Biodegradable Suspension Paper Bridge

First Author, Second Author, Third Author

Marwadi Education Foundation Group of Institute (MEFGI),

Rajkot-360004, India

Abstract

The design of this bridge is taken as suspension bridge. In this type of bridge there are two type forces are generated compression and tensile. The idea of this bridge is taken from IIT Madras. Total length of this bridge is 12.5m and height is 3.2m. This bridge is made by biodegradable materials like, newspaper, manila rope, cotton rope, and bamboo sticks. This bridge can successfully carry 350kg. This project is complete in 8 months.

Keyword: Biodegradable Material; Organic Glue; Newspaper Ropes; Tensile Force; Compression Force

Introduction

The idea of paper bridge first emerged after discovering the information of one such cable stayed bridge which was constructed by the students of IIT Madras during their annual tech-fest '*Shaastra'* in 2002. Students of MEFGI wanted to do something creative and unique which was never built before. So, it was finally decided to construct bridge made out of newspaper and other unconventional biodegradable materials. Hence system of suspension bridge was adopted because of its pleasing elevation along with good structural strength and with an intention to for studying force distribution patterns.

The main principle involved in making of the bridge was only to learn the force distribution patterns, load carrying capacities, endurance against compression and tension as well as working in a team and in an organized way by following time management strategies. It was indeed a great learning experience for all the students involved in the making of the paper bridge. Design, material testing, fabrication and assembling of all the elements of the bridge got simultaneously completed with ongoing construction of the bridge.

Objectives of Study

The main principle involved in making of the bridge was to learn the force distribution patterns, load carrying capacities, endurance against compression and tension as well as working in a team and in an organized way. The main aim of the bridge was to make it possible for people to walk on it safely. Additionally, the comparative analysis of behavior of paper members with concrete structures were aimed at. Different strength properties of paper can be investigated.

Scope of Study

Many books were referred to study the properties of paper and many unsuccessful trials were made in order to prepare the biodegradable gum. The theories of basic fundamentals of load transfer and force distribution patterns were studied and were subsequently applied.

Several limitations were also encountered at the beginning stage. Paper is fragile material which is also irrepressible against water and fire. These limitations were very difficult to overcome. Also, the paper gets abrasive after passage of time. The newspaper is manufactured in such a way that it can resist more shearing force when teared in longitudinal direction than in transverse direction.

Methodology and Concept

The main members of the bridge were prepared using newspapers in bulk, cotton ropes, manila ropes, organic gum and bamboo sticks. The main idea was to transfer the horizontal live loads to the piers and prevention of side sways. Load should be equally distributed among all the piers and the deformations should be minimum. The basic requirement of the suspension bridge system is that all the separate elements should carry load in monolithic manner and equilibrium should be maintained during application of live loads. Also, the force distribution should be made in such a way that majority of force should be transferred to the ground.

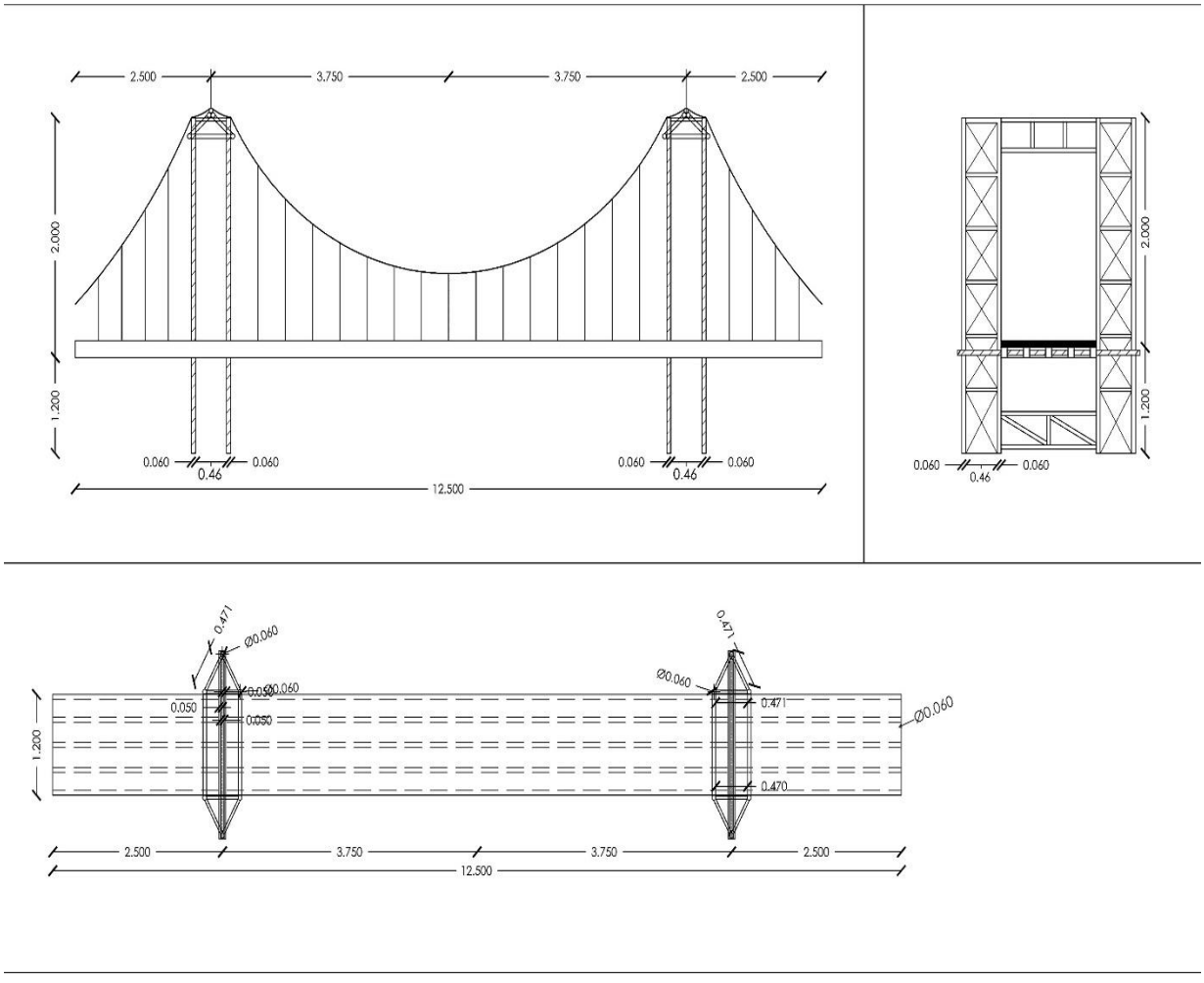

Fig.-1 Design of suspension bridge

Materials and Its Characterization

Mainly newspapers, manila ropes, organic glue are used for making of this bridge. Various tests had performed to obtain tensile strength, compressible strength, buckling of member, etc.

Making and Testing of Tension Members

Each member of a suspension bridge except piers are subjected to direct tension or flexure which makes it imperative to use materials which are extremely strong in tension. For achieving this tensile resistance in the members, manila ropes were used along with the newspaper. Both materials were combined together in such a way (by folding plaits) that the external resistance to wearing was offered by newspaper and the tensile strength was provided by manila ropes.

For testing UTM (universal testing machine) is used.

Fig.-2 Making and testing of tesnile member

Making and Testing of Compresion Members

Member of piers are subjected to direct copression, buckling and creeping. So, it has to be strong. Useing newspaper and orgnic glue to make rools to achive compressible strength

For testing UTM(universal testing machine) is used.

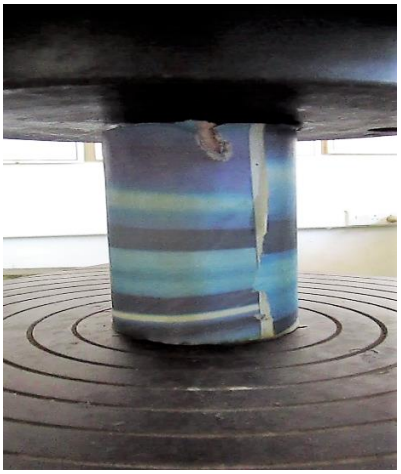

Fig.-3 Making and testing of compresion member

Preliminary Design

Piers

Concept of constructing piers was planned by forming a framework of newspaper rolls woven tightly and forming a solid bar. Two types of rolls were prepared; First *450mm to 500mm* long, *60mm* in diameter (referred as main members) and Second *450mm to 550mm* long and *30mm* in diameter (referred as lateral ties). These rolls were prepared by gluing the newspaper roll using 100% biodegradable glue made of sugar, wheat flour and water. The main members formed the primary members undertaking all the compressive loading. Arrangements of these rolls were done in a triangular lattice pattern in plan and these columns were connected by lateral ties and diagonal bracing to reduce its effective length. Height of the pier is 3.2m from the ground level.

The piers were stabilized by providing additional struts of bamboo sticks which transmits any lateral force which was exerted on the pier during walking process. More over care was taken to ensure that tangent of cable at the junction of pier and anchor cable both have same angle with respect to horizontal to avoid any horizontal forces on the piers.

Deck

The deck was prepared using the woven ropes (by folding plaits) which were initially prepared using manila ropes and newspaper. Five parallel such ropes were laid after assembling the piers in its position in such a way that the width of the deck was obtained *1.2m*. These ropes were then tied with three numbers of *45mm* diameter rolls which in lateral direction perpendicular to the laid ropes which provided a member capable of undertaking flexural loading.

Main Cable

The main cable supposed to be the strongest member in the entire bridge was chosen to be a cotton rope having diameter of *35mm* which consequently weighed around *16.25kg*. These ropes were passed from top of pier resting on a framework of bamboo sticks which was tied with the pier forming a pulley support mechanism. The main cable was anchored in such a manner that it formed a total length of the bridge equal to *12.5m*.

Supporting cable

Supporting cable is mainly made for support deck's rolls. It was made by interwoven manila rope-newspaper strings, by folding plaits of newspaper strings.

Suspenders

The suspenders attached to the main cable and supporting the deck was made up of interwoven manila rope - newspaper strings *(by folding plaits)* similar to which was used in deck. These suspenders were tied with the main cable with manila ropes so that it does not dislocate during the live load which was being applied on the bridge.

Organic Glue

Organic glue is made by thorough mixing of wheat flour, sugar, water and then subsequently heating it on gas stove. It is thoroughly agitated till it turns into a jelly like sticky substance.

Fig.-4 A) Piers with bracings; B) Supporting cables; C) Bracings

Fabrication of Piers

For making on pier it need three units each unit has height of 3.2 m. To reach that height members has to be attached with cover of newspaper which work as a flange and connector. These members were efficiently connected to each other by end to end and glued. These connections were cover by newspaper. These newspapers rolled over joint. For making long member of height of 3.2m.

After fabricating such flanged structure,12 such vertical members of height 3.2m were made. To connect these in triangular lattice pattern[Fig.-5(a)], it was very necessary to maintain uniformly and equal distance among all the 3 members. For that a triangular frame(equilateral) of iron rods is welded. this made it more easily and all the three members can be placed uniformly.

Bracings are provided to carry and transfer the axial load to the foundation. For that 35mm diameter rolls were prepared. And it was ties with main member with use of manila ropes. [Fig.-5(b)]

Fig.-5(a)

Fig.-5(b)

Fig.-5(b)

Fabrication of deck

The deck was prepared using the woven supporting cable which were initially prepared using manila ropes and newspaper. Five parallel such cables were laid after assembling the piers in its position in such a way that the width of the deck was obtained 1.2m. These cables were then tied with three numbers of 45mm diameter rolls which in lateral direction perpendicular to the laid ropes which provided a member capable of undertaking flexural loading. The entire framework of rolls and ropes were covered using old folded paper boxes used for packing. This formed a solid pathway for persons to walk on the deck.

Fig.-6 Components and Connection of deck

In deck, arch is important to transfer the load to the piers. That's why it has to be strong so in that instead of using paper cable, cotton rope of 35mm diameter is used for making arch.

STUDY AREA

Compression Test on the Rolls

The paper rolls used as main members of the column were tested in compression by the help of universal testing machine available at the institute. The cylinder was *120mm* high and *60mm* in diameter. The load versus elongation curve obtained in the test. The compressive load at which the failure was observed to be *24.88 kN* (approx.) and the compressive stress observed was *8.79 N/mm*^{2}, almost double the value of an average brick masonry wall.

Tensile Test on Ropes

The ropes were tested in tension on the same machine. To improve the gripping of the suspender rope, both the ends of the block were tightly ties by manila ropes and they were eventually fixed into the universal testing machine. The maximum tension taken by the ropes was *5.6kN*.

Components	Strength	Material used
Compression members	24.88kN	60 units
Diagonal members (Lateral Ties)	12kN	170 units
Newspaper ropes	10kN	5 units
Suspenders	5.6kN	24 units
Organic Glue	Settling time 1 hr	20kg

CONCLUSION

Time taken for preparation of bridge members was around three months, and assembling of the same on site took almost one month. The bridge was protected by covering it entirely with plastic cover to provide protection against dew which is quite severe in Saurashtra region during winter season. The bridge was inaugurated by the Dean, Faculty of Engineering Dr. R. B. Jadeja on Thursday, February 25, 2016.

The paper bridge showed the capacity up to 350kg of live load to pass across it. The bridge was demolished just at the onset of monsoons.

ACKNOLEGMENT

We thank Professor Tarak vora, Mazar Dhankot, and A.V. Reddy of civil engineering department for helping in the designing of the bridge and helping to complete the project. Also, thanks to library and college mess for providing the material for the bridge. And to Professor Yogesh Alvani for helping publishing this paper.