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Amalgamation of Structures and Architecture in Architectural Pedagogy

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ABSTRACT: The Architect who considers being an artist dealing through the medium of built form. The relationship between Architecture and structure is fundamental aspect of the art of building. It is the confluence of technical and aesthetical elements. However, it is highly essential for an Architect to fulfil all the requirements of structural design to achieve durability for longer time. Therefore, if in Architecture Education in the process of teaching learning, teacher would explore with innovative methods in structural pedagogy, student will learn rapidly as well as remember throughout their life. This paper deals with the understanding of structure subject in the context of Architecture Education to enhance Architectural pedagogy.

KEYWORDS: Structural Design & Systems, Architectural pedagogy, Architecture Education, Architecture and structure

I. INTRODUCTION

Structural Design & Systems is a subject taught in the curriculum of B.Arch. from first semester to seventh semester in Rashtrasant Tukdoji Maharaj Nagpur University. Architecture is a field that specializes in aesthetics and spatial functionality aspects of designing and developing infrastructure projects. This subject of structural design & systems comes from a civil engineering background and it is a linear progression from mathematics, physics, rigid body statics, and mechanics of deformable bodies, structural materials design and analysis to lateral forces and overall building behaviour. A need exists to develop new way of thinking about this current problem and explore a structures pedagogy in the context of Architecture that is consistent with the mental framework for architecture students.

Structural Design & Systems I deals with applied mechanics, structural design & systems II and structural design & systems III deals with strength of materials whereas structural design & systems IV deals with structural analysis, structural design & systems V consists of design of elements of reinforced concrete structures like singly reinforced beam, doubly reinforced beam, T and L beam, shear reinforcement in beams. Structural Design & Systems VI involves design of reinforced concrete elements such as one way simply supported slab, cantilever slab, one way continuous slab, two way slab, square, rectangular and circular column and isolated footing.

There are various ways to make the subject interesting for students through innovative techniques like presentations, videos, quiz, sheet drafting, chart making, model making, site visits, material testing, experiential learning, etc. Moreover setting up a laboratory for structures is also an effective way to understand by performing various experiments.

The three principles of Architecture are stability, utility and beauty. Utility and beauty will play their role only when the structure achieves its stability. Stability of structure is studied in the subject structural design & systems. So, for an aspiring Architect student, it is of shear importance to study and understand concepts related to mechanics, strength, advance construction materials, properties of materials, and design of various structural elements.

This paper deals with teaching structures to architectural students in an innovative and interesting way through model making. The students' outputs are presented here and this technique of model making hence is proved to be an effective method for practical understanding of structures concepts. Efforts have been made to express the experience in words.

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II. RELATED WORK

The following tasks were introduced to the students:

- 1) To Design and create a Model of cable-Bridge to understand cable as structural member to take, divert and transfer load.
- 2) To Design and create a Model of Arch-Bridge to understand arch as member to take and divert load in structure.
- 3) To Design and create a Model of Truss to understand vertical, horizontal and inclined forces
- 4) To Design and create a Tall building to understand wind forces

The objective of all above exercises was to study structure and architecture. Emphasis was given more on structure vis-à-vis stability of forms. While dealing with different structural concepts, their importance is related to architectural requirements. All above exercises were based on “to understand importance of different **structural elements** in architectural form and that are taking loads and transfer the loads to subsoil.”

Moreover, a structure laboratory is introduced which has following experiments:

- 1) Reactions on simply supported beam
- 2) Hooke’s law
- 3) Buckling of column for different end conditions.

Applying the equations of equilibrium and calculating reactions on simply supported beam with two point loads.

III. EXPERIMENTAL RESULTS

Figures show models of cable-bridge, arch bridge, truss, tall building as mentioned above.

1. It is very difficult to theoretically understand the load carrying mechanism in a bridge. Firstly it is important to study the difference between suspension bridge and cable-stayed bridge. In a cable bridge, cables are in tension, they transfer the load to the columns or piers which are under compression. Columns transfer the load to foundation and then the load is transferred and distributed into soil. These bridges are used where the load coming on bridge deck is heavy and piers cannot be used under a long span. Students understood the role of cables, nature of cables, and connection of cables to the deck and to the columns.

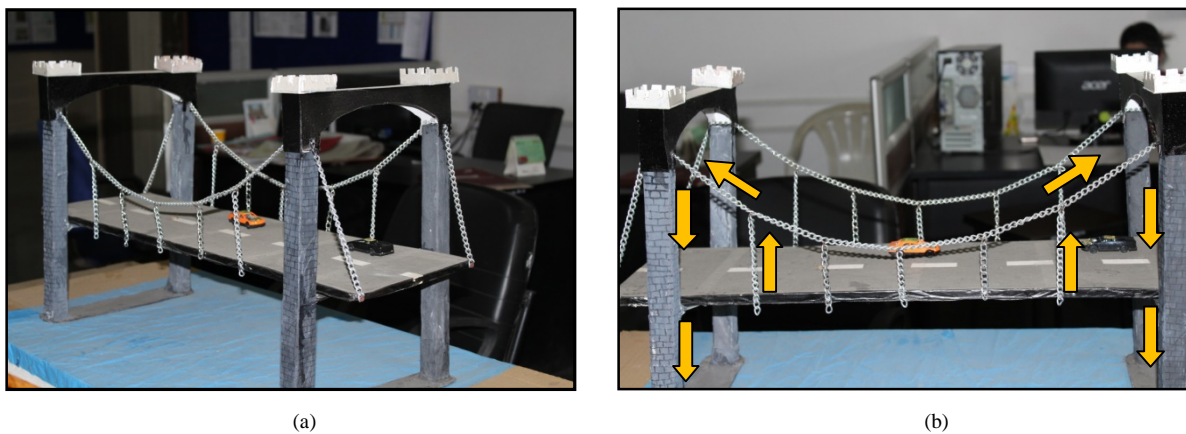


Fig. 1. Cable-bridge (a) Model of cable-bridge made by students with the help of cardboard, thermocol, steel chain, etc. (b) Image showing the load transfer mechanism in cable-bridge as a result of load coming on bridge due to moving vehicles.

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2. In Arch Bridge, as the name suggests the load is carried and transferred through arch action. Arch bridges are always under compression. The arch can be below the deck or above the deck according to the conditions on site. The movement of vehicles on the deck produces loads, stresses and bending which are carried by the arch and transferred to the columns which then transfer to the foundation. The advantage of arch-bridge is that instead of pushing straight down, the load is carried outward along the curve of the arch to the supports at each end. These supports are called abutments in a bridge.

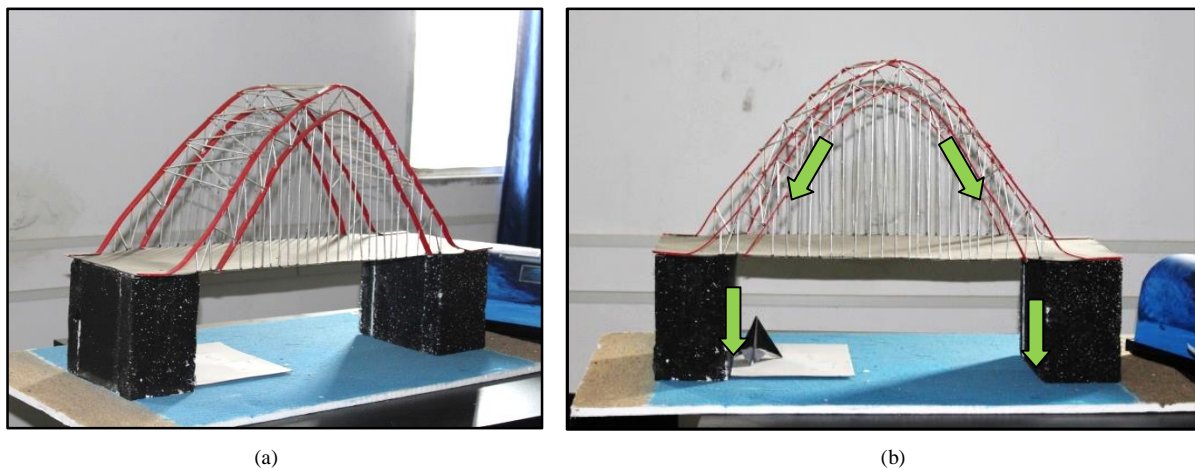


Fig. 2. Arch-bridge (a) Model of arch-bridge made by students with the help of cardboard, thermocol, steel spokes, etc. (b) Image showing the load transfer mechanism in arch-bridge as a result of load coming on bridge due to moving vehicles. The shape of arch-bridge is an advantage for carrying and pushing the load to the supports or abutments.

3. Trusses are of various types, each having different suitability and different spans. Truss is a steel or timber structure made up of many tension and compression members with pinned joints. Truss is made up of different members like principle rafter, purlin, common rafter, top chord, bottom chord, ridge, etc. Students understood the joints in truss, connection of members and load transfer technique. Trusses are used in industrial areas where heavy loads are predominant along with wind load.

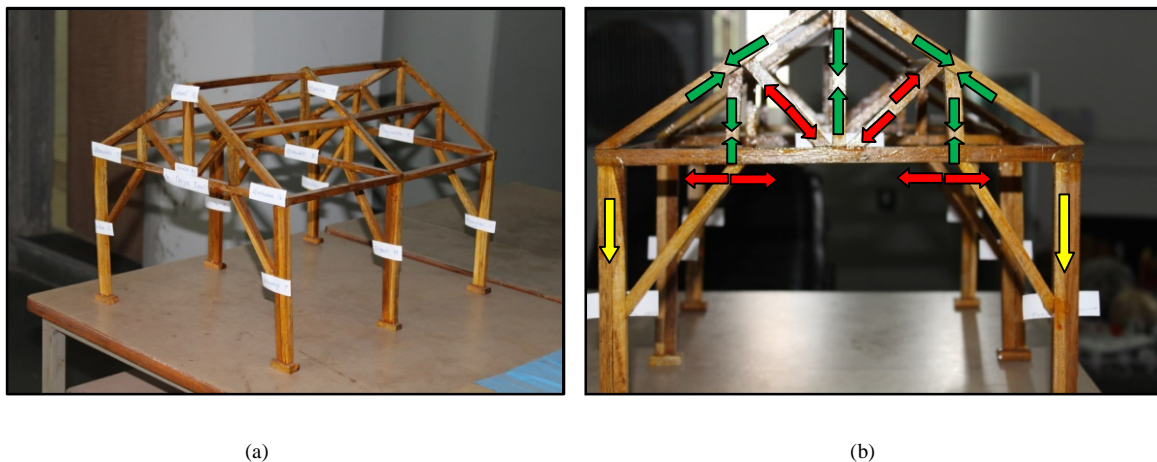


Fig. 3. Timber truss (a) Model of timber truss made by students with the help of wooden sticks, glue etc. (b) Image showing the load transfer mechanism in timber truss as a result of load coming on the truss.

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Green arrows represent compression whereas the red arrows represent tension. Top chord is in compression and bottom chord is in tension. Vertical members are in compression and inclined members are in tension. This just an example to show the tension and compression carried by the members of truss.

4. Tall buildings or high rise buildings or sky scrapers are the trending topics in the field of Architecture as well as engineering. The most critical force for which tall building needs to be checked is wind load. The cantilever action of a tall building can be studied with the help of model. It is essential to understand the column-beam frame structure of a tall building along with floor wise live load reduction.

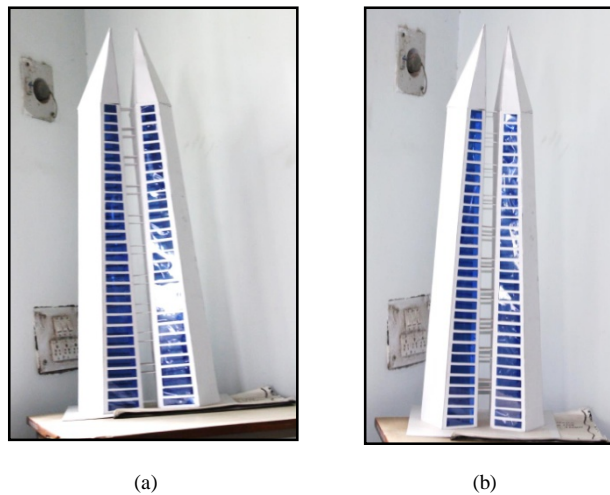


Fig. 4. Tall building (a) Model of tall-building made by students with the help of foam sheet, cardboard sheet, etc. (b) Image showing the various floors and floor to floor connection of twin tower.

Applying the equations of equilibrium and calculating reactions on simply supported beam with two point loads. The gauges on both the sides show the readings of reactions corresponding to the loads applied. The ease of this experiment is that manual calculations take time but experiment performance makes it easy. Just by moving the loads, the reactions on the beam vary.

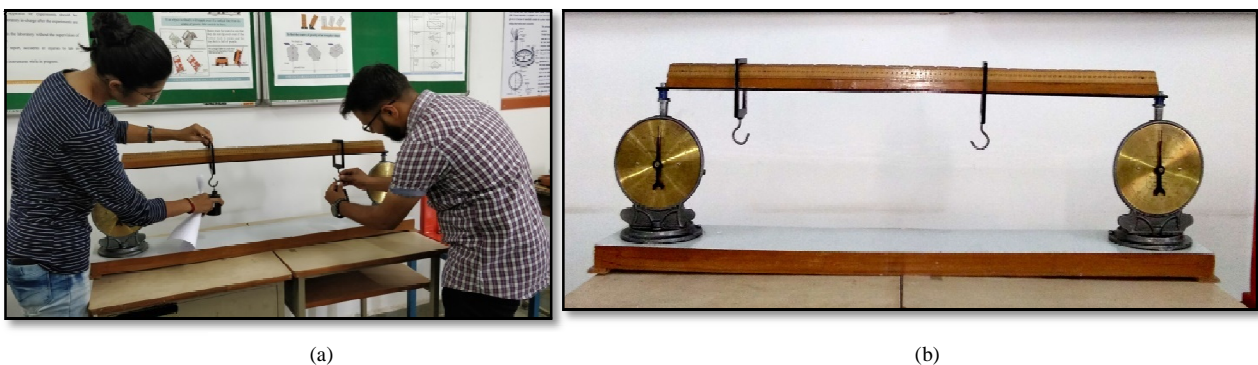


Fig. 5. Simply supported beam (a) Experiment of simply supported beam performed by students by applying 1 kg loads to find out the reactions on dial gauges (b) Image showing the experimental setup having a ruler fixed on two dial gauges with movable loading hooks. Just by varying the distance between loads, change in reactions can be seen in dial gauges.

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Hooke's law states that the stress is directly proportional to strain within elastic limit. Theoretically this statement is easy to learn, but when it comes to practical understanding, anyone reading this statement can be confused with the practical meaning of stress and strain and proportionality of both. For practical and easy understanding of this concept, a model was prepared in the laboratory which consists of a stand, spring, scale etc. Spring is attached to a stand. As the spring is loaded, it extends and the values of load applied and the extension observed are noted. It is observed that load and extension are proportional to each other which is nothing but Hooke's Law.

Column is a compression member. Column is the most important element in a structure playing the role of transferring load from slab and beam to the foundation. The phenomenon of buckling in columns is necessary to understand. The nature of buckling is different for different end conditions of column. Ends can be both fixed, one fixed and one hinged, both hinged, one fixed and other free. So, an experiment was introduced to students understand the behaviour of column buckling under load application for different end conditions.

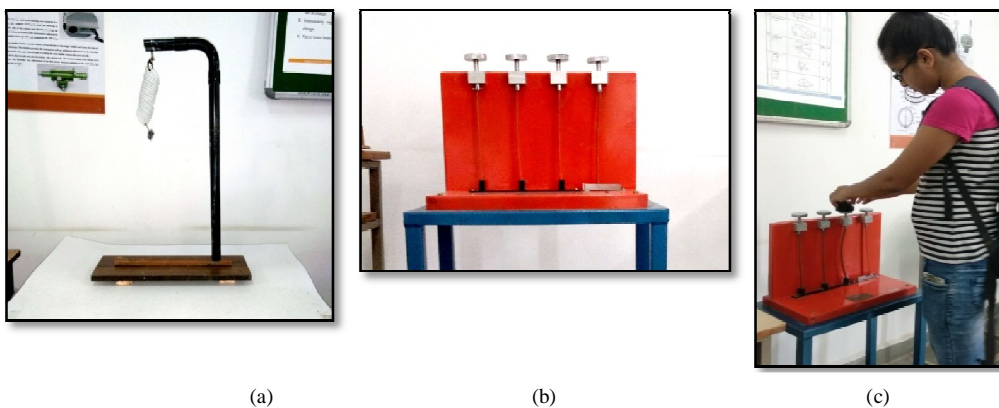


Fig. 6. Experimental setup (a) Image showing Experiment of Hooke's law made by students with the help of wooden board, using pipe as stand, spring, etc. (b) Image showing the experimental setup of four end conditions of column. (c) Image showing student applying load on column to observe the different shapes of buckling corresponding to different support conditions.

For making the students understand types of supports through practical examples, they were informed to look around their surroundings and find the supports like hinged support, roller support, and fixed support to understand the reactions and degree of freedom of supports. Also, they were asked to look around types of beams like fixed beams, cantilever beams, overhanging beams. The results of this experiential learning are in the form of sheets made by students. This exercise of practically observing the surrounding and drawing it down on sheet was given to first year students where they are absolutely blank about the knowledge and pre-requisites required for structural design & systems. So, this transition exercise to introduce them to the subject was conducted and successfully implemented. It was observed that this technique helped them to observe what we learn in our daily activities.

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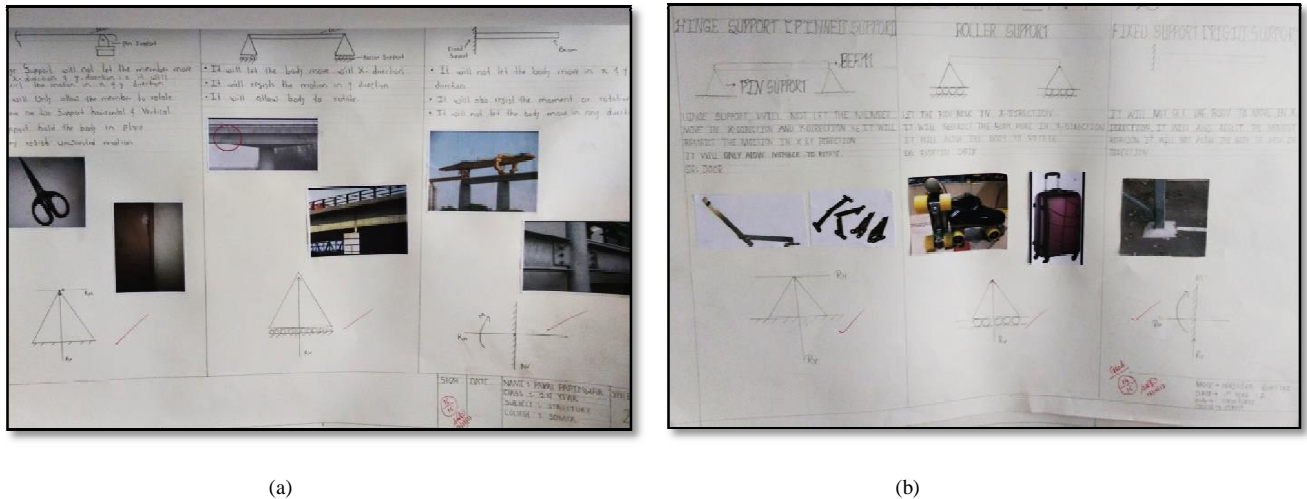


Fig. 7. Experiential learning (a) Image showing sheet prepared by the student for hinged support with an example of a scissor and door, roller support with an example of roller bearings used in bridges and fixed support with an example of fixed steel connections of gusset plates. (b) Image showing the sheet prepared by the student for hinged support, roller support and fixed support with various examples, definitions and diagrams.

IV. CONCLUSION

Teaching and learning is a collaborative approach with a clear objective and process. By conducting the above mentioned exercises for learning structures in architecture, the students were able to understand the concepts of cable bridge load transfer mechanism, arch bridge load transfer mechanism, tension compression members and load transfer in truss, cantilever action in tall buildings, hooke's law, reaction on simply supported beam, buckling of column with different end conditions, types of supports and reactions on supports through experiential learning. These activities increase the intuitive understanding of the structural behaviour of systems and help student remember the concepts. Teaching hard knowledge through soft method helps students to intuitively comprehend the subject matter.

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