.097	0.007	1.777
Min X	188	22:LOAD GENERATION,	0.000	-1.774	-0.097	-0.007	1.777
Max Y	180	2:LOAD GENERATION,	2.750	0.551	0.505	0.000	0.747
Min Y	37	18: LOAD GENERATION,	2.750	0.000	-14.337	-0.000	14.337
Max Z	279	2:LOAD GENERATION,	1.800	0.086	-0.017	0.985	0.989
Min Z	281	2:LOAD GENERATION,	1.800	0.086	-0.017	-0.985	0.989
Max R _{st}	37	18:LOAD GENERATION,	2.750	0.000	-14.337	-0.000	14.337

Table 2. Beam forces summary

	Beam	L/C	d (m)	Axial Fx (kN)	Shear Fy (kN)	Fz (kN)	Bending My (kNm)	Mz (kNm)
Max Fx	257	18:LOAD GENERATION,	0.0	341.5	6.6	-0.1	0.1	2.2
Min Fx	263	10:LOAD GENERATION,	0.0	-314.7	4.6	5.6	-6.3	6.2
Max Fy	33	2:LOAD GENERATION,	0.0	0.0	714.9	0.0	0.0	784.5
Min Fy	35	10:LOAD GENERATION,	5.5	-3.4	-714.9	0.0	0.3	807.4
Max Fz	281	2:LOAD GENERATION,	0.0	112.5	23.2	59.3	-35.8	-4.4
Min Fz	279	2:LOAD GENERATION,	0.0	112.5	23.2	-59.3	35.8	-4.4
Max Mx	278	2:LOAD GENERATION,	0.0	96.4	-1.0	9.9	-11.8	-0.4
Min Mx	270	2:LOAD GENERATION,	0.0	96.4	-1.0	-9.9	11.8	-0.4
Max My	281	2:LOAD GENERATION,	3.0	121.7	23.2	59.3	142.2	-74.1
Min My	279	2:LOAD GENERATION,	3.0	121.7	23.2	-59.3	-142.2	-74.1
Max Mz	40	30:LOAD GENERATION,	5.5	3.0	-714.9	0.0	-0.1	811.2
Min Mz	72	34:LOAD GENERATION,	1.5	-1.0	317.2	-0.1	-0.1	-655.1

B. Manual Checks for moment and Shear carrying capacity of members.

From the software output it was found that the highest values for bending moments and shear force were acting on the shaft members, hence the calculations for shear force and bending moment carrying capacity of the member are done below:

1. Bending moment carrying capacity:

Referring to page 53, clause 8.2.1.2 of IS 800 : 2007 ,the design bending moment is given by,

$$M_d = (\beta_b Z_p f_y) / \gamma_{mo} \quad [7]$$

where,

$\beta_b = 1.0$ for plastic and compact sections;

$\beta_b = Z_e / Z_p$ for semi-compact sections;

Z_p, Z_e = plastic and elastic section moduli of the cross-section, respectively;

f_y = yield stress of the material; and

γ_{mo} = partial safety factor

Plastic section modulus for the circular section is given by,

$$Z_p = d^3 / 6$$

$$Z_p = 300^3 / 6$$

$$Z_p = 4.5 \times 10^6 \text{ mm}^3$$

From Table 2 of IS 800: 2007 we get the class of the section as plastic. Therefore the value for β_b is 1.0.

From Table 5 of IS 800: 2007 we get partial safety factor γ_{mo} as 1.10.

Yield stress of the material is taken as 250 N/mm²

Thus,

$$M_d = (1.0 \times 4.5 \times 10^6 \times 250) / 1.10$$

$$M_d = 1022.72 \times 10^6 \text{ N-mm}$$

$$M_d = 1022.72 \text{ kN-m}$$

2. Shear force carrying capacity:

Referring to page 59, clause 8.4 and 8.4.1 of IS 800: 2007 the design shear carrying capacity of the section is given by,

$$V_d = A_v f_y / (\gamma_{mo} \sqrt{3}) \quad [7]$$

where,

A_v = Shear area;

f_y = yield stress of the material; and

γ_{mo} = partial safety factor

Now, Shear area is calculated as below,

$$A_v = \pi d^2 / 4$$

$$A_v = (\pi \times 300^2) / 4$$

$$A_v = 70.685 \times 10^3 \text{ mm}^2$$

From Table 5 of IS 800: 2007 we get partial safety factor γ_{mo} as 1.10.

Therefore,

$$V_d = (70.685 \times 10^3 \times 250) / (1.10 \times \sqrt{3})$$

$$V_d = 9275 \times 10^3 \text{ N}$$

$$V_d = 9275 \text{ kN}$$

For shear check the 60% of the design shear strength is considered [7],

$$0.6V_d = 0.6 \times 9275$$

$$0.6V_d = 5565 \text{ kN}$$

C. Analysis of high strength steel cables.

This bridge acts as a cantilever bridge until it is completely opened and the deck rests on far end of the obstacle to be crossed. So to support the weight of the bridge until it is completely opened we are using high strength cable. The total weight of the structure is obtained from software and its value is 1058.87 kN. Let us consider 15% extra weight considering factor of safety and impact factors, therefore total weight is 1217.70 kN. This weight will be equally distributed on the two cables i.e; 608.85 kN on each cable.

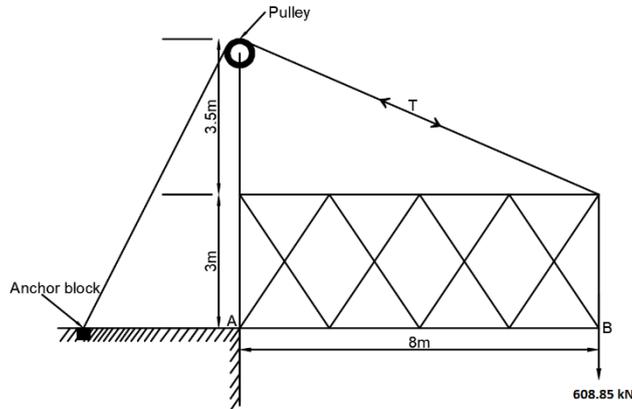


Fig 4. Line diagram of the structure.

Now taking moment about point B,

$$8V_a - 3.5H_a = 0$$

$$\therefore H_a = (608.85 \times 8) / 3.5$$

$$\therefore H_a = 1391.65 \text{ kN}$$

Tension in the cable is found using the formula given below,

$$T = \sqrt{H_a^2 + V_a^2}$$

$$\therefore T = \sqrt{1391.65^2 + 608.85^2}$$

$$\therefore T = 1519.00 \text{ kN, on each cable.}$$

Referring to Table 3 of IS 2266: 2002 the diameter and type of cable are as below:

Considering steel core wire of grade 1960 and type 6 x 37 M (18/12/6-1) [8] we get the diameter of cable as 52 mm. The table below describes strength and mass of the cable.

Table 3. Cable strength

Nominal Diameter	Approximate mass (kg/100 m)	Minimum Breaking Force Corresponding to Rope Grade of 1960
52 mm	1029	1687 kN

The figure below shows the sectional view of the cable:

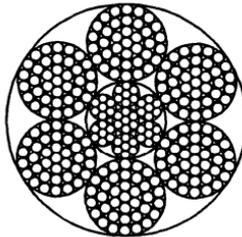


Fig 5. 6x37M (18/12/6-1) Type 52 mm Dia cable

IV. RESULTS

1. Results of the main structure:

Parameters	Allowable / Design capacity	Obtained
Max Displacement (in mm)	45.83 mm	14.337 mm
Max Shear force (in kN)	5565 kN	714 kN
Max Bending moment (in kN-m)	1022.72 kN-m	811 kN-m

2. Results from the cable analysis:

Tension in the cable = 1519 kN

Type of cable = 6x37M (18/12/6-1) Steel core cable^[8]

Diameter of cable = 52 mm.

V. CONCLUSIONS

- Since the maximum deflection of the structure is 14.337mm which is less than maximum allowable deflection i.e., 45.83 for the given load combinations it is concluded that the structure is safe under deflection.
- It is also seen that the maximum shear force and maximum bending moments of the structure under the given load combinations are less than the design shear force and design bending moment calculated in accordance with IS 800: 2007.
- Since the structure safely carries the IRC class AA tracked load of 700 kN it can be used for military operations.

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