IMPACT OF USING STRUCTURAL MODELS ON FORM FINDING

Incorporating practical structural knowledge into design studio

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Abstract. Physical Models, as an architectural design tool, have a major influence on the architectural learning process. In structural form finding, it helps in improving visual design thinking to track form creation processes during form finding design stage. This is a study of the impact of using physical models for second year architecture students in design studios learning. By analyzing and comparing students' performance and progress; to clarify the effect of using physical models as a tool for designing progression, followed by analytical study on the students' structural models, in order to investigate the influence of models on their design educational progress. Research achieved that there were three basic phases the students pass through during form finding process when used manual physical models that improve the students' design capability.

1. Introduction-Scope of Work

One of the significant goals in any design studio, is helping the students to transform theoretical thoughts into drawings through architecture education. To develop design knowledge process, most students in the early design studio begin their architectural education without or with limited expertise in understanding the structural system of various spaces and forms. Whereas, an architect needs full understanding of structural principles in order to effectively communicate with structural engineers. Each design stage requires a specific way of visual design thinking and perception that varies from one medium to the other and from one designer to the other. It is necessary to develop manual abilities to improve imagination and design capabilities of the architect, specifically in the early stages of the design process.

1.1 CLASSIFICATION OF DESIGN CAPABILITIES

Design capabilities of an architect could be classified into five main types: Conceptualization, Form Giving, Representation, Decision-Making and Knowledge Building and Retrieving, Abdelhameed (2005). This research reports on the form giving stage, which can be described as the capability which enables architects to translate their concepts /or conceptual frameworks into actual formal architectural propositions and compositions, Abdelhameed, (2002).

Students of architecture in this stage need to visualize the structural elements at work, because their understanding during the early learning stage depends mostly on visual and oral communication rather than imagination, so forms had no meaning and are not realistic.

1.2 REASEARCH AIMS

Physical modeling allows designers to move easily between, form properties, abstract representation, component assembly and material shaping through a single design activity. So, physical models were chosen as a design stage tool, which students must learn manually during the 2nd year at the department of architecture in order to overcome the gap between what was taught in the theoretical structure courses and its application in the design studio. Physical models help in understanding, or validating structural system in the design process.

Architectural students must understand the structural systems during their projects, in order to identify when a system or a structural member is not appropriate fit for an idea by using physical models to display the structural principles during the design process.

To explore the physical model's value as a conceptual design tool of structural studies, the study aims to instruct students on how to build an environment through optimal design, by choosing the suitable structural system and most suitable materials during the design studio classes, and ultimately to help them test the form constructability and material choice. Getting feedback during design classes, help them to enhance their model and upgrade the design to the next level by transferring the physical model into 2 dimensional drawings.

1.3 LITERATURE REVIEW

Various studies had been conducted to explore the optimal way of teaching essential structural engineering knowledge to architecture students. One focus is placed on the act of manual modelling and its influences on studio design.

Abdul Aziz, (2010), Indicates that physical model at an early stage of design, enables the student to visualize the structural elements clearly to show more space planning and the materials selection. In addition, Abdel hameed (2011) described how physical modeling helped in studying the components assembly and construction aspects. Then, the student's awareness of the structural properties and form component assembly by hand is definitely increased.

While, Fahmi (2012), discusses the reason architectural students face difficulties in integrating structural knowledge into their design. He emphasizes the importance of coordination and communication between classes of structure and design studios, particularly, in studio projects to improve the integration ability with structural topics.

Moreover, Yazici, (2013), shows that design has a unique learning environment based on the principle of "learning by doing". Where all architectural knowledge is obtained and put into practice, so the supplement of the classroom teaching with active experimentation could help the structural concepts integration in the design studio work. Besides, Vrontissi (2015), argues that there is an actual lack of conceptual structural design studies in architecture education when discussing the presence of physical model in generating a structural concept process at early design process stages, and how it could offer a rich field for exploring conceptual structural design studies.

2. Methodology

2.1. MAIN PROCESS

The proposed framework uses physical models in the form finding stage through the design process, to study their impact on the students' progress in developing their design concept to clearly visualize structural elements. The main target is to study the complex structural systems with wide span projects. So it enables students to have a better understanding of the building structural system, and increased awareness of space and form impact, as well as space making.

The design studio of 2nd year students in its first semester (2015-2016) were selected as a case study for the application, after their studies all structural systems in the first year for two subsequent semesters. Aiming to link between what had been studied theoretically and raise it to another level in the design process, to understand the fundamental concepts of used structural materials, which related to structural design during the undergraduate education level.

2.2 PROCESS STEPS

The process is divided into three phases, at the first phase; a pilot study is conducted on a cohort of students, to investigate their awareness of using physical models during the design process. More than half of cohort confirmed its importance. The second phase is a 3-stage project for the design of a "Pavilion for Expo Dubai 2020". The stages are: 1- concept, 2- sketching, then 3-physical modeling for five weeks, ending with complete plans, sections, and facades drawings. The project takes into account students' desire to select their materials and modeling techniques (as strings, paper and cardboards), while maintaining the possibility of ease of assembly and installation model, to allow for changes during the weekly evaluation process. An assessment was done at each stage, to record the students' progress during the design stages. Scores are been recorded and compared with the earlier scores in the previous weeks, to measure the student education progress.

In the last phase, a questionnaire was carried out utilizing both qualitative and quantitative methods of analysis. The Qualitative part explored and propped into the role of physical model in form finding phase. With quantitative analysis, an attempt was made, using the statistical analysis programme SPSS to analyze the outcome of the survey questionnaire. The aim was to find correlations, the criteria for correlations that could highlight the importance of the physical model, which would ultimately lead to obtain the important affective factors in the form finding process.

3. Results and Discussion

3.1 STRUCTURAL FORM FINDING AND PHYSICAL MODEL CRITERIA

In the second phase, during the first week, students' ability to generate the structural system forms varied, and their skills in predicting stable structures without calculations became known to tutors. Whereas, the second week, saw variations among students in ability to integrate structural information within the design idea. While some students managed to produce many structural alternatives for their projects as in cases (1, 4), a majority of students experienced a decrease in their performance in the second week than in the first week as in cases (2, 3). Average performance improved in "merging structural element criteria" for most students who used the manual model in different stages, and a noticeable development was observed in the structural form with the design idea. In the advanced stages of the project, students' performance improved more than in former weeks, through developing the generated form and manipulation using the model. Figure (1)

shows the progression of a random selection of students from a sample of 40 through the five weeks.

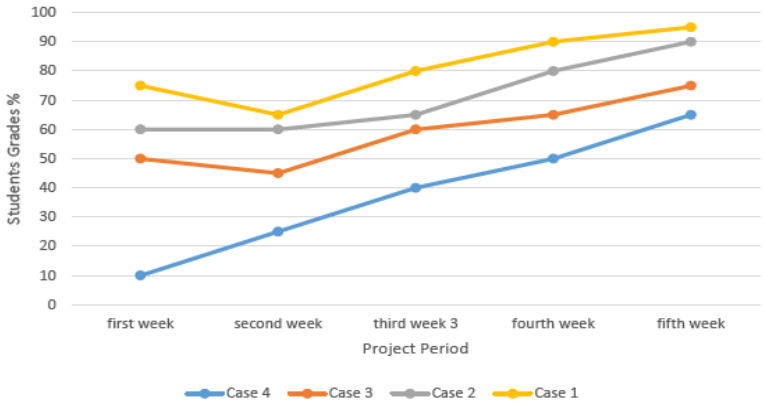

Figure (1) Assessment of Students progress during the design process.

In addition, figure (2) showed the student's physical models (case 1) as an example, during five weeks, to highlight the major progress that happened in his model, during the design process, as following. At first week, several ideas for long span structures were presented, then in week 2, design parameters were identified and some alternatives were displayed. In week 3, the best idea was selected, and then the architectural and structural drawings were fulfilled in the fourth week. Finally, the final model was completed in week 5.

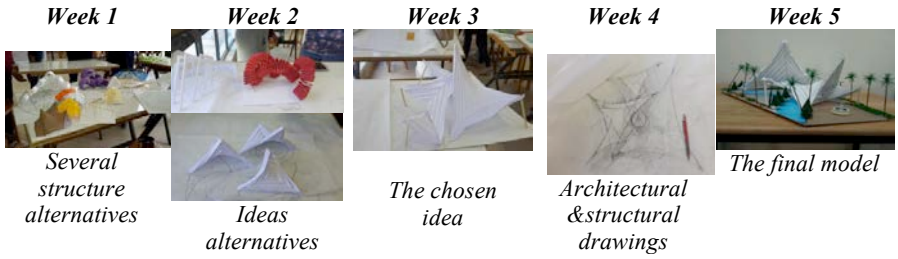

Figure (2) Example of a student' models through five weeks.

3.1.1 Frequencies

Finally, after conducting the main questioner in phase three, most of the students found that physical models helped them to think realistically in the structural design stage, while more than half of them confirmed the importance of physical model in the structural form finding process. The importance of the physical model was reflected in the increase in using it as a tool to "produce multiple alternatives of different structural systems for the

proposed design, generating creative ideas based on structural concepts, and to help in choosing the best structural form".

Most students agree, that physical models help in discovering errors, choosing and evaluating the proposed structural concept, "creating ideas in a visible way – building, merging experience between structural and design elements". Figure (3), shows the response of students on the investigated criteria from the main survey, which were unimportant, semi-important, or important.

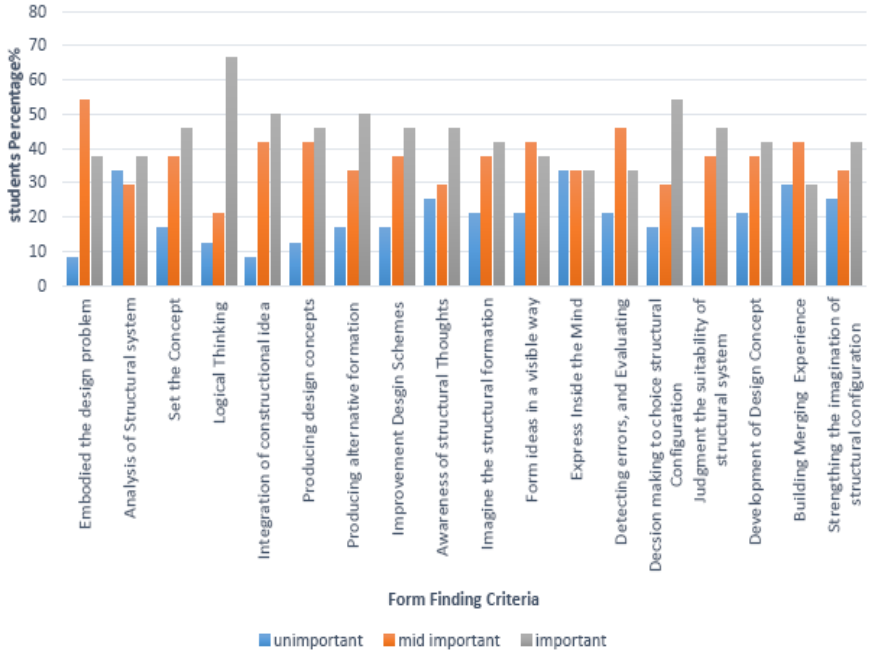

Fig (3) The Importance of Physical Model Related to Form Finding Criteria.

3.1.2 The Correlation

As shown in table (1), there was a correlation network with a strong, statistically significant relationship between "creating ideas in a visible way" criterion that related to the structural forms and their elements, and "building, merging experience between structural and design elements" criterion, and "generation of structural forms", that confirm the important role of using manual physical models during form finding design stages.

There is a direct correlation between thinking in a realistic way and visual form generating, with the structural thoughts awareness, and structural form generation all while being integrated in the design idea. Students' ability to produce alternative design ideas related to structural aspects increased, with an observed improvement in their decision-making skill, selecting optimal

configuration and forming a sound opinion on the suitability of a structural system. Finally, their ability in "Merging Structural Experience of Knowledge into Design Studio" improved.

TABLE (1) Shows SPSS Output for the Spearman's Correlation Coefficient between Criteria.

	(1) Embodied the design problem	(2) Analysis of Structural system	(3) Thinking in logically way in structural system in project	(4) Integration of structural idea	(5) Awareness of structural Thoughts	(6) Imagine the structural formation	(7) Form ideas	(8) Detecting errors, and Evaluating	(9) Development of Design Concept	(10) Imagination of structural configuration
A) Producing design related to structural concepts	0.165	0.385	.573**	.537**	0.322	0.265	0.136	0.334	.424*	.506*
B) Producing alternative structural formation	0.244	0.222	.528**	.495*	.434*	-0.049	0.223	.462*	0.318	0.326
C)Better Decision making for suitable form	0.124	0.288	0.088	0.367	.619**	.517**	0.334	0.295	0.299	0.311
D) Judgment the structural system suitability	.460*	.424*	.418*	.539**	.455*	0.338	.596**	0.401	.486*	.485*
E) Development of Design Concept	.674**	.858**	.564**	.505*	0.399	.499*	.672**	.706**	1	.627**
F) Merging Experience	.625**	.649**	.696**	.597**	.602**	.659**	.572**	.677**	.644**	.751**

**. Correlation is significant at the 0.01 level (2-tailed).
.*Correlation is significant at the 0.05 level (2-tailed).

3.1.3 Factor Analysis

Through analyzing the criteria by using the factor analysis, the criteria show, that there are four major factors in the form generation stage by using the physical model:

First: express and generate structural ideas in a visible way.

Second: ability to combine structures and architectural design.

Third: producing alternative systems and forms.

Fourth: decision-making ability in choosing the best structural system and form of the project. Table (2) shows the main factors merging the structural knowledge in form finding stage.

TABLE 2. The Main Factors merging the Structural knowledge in form finding stage.

	Rotated Factor Analysis			
	First Factor Express and generate structural ideas in a visible way.	**Second Factor** Ability in combining structural info with architectural design.	**Third Factor** Produce structural systems alternatives and forms.	**Fourth Factor** Decision-Making ability in choosing the best structural form for the project
Criteria				
Express Inside the Mind	.838			
Embodied the design problem	.829			
Development of Design Concept	.828			
Analysis of Structural system	.818			
Detecting errors, and Evaluating	.708			
Form ideas in a visible way	.633			
Integration of constructional idea		.70		
Logical Thinking		.672		
Building Merging Experience		.670		
Imagination of structural configuration		.602		
Producing design concepts			.814	
Producing alternative formation			.749	
Decision making to choice structural Configuration				.909
Awareness of structural Thoughts				.750
Imagine the structural formation				.641
Judgment the suitability of structural system				.543

3.2 DISCUSSION

The learning methodology, especially in the first week, was leaving students to explore structural form freely, to help them easily connect with what was studied in structural courses. As a result, students developed a better awareness in form finding stage, and gave unexpected results, also they were able to gain benefits from using simple materials, and gave variation in using structural form ideas. They also developed a sense of understanding structural loads without the need for mathematical calculation.

During the second week, number of students faced difficulty in finding a structural form suitable to the nature of their projects, despite of their good performance in the first week. More experimentation needed, which was achieved by producing more alternatives for the same design proposal, and then selecting the best one after assessment. This suggests that a comprehensive design process can account for development much better than separate stages.

4. Conclusions

Physical models offer students a method of embodiment to their vision, and examination to their structural ideas, which eventually enhances their skills in choosing the best structural concept to develop their design ideas. The ability to produce design based on structural systems, produce design and structural alternatives, improve decision-making, and offer better judgment

on structural system suitability to a project, all ensure the quality and skill of integrating structural info into design.

After correlation and factor analysis, there are three basic phases that students pass through in form finding process by using manual physical models, namely: generating ideas stage related to projects' structural elements, generating structural forms related to design stage, and developing their ability to choose and to evaluate the best structural form. Also, "Incorporating Practical Structural Knowledge into Design Studio" criterion exhibited a strong correlation with all the other criteria elements.

References

ABDELHAMEED, W., DAEF, A., ADDELATIFF, M., OZEL, F., 2002, Assessment of the Impact of Digital Manual Media Types on the Basic Design Capabilities of Architects: A Proposed Framework and Directive Measures, *sigradi, 275-277*

ABDELHAMEED, W., 2005, Digital-Media Impact on the Decision Making Capability of Architects, *sigradi, 478-482*

ABDELHAMEED, W., 2011, Architectural Form Creation in the Design Studio: Physical Modelling as an Effective Design Tool*, Archnet-IJAR,* Volume 5 - Issue 3 (81-92)

ABDUL AZIZ, A., MOHANI FAHMI, M. AND TAKE BANE, L. 2010. Integration of Structural Knowledge In Design Studio Project: Assessment Study of Curriculum in Architecture Course in University of Malaya*, Journal of Design and Built Environment*, Vol. 7, pp. 59–74

FAHMI .M. M., A. ABDUL AZIZ, S. ELHADI M. AHMEND, 2012, The Integration of Structural Knowledge in Studio Design Projects: An Assessment Curriculum in: Architecture Course in SUST, *Journal of Science and Technology* vol. 13, www.sustech.edu

VASSIGH, S., 2005, Structure Learning Center Home, Retrieved May 21, 2009, www.learningstructures.org\home. asp.

VRONTISSI, M., 2015, The Physical Model in Structural Studies within Architecture Education: Paradigms of an Analytic Rationale?, *Proceedings of the International Association for Shell and Spatial Structures (IASS)*, 17 - 20 August

YAZICI, G., YAZICI, Y., 2013, A "Learning by Doing" Approach in the Delivery of Structural Engineering Courses of Architecture, *International Journal on New Trends in Education and Their Implications,* Volume: 4 Issue: 2 Article: 13

*Program SPSS "Statistical Package for the Social Science", version 16