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Capacity Evaluation of Existing Suspension Bridges: A Case Study in Afghanistan

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Abstract

This research has been done in more than dozens of pedestrian and motorway suspension bridges that have already been built in our country (Afghanistan). This work uses library and field research, experiences in suspension bridge design, experiences in suspension bridge repairing, and AASHTO's loading method. For the purpose of assessing this issue, suspension bridge professional designers' experiences, suspension bridge professional repairers' experiences, Afghan professional bridge engineer's experiences, internet websites, research, and The investigation of the traditional suspension bridges built in Afghanistan have been used.
From the research that was done, it is concluded that due to the lack of a complementary standard in the field of design and poor quality implementation of suspension bridges in Afghanistan, it should be considered as a standard in the field of suspension bridge design that all proposals are applicable in the design of future suspension bridges until a complete standard is issued in the country.

Keywords: Anchor Blocks, Cable, Concrete, Reaction, Rebar, Suspension, Tension and Tower.

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1. Introduction

One of the main duties of a bridge designer is to choose the type of bridge, its shape, and stability in aspect of all factors. The existence suspension bridges which constructed in our country, including pedestrian bridges, jeep bridges, and bridges with heavy tonnage vehicles.

Most of these bridges have been designed and built by the honorable Ministry of Rural Rehabilitation and Development (National Rural Access Program-NRAP, Engineering Services, Field Development, and partner institutions), the honorable Afghan Aid Institute, and former PRTs. In order to collect data and more information about the mentioned bridges, visited the offices of the design and implementation of programs of the honorable Ministry of Rural Rehabilitation and Development and the honorable Afghan Aid Institute, studying the maps of the suspension bridges, joint meetings with the designers and implementers of the projects, and also travel to the area and measurement of all the elements of the bridges have been done. The mentioned bridges were built with the following specifications:

The decks or their crossing parts are made of wood, metal, and mixed metal and wood, their Main suspension cable are 32 mm, 36 mm, and 40 mm diameters, the vertical suspenders are made of 13 mm, 26 mm cables, and 14 mm rebar's, the main anchor blocks and the cable anchor blocks are constructed from stonemasonry, concrete, and concrete with 30-40 percent of stone. Different marks of concrete such as 3000 and 4000 pounds per square inch, and different grades of steel such as 40 and 60 kilopounds per square inch have been used in bridge elements. In the design of the mentioned bridges, different codes and sources of the world are used, such as the codes of the former Soviet Union, AASHTO, Sri Lanka, and Bangladesh, and the bridges were designed and built with different capacities. The reason for the damage to some bridges is the lack of a specific norm and a design control center in our country. Therefore, it is necessary to evaluate their capacities and if necessary to strengthen their elements and guide and train the people of the region for their proper use. More research should be done on bridges, especially on suspension bridges on the other hand, research on the plan and design of suspension bridges is done for the reason that the plan and design of bridges in the future will not be based on temporary loads and engineering norms of different countries. This research has been done on several numbers of suspension bridges that have been built in our dear country, and the results and suggestions have been mentioned in the last part of the article. From an economic point of view, this research is very important, because it prevents the design of a non-economic project design, and from a technical point of view, it offers stability.

2. Presenting the issue

It is assumed that the basic elements of suspension bridges are designed in a critical state and their maximum capacity is used under service loads. And it should be evaluated that the suspended bridges that have already been built how much their capacity is. The mentioned issue will be considered after a comprehensive analysis of the existing suspension bridges.

3. Research hypotheses

At the end of this article, we will reach the following conclusions:
1- The existing bridges will have the desired capacity.
2- The geometric dimensions of the cross sections of the existing bridge elements will be sufficient.

4. Research Purposes

The purpose of the research is to analyze and evaluate the ultimate capacity of the existing suspension bridges in order to ensure as much safety as possible for the movement of riders, vehicles, and animals in the suspension bridges of the country, suggestions to prevent their destruction and collapses, the construction of contemporary buildings considering the special conditions of our country and utilize the experiences of various countries of the world and also to prevent huge financial losses in the country, this research has been done for.

5. Research method

This work uses library and field research, experiences in suspension bridge design and suspension bridge repair, AASHTO's loading method, and for the purpose of assessing this issue, suspension bridge professional designer experiences, suspension bridges professional repairers' experiences, Afghan professional bridge engineer's experiences, internet websites, research and The investigation of the traditional suspension bridges built in Afghanistan has been used.

6. Literature review

The construction of contemporary bridges must meet the demands of strength, stiffness, structurer geometrical stability, beauty, and economy. The crossing part (deck) of suspension bridges is mostly made of wood and metal. The existing suspension bridges in our dear country Afghanistan have been designed and built by various departments, such as the honorable Ministry of Rural Rehabilitation and Development, the honorable Afghan Aid Institute, and private companies. In the United States of America, according to AASHTO bridge specifications, bridges are made of different materials in various shapes, and their calculations are based on the reliable sources of that country. Also in our country, suspension bridges have been calculated and constructed using the Soviet bridges, United States of America, Bangladesh, and Sri Lanka countries codes. In this work, field, and library research have been conducted regarding the investigation of existing suspension bridges in our country (Afghanistan), but no case-based research has been done in this field before so the results are to be compared.

7. Research topic

In this case, researchers have done a lot of research, mostly different loads and loading methods have been used and it does not answer the current conditions of our country. This research has been studied by using the AASHTO method in order to ensure that the bridge is economical on the one hand and its strength and stability on the other hand. Because until now we have witnessed the destruction of a large number of suspension

bridges, especially during the passage of loads. They were designed without the existence of any single norm and variety of standards. In this work, dozens of bridges over different seas have been studied. Bridges should be designed for the most critical mode of load combinations [2]-[3], [7]-[8] and WWW.crcpress.com

8. Calculation of Suspension bridges

Tower height

The height of the bridge towers is determined based on the following formula:

$$h_t = f + c + h_r \qquad (8.1)$$

Here:

h_t - The height of the tower

f - The height of the cable arch peak, which is determined in the following limits.

$f = (0.075 - 0.14)L$

c -The height of the peak of the arc of the deck, which is chosen in the following range.

$c = (0.015 - 0.03)L$

h_r -The height of the handrail, which is chosen in the following range.

$h_r = (1 - 1.5)m$

L -Bridge length in meters

Determining the amount of temporary load

1- Pedestrian load

a- If the length of the bridge is greater than 50 meters.

$$P = (3 - \frac{50}{L}) \qquad (8.2)$$

Here:

L- the length of the bridge in m

P- Temporary load in $\frac{kN}{m^2}$

b- If the length of the bridge is less than 50 meters.

$P = 4\frac{kN}{m^2}$

2- Vehicle load

a- Hilux load

$w = 45kN$

Here:
w- Total weight of Hilux
b- Load HS-20

- Calculation of the maximum tension of the cable
a- horizontal reactions

$$A_x = B_x = H = \frac{wL^2}{8f} \qquad (8.3)$$

Here:
w - Uniform regular distributed load
L- The length of the span
b- Vertical reactions:

$$A_y = B_y = V_{\max} = \frac{wL}{2} \qquad (8.4)$$

c- Maximum tension in cable

$$T_{\max} = \sqrt{A_y^2 + H^2} \qquad (8.5)$$

Here:
$T_{\max}$ - Maximum cable tension
A_y - Vertical Reaction
H -Horizontal Reaction
d- β_f Angle means the angle between the horizontal axis and the axis of the main cable

$$\beta_f = \arctan(\frac{4f}{L}) \qquad (8.6)$$

[1]- [8] And WWW.crcpress.com

Based mentioned formulas capacity of existing suspension bridges is calculated in below Table (1)

Table 1. Calculation of the capacity of existing suspension bridges in Afghanistan

S/N	Bridges Location			Specification of bridge		
	Name of Bridge	District	Province	Length (m)	Wide(m)	Number of Cable
	1	2	3	4	5	6
1	Qarluq Bridge	Qarluq	Takar	106	3.0	16
2	Takhashor Bridge	Bangi	Takar	140	3.2	12
3	Ghazi Bik Khail Bridge	Nejrab	Kapisa	100	2.6	12
4	Badakhshan Bridge	Center	Badakh-shan	60	2.6	8
5	Deh Naw Bridge	Guldara	Kabul	50	1.5	4
6	Mia Khan Kas Bridge	Qarghaei	Laghman	100	2	8
7	Gandab Bridge	Qarghaei	Laghman	65	3	8
8	Shingal Bridge	Want Wigal	Norestan	50	2.2	4
9	Akhudzada Bridge	Alishing	Laghman	92	1.7	8
10	Ghulaman Bridge	Alishing	Laghman	90	1.5	8
11	Ghalbilai Bridge	Nangalam	Kunar	50	1.5	4
12	Kandi Bridge	Alingar	Laghman	54	2.5	4

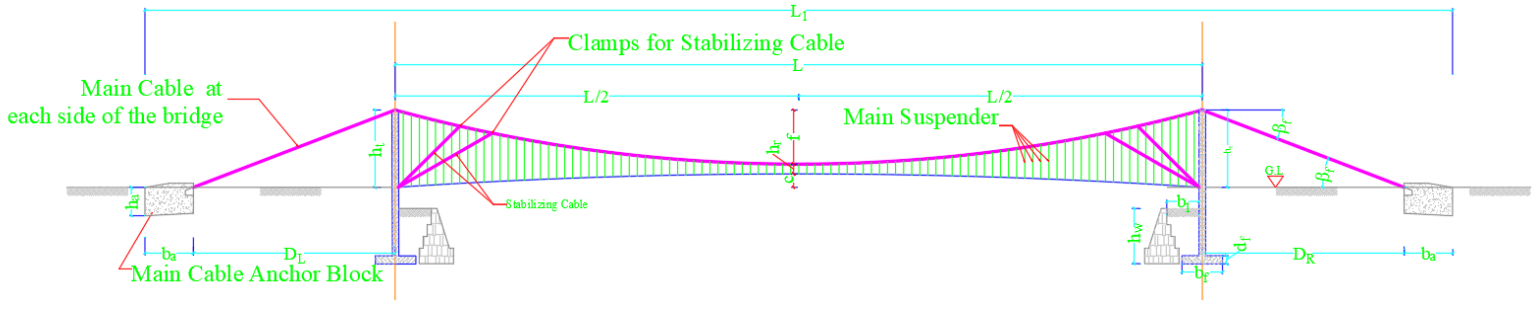
Continued table (1).

Specification of bridge				Specification of materials		
Dia. of Cable (mm)	Dia. of Sus. (mm)	Crous Beam size (mm)	Colu. size (cm)	All. Load. (kN)	Grad of steel	All. Wood str. (kN/cm2)
7	8	9	10	11	12	13
40	Φ26-cable	][2(300x100x6.5)	100x100	Φ40(305) Φ26(129)	60 40	-
40	Φ26-cable	I (270x125x5)	60x100	Φ40(305) Φ 26(129)	60 40	-
40	Φ26-cable	I (270x125x5)	60x100	Φ40(305) Φ26(129)	60 40	-

40	Φ26-cable	I (270x125x5)	60x80	Φ40(305) Φ26(129)	60 40	-
32	Φ14- steel	100x150 wood	50x60	Φ32(195)	40	1
32	Φ14- steel	200x150 wood	70x90	Φ32(195)	40	1
32	Φ14- steel	100x140 wood wood	65x80	Φ32(195)	40	1
32	Φ14- steel	100x150 wood	50x60	Φ32(195)	40	1
40	Φ13-cable	[(140x58x4.9)	60x100	Φ40(305) Φ13(34)	60 40	-
40	Φ13-cable	100x150 wood	60x100	Φ40(305) Φ13(34)	60 40	1
36	Φ14- steel	100x150 wood	60x80	Φ36(247)	40	1
32	Φ14- steel	100x150 wood	60x80	Φ32(195)	40	1

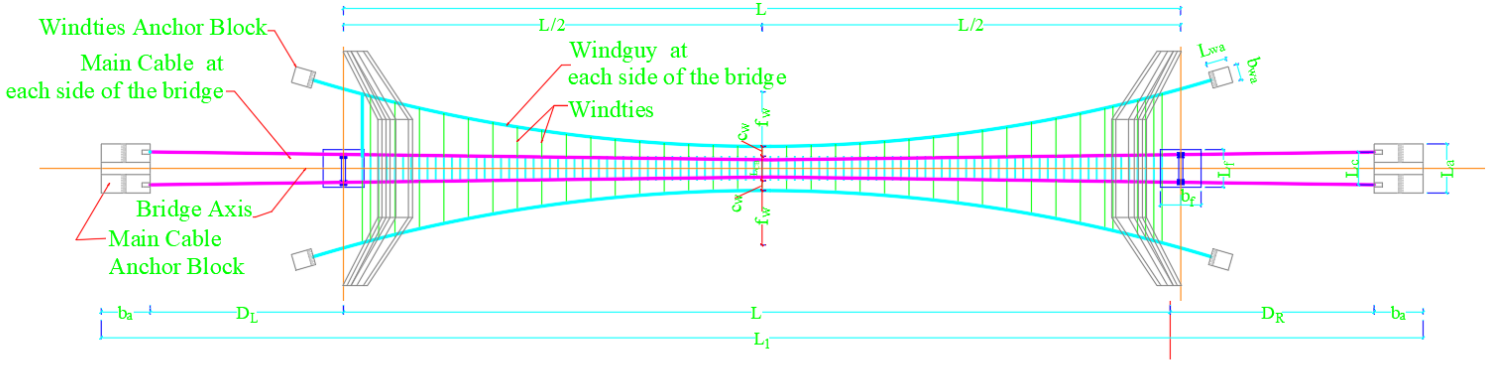
Continued table (1).

Capacity of bridges				Remarks
Live load				
Foot path (kN/m2)	Car (25kN)	High lax (45kN)	HS-20 (326.25kN)	
14	15	16	17	18
4	√	√	√	
2	√	√	0	
4	√	√	0	
4	√	√	0	
3	0	0	0	
2	√	0	0	
3	√	0	0	
2.5	√	0	0	
4	0	0	0	
5	0	0	0	
2.3	0	0	0	
1.6	√	0	0	



LONGITUDINAL SECTION

Fig. 1. Bridge Cross-sectional longitudinal



PLAN

Fig. 2. Plan Bridge

9. Materials and Work Methods

Primary materials (quantity), diameter and the mark of main cables, diameter and the mark of suspenders, cross-sectional dimensions of beams, type of material and mark on them, dimensions, type of material, and the mark of longitudinal beams (for the deck), dimensions of wooden sheathing boards (deck), anchor blocks dimensions and type of material and their marks, clamp cables, bulldog grips and the mark of them, turnbuckles and mark of them, channels and mark them, dimensions and materials types, towers and foundations materials and marks, obtained from field surveys of bridges built in the provinces of Kunar, Nangarhar, Laghman, Kapisa, Takhar, Badakhshan and Kabul which are designed by design Offices of the Honorable Ministry of Rural Rehabilitation and Development, the Honorable Afghan Aid Organization, using Excel and Mathcad programs. And capacity of the suspension bridges is calculated then.

10. Controversy

- Contemporary suspension bridge constructions should meet the requirements of sustainability, strength, stiffness, geometrical immutability, beauty, and economy. But the bridges that have been built before do not meet the above requirements, in this work, special attention has been paid to this matter, see the pictures.
- In the design of the elements of some of the existing suspension bridges, high-quality building materials are not taken into account, which has caused damage to them.
- One of the factors of the low load-carrying capacity of the elements of some bridges is the temporary loads that are not considered according to the valid code.
- There were mistakes in the design of the elements of some bridges, which reduced their capacity.
- The height of the towers of some built bridges is considered less, which causes the increase in the number of the basic cables of the bridge, see the pictures.
- The lack of experience of some domestic and foreign institutions in the design and implementation of projects has caused their low load-carrying capacity.

1.1. Pictures of parts of suspension bridges in different provinces of our country.



Fig. 3. The pedestrian suspension bridge in Kunduz province



Fig. 4. Takshor suspension bridge with Hilux crossing



Fig. 5. Qarluq suspension bridge with the passage of high tonnage vehicles



Fig. 6. Ghazi Beik Khel suspension bridge with Hilux crossing



Fig. 7. Miakhan Kats suspension bridge with car crossing



Fig. 8. Kanda suspension bridge with car crossing



Fig. 9. Shingal suspension bridge with car crossing



Fig. 10. Gandab suspension bridge with car crossing



Fig. 11. Kanda suspension bridge with car crossing, during measurement

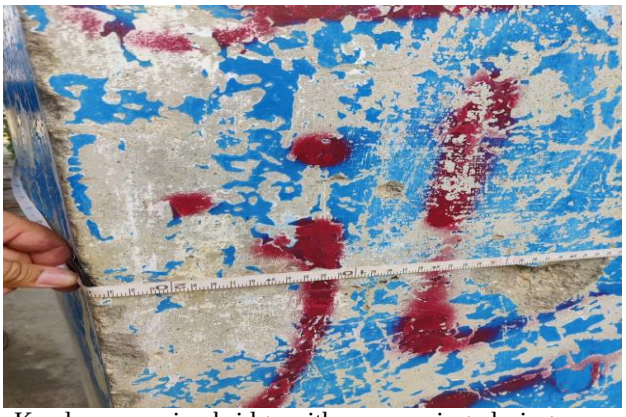


Fig. 12. Kanda suspension bridge with car crossing, during measurement

11. Conclusion and Suggestions

Conclusion

The following conclusions can be drawn from the research:

Inaccuracy in the calculation of fixed and temporary loads causes mistakes in the number of main cables, dimensions of anchor blocks, dimensions of cross beams, etc., which has caused low capacity in bridges. Like some bridges in Kunar, Nangarhar, Laghman, and Kunduz provinces. See the pictures.

As a result of the research, it was found that the capacity of some bridges is low and does not overcome passage of the expected temporary load, such as the bridges of Nangarhar, Laghman, Kabul, and Kunar provinces.

The height of the towers of some bridges is low, which causes an increase in the number of main cables, and they are still not beautiful. Like some bridges in Nangarhar, Laghman, Kabul, and Kunar provinces.

4- As inspected quality of the applied construction materials of the bridges was lower than the estimated quality in the technical specifications, which caused a decrease in their capacity.

5- The design of the bridges has been done with the help of various codes, which did not comply with the AASHTO code and caused a decrease in the capacity of the bridges.

6- There are some mistakes in the design of the bridge, which has caused a decrease in the capacity of the bridges.

7. the majority of the bridges that have been designed and implemented in the National Rural Access Program-NRAP of the honorable Ministry of Rural Development have their capacity according to the design.

8. The decks of suspension bridges should be made of metal so as not to be destroyed by the effect of cold air.

12. Suggestions

The following is suggested for the research results:

1- Due to the lack of a complementary standard in the field of pedestrian suspension bridge design in Afghanistan until a complementary standard it should be considered as

a standard in the field of bridge design that all of the following suggestions are applicable during the design of future bridges in the country.
2- It is better that the pedestrian suspension bridges are designed to allow jeeps to cross, because, in addition to the pedestrian crossing, lightweight vehicles such as jeeps can also pass through in order to solve the problem of the residents of the area.
3- Bridges whose capacity is less will be better if barriers are built in their towers.
4- Bridges whose capacity is less, their elements should be Strengthened (retrofitted) to increase their capacity.
5- Design control committees should be established in design and implementation offices so that mistakes do not occur in design and implementation.
6- The decks of suspension bridges are better to be made of metal so as not to be damaged by the cold weather.

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