‘’Experimental based learning to Integrate Architectural Design with Theory of structures’’

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ABSTRACT:

This paper is about

‘’Experimental based learning to Integrate Architectural Design with Structural Design’’

How it effects the Architects and the method of teaching ‘’Theory of Structures in context to Architectural Design ‘To make student understand the basic principles of structural mechanics so that it forms the basis for study of structural design through these topics. One should have a reasonable understanding of its operational and economic implications, and lastly

‘’To evaluate the understanding of the relationship between form & structure through Structural Analysis’’ with the help of Structural Engineer.

Purpose is

To Inculcate and develop the knowledge of structural designing in Architecture students and to enhance the structural knowledge of the Architecture students.

Introduction

Background

Throughout the history, buildings has mostly been designed and built by one person, the so called Master-Builder. The Master-Builder was an Architect, Engineer and Constructor, all in one.
When the industrialization started, the constructions became more and more complex, and the demands of the buildings increased. Material and instruments developed with the technical development. This made it harder for one person to know everything, and to think about every factor in the constructing/ designing of a building or a bridge.
The work was divided between the architect, the many different Engineers, and the Builder. With the distribution of work came other problems. The greatest was probably the communication between the different professions. A good communication is required in all building projects and collaborations. What in the past was one man’s work became now cooperation between many and the different professions grew at the same time longer apart from each other rather than closer.

In the last decade, this issue has got more and more focus, both in the universities and out on the field.
It is clear that for the technical development of new architecture in the future and for the technical development in the construction business shall have a constructive and important role in the future it is necessary for Architects and Engineers to work together much closer, both in the school and out on the field.
This paper author has chosen is about near cooperation between Engineers and Architects for better understanding of structure to the Architects.
The author have chosen to do so because both Architects and Engineers convinced that more collaboration between Architects and Engineers gives much more possibilities and is a right step to take to develop complex Architecture in the future and for the professions has a lot to offer each other.

AIM AND OBJECTIVES

Aim-

To teach Theory Of Structures in a best suited and appropriate way to the Architecture student in co-operation with the Structural Engineer.

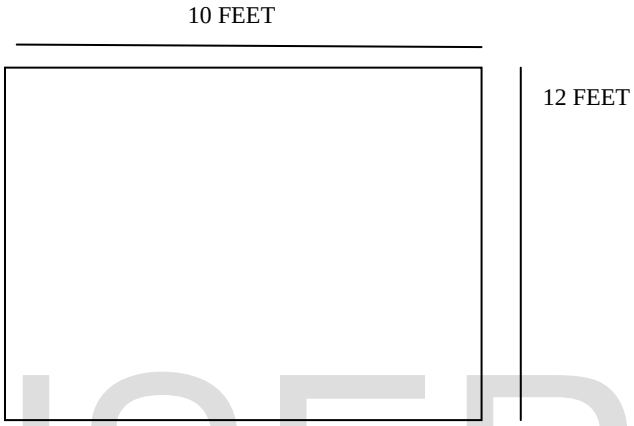
Objective-

The purpose of this Experimental study is to study and establish strong interdependence of the two streams of Design between Architectural students and Structural Engineers.

- To find the strong commonalities between the two towards an integral approach to Design.
- To know how difficult the cooperation could be, if there were any difficulties and what are the reasons of these difficulties.
- Interested in how one could make Architecture develop in better collaborations and how structure could be expressed in Architecture.
- To evolve best suited syllabus of Structural Design for the Architectural students**.**

Experimental Section

This analysis of a room of (10'X12') was done in order to judge Architect and Structure Engineer. Architect has superficial knowledge comparatively the Structural Engineer had a detailed knowledge.



ANALYSIS DONE BY AN ARCHITECT

- ONE WAY SLAB
- 4 COLUMNS OF (9''X9'')
- MARKING OF BEAM
- SOIL BEARING CAPACITY-AS PER SITE
- REGARDING D.P.C-DAMP PROOF COURSE AS PER DESIGN.

ANALYSIS DONE BY A STRUCTURAL ENGINEER.
(Mr.Naveen Kumar Jha from Galgotia University)

- WALL BOND-ENGLISH BOND
- TOTAL NO OF BRICKS- 3000K BRICKS
- TOTAL NO OF BAGS of Cement - 15-20 BAGS
- TOTAL STEEL RODS- 8MM-1 BUNDLE
  10 MM – 4 BUNDLES,-12MM- 3 BUNDLES.
- FOUNDATION DEPTH- 130 KN/M2
- SOIL BEARING CAPACITY-AS PER SITE
- REGARDING D.P.C-DAMP PROOF COURSE AS PER DESIGN
- REGARDING TIE BEAM-12MM DIA =12 BUNDLES
- TYPE OF FOUNDATION –RAFT FOUNDATION

Our process in the Art Museum Project started.

A collaborated experiment was performed between Architect and the Structural Engineer.

The Author and the Structural Engineer (Mr.Naveen Jha) decided to design a building together.

1.The Guard Rooms was chosen to have an easy background and for easy calculation instead of making it up all by ourselves.

Also we thought that the ART MUSEUM PROJECT could be given an interesting form and structurally also will be very sound for students calculation.We wanted to make a decision of a form as soon as possible, so that it was the development of the form that would be discussed and not be concentrating on finding the perfect new form. Because this was just an experiment and it was a master thesis we had to control ourselves to not go into details.
The overall job for us was to experiment with the form, to find one that was both befitting and structural efficient. The importance was to get a building where the force play would be shown in the form.
The engineer wanted to play with round, formative structures, and tried to explain about this to the Architect.
The architect also wanted smooth, round forms, so the result became this organic, weaving form. But it was not at all a formative structure. In some place it actually less strength than if it had been a square building, for example in the curves.
Here were the communication maybe not the best, but on the other hand the engineer understood that the building would not be that interesting if it should have a totally formative structure. The engineer learned that no new forms would be made if you always followed the laws of mechanics. But it was not exactly what the Architects wanted either.

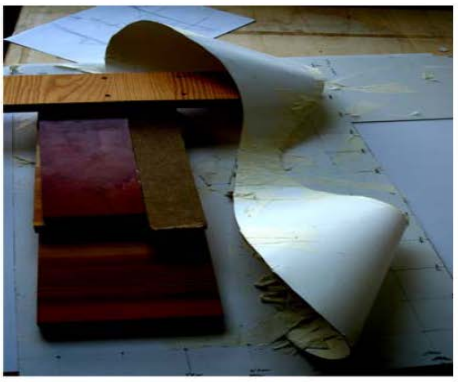
Architect made a **model of thick paper** to understand and see the form he wanted to find better.

He then took out coordinates from this and the Engineer **made a first computer model out of it**. To make the curves in the computer program we used splines with some of the coordinates.
This made the computer model and the paper model not get exactly the same form but almost. The computer model was also changed a little bit by both the engineer and the Architect to make it smooth also in the computer.
The angles and curves were discussed and finally we had agreed upon an outer form of the museum.
We decided to hold that form and instead play with different situations and thicknesses to express strength and illusions. This was decided most of all because of the time schedule. To give the architect time to start on the cad-drawings and models, the form had to be set in an early stage.
The engineer then played with different supports, and how it would make the thicknesses of the form move and change.
The results from the calculations were discussed and we chose a form that best suited both our wants.

The project of the Art- museum was chosen and the surrounding was studied, mostly by the Architect. From the surroundings and a few mechanical laws, choose an outer form.
The curvy form was chosen.
The Author as an Architect Concentrate on the Column, Beam and Slab.

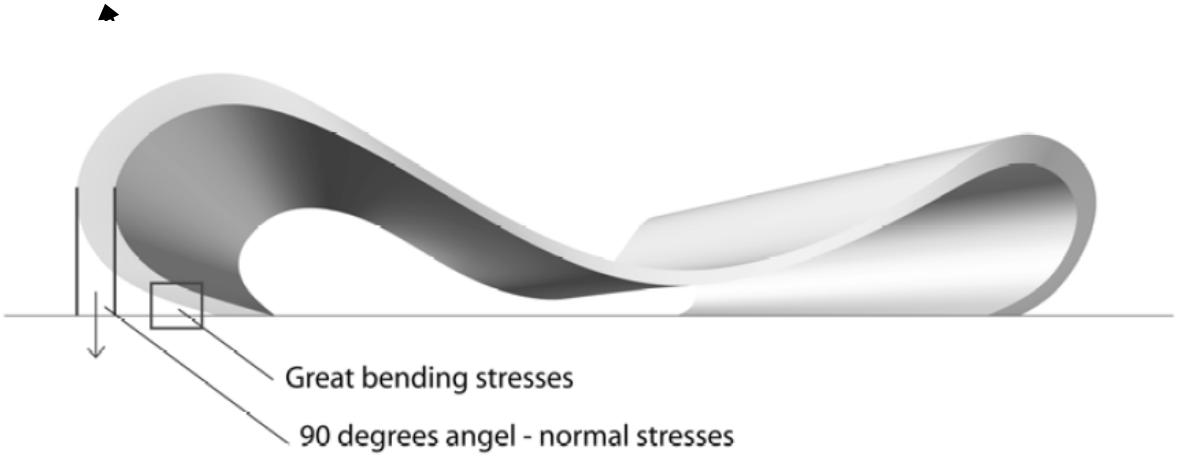
The Engineer (Mr.Naveen Jha from Civil Department, B.Tech.M.Struc. Golgotia University) made calculations of a variation of solutions, with the attempt to make the building, as efficient as possible.

From the calculations we discussed pros and cons in each model. The decisions have been made in a few steps, to try to make our cooperation better. With some steps we could both follow the development of the building together and make a difference along the way.



The Engineer used two different computer programs for calculations of the
Art- museumSolid Works, which is a CAD-program, was used to draw the form from the first physical model which the Architect did.This form was imported into STAD PRO, which is a Finite Element Method-program that was used for the Calculations. When the form was chosen it was imported into Auto cad which is a CAD-program for Architects also. .With the STAD PRO -model he also printed out the finished physical 3d model.

Observations



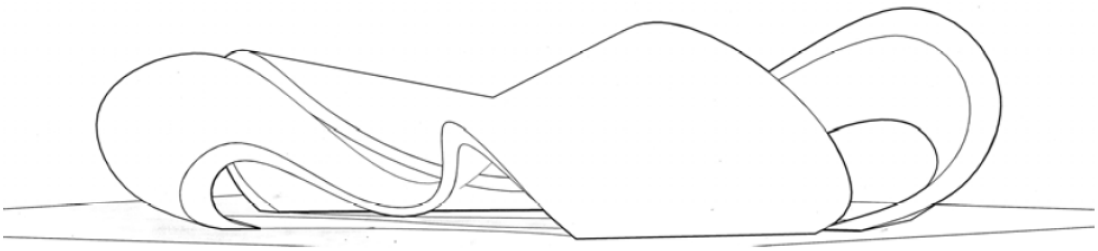
On the other hand the engineer found this complicated. The laws of mechanics say that in a structure with that kind of bow, there will be a lot of bending stress. This stress could make the supports cracks, if they are not strong enough. The best solution, in a mechanical way, would be to have the building meet the ground in a 90 degree angle. The building would then be subjected to a normal stress, which is easier to handle than a bending stress and vertical stress. But on the other hand with a 90 degree angle the building would loose its expression totally. And the challenge to make it stand will no longer be a challenge. The solution became a compromise between the two ways. The curve was not as extreme as the architect wanted, but to save the important expression of the building the rounded support was not abandoned.

In the later chapters the calculations of the supports have been ignored. This is because in the programs it is hard to make a realistic cross section of the supports. In the pictures above you can see that the cross section is much larger than it is calculated. In the production it is hard to make a real fixed support. In this case it would not be bad to have a support that could rotate a little bit. This would give the end of the form less stress but the total building more deflection.

3.4 The curves

Observations

The building can be seen as a large beam. However it is a different beam. How many have for example seen a beam bridge with a span on over a hundred meters?
The largest problem with a long spanned beam is the deformation.
The largest deformation is, in a normal symmetric beam, always in the middle. Our building is as said before neither symmetric nor normal.
From this maybe you will understand that in this form the largest deflection will not be in the middle.
It will be a little bit displaced, because of the twisted, leaning, asymmetric form of the museum.
Towards which direction the maximum deformation will be displaced depends on which supports it will have.

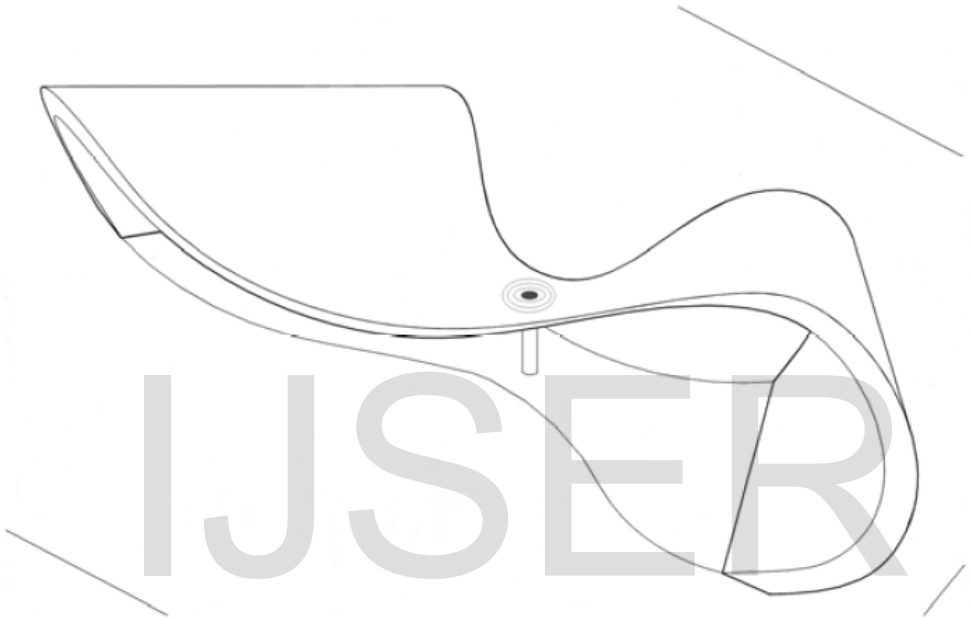


Without the support in the middle the form is clean and clear of any distractions. With a support you would have to think about the expression the support and the building would show together. Should they be one whole form or two separate? Should the support be hidden or brought out as a big part of the architecture? These are some of the many questions that could appear in this case. In our building we chose to not have the support and have then ignored these questions. We wanted to

have a clean shell that should be able to stand without any extra supports. What was the challenge in having a crutch which would handle the weights? The total idea of the building would have lost. The challenge was to get the building to stand without supports in the middle, in some way, without losing the clean expression. This was to give the shell an extra impression of a sculpture. There was also a challenge in getting the building to stand without any supports in the middle. An extra support would subject the building to high point stresses around the support. Because of that the building should be thicker in the middle and the curves could be a little bit thinner than without the middle support. Without a middle support, we had to find another solution to our problem. The deformation depends on how large the load is, and in our case the load depends mostly on the dead weight of the shell.

Here does the complex form help. The part in the middle is a lot smaller than the curvy parts, which means that the form have a smaller load there. It is however not enough. The mass have to be reduced.

This can be done with a lower density, for example by making holes in the shell, or with a thinner thickness. We have chosen both ways. By diminishing the thickness, the form is given a certain expression.



Observations

- When the curves are thicker and the middle hanging part is thinner, the building looks less stiff and more dynamic.
- The whole building gives an impression of lightness. The curves look like they are carrying the middle, which they also are. This is a typical ‘Structure as Architecture’-expression in this project.

Results and Discussion

Results and Discussion

This may sound easy but it was not at all easy, for us especially because of the lack of time.
When the engineer made calculations and simulations in Abacus, the Architect was forced to already be drawing the building as if it had its finished form. Therefore there was not a lot of space for form finding together in the process if the result was

supposed to be a building. On the other we found a first form, which we both agreed upon, very quickly. Still this model could have been even more optimized. We feel more that we just planted the idea of more processes like this than creating a model to follow. This project is kind of a pilot project for the educations, and we would like it to be evaluated as an experiment. Our hope is that other students will continue this idea and work over the borders of the
Different education and divisions. You learn a lot about cooperation, problem solving, time planning, understanding for the different educations and professions. You also get a more substantial understanding of the teamwork between engineers and architects, and how differently you actually think in certain situations.
In the beginning there were discussions about what the thesis would be about and how we would accomplish that. We both had different views and thoughts, which surely originates in the educations
that is very unlike each other. Engineering students are characterized by the rules of physics, and do then often do exactly what they are told. Sometimes they block themselves in thinking only in possible directions and take their point of departure form that view. In opposite to the architectural students who somehow have plans for things that in a matter of fact are impossible. They work with the project and often the result is nothing like the starting point. Architecture is often a matter of opinion, and in the education of architecture you learn to defend your own views.
Because this kind of cooperation was new to our school, we had to make the rules ourselves. This was hard with two people with totally different prerequisites.

PROS AND CONS

The first problem was to get started. As said before we had some difficulties on agreeing in what it would be about.
When we decided to work on the Modern Museum of Art in Warsaw, it was hard to find enough material on the surroundings and the building area. This, you could say, was also a problem in communication. Just this time it was between us and the polish committee of the competition. All through the process there were confusions about what to do, how to do it and which order to do it. Especially the last aspect was hard. We believe that the normal way, to make an offer to a competition, is to let the architect decide how it should look. Then the engineer will make some calculations of if it will work, and last the architect will make his drawings of the form that they have found together. This is also how we wanted to play it, but with more collaboration. However the time plan would not hold for this and we had to work with each our part on the same time. The engineer had to start calculating before the outer form was ready, and the architect had to start drawing before the calculations were finished and we knew how the building would look. Of course it was meant to be collaboration process, but it was still a little bit stressful. Another problem was the computer programs, they were too many. The engineer had to have a program that could make calculations, and the Architect wanted a program that could make serious drawings. We then spent a lot of time on exporting and importing the model, after the time we used to find a method to connect the several programs used. The reason that this was harder than it could have been was the round forms of the building; many programs have problems with that. This is something we do not understand. You would think that the connection between the engineers and the architect work would be a little bit easier. To have a good collaboration also needs good instruments to make it work. The total time we got delayed because of computer problems was 20-30%. We feel that even though we are students, there should be better computers to ease our work, especially in a time like this, where everything depend on computers. We found it tough working together with the different views and aspects of how the process was supposed to be. There were no clear rules but we easily took on our typical roles in the game, and if we knew in the beginning how it would be we maybe would have done it differently. The engineering student feels that the cooperation in the beginning could have been better. We should possibly have taken more time to discuss the ideas in the start, instead of rushing through it just to be ready. Also the brainstorming for new solution that should work structurally is hard for a student. It is easy to be uncertain and wanting proofs for everything. However it was a great learning experience. These are the roles we will have in the working life. Therefore we believe that collaborations should be used as early as possible in the student period.

Conclusions

- The experiment based learning played a very important role in understanding of structure by the Architect in collaboration with Structural Engineer.
- Theory of structures should be a core subject not an allied subject.
- Theory of structures should be taught in collaboration with structural Engineer.
- The collaboration should be in the student period and that too from 1st Semester of Bachelor of Architecture.

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