Structural and Technological Principles within Architecture Education

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ABSTRACT

One of the most challenging disciplines of architecture is the structural and technological issues of building design. In the past design and construction of the buildings used to be done by master builders, who were responsible for all aesthetical, technical and structural issues of design, but after industrial revolution and division of skills, architecture and structural engineering appeared as two different professions. Although, this fact have had many advantages, in some architectural projects have caused inadequate attention to structural disciplines by architects and disorder between building components.

Since architectural education systems play important and critical roles in structural knowledge of students, "Structural and technological principles within architecture education" has been attended in this research. Consequently, some existing literature and also curricula from different regions and systems have been selected and studied. Within the studied curricula, architecture curriculum of Eastern Mediterranean University (EMU) has been selected as a case study and studied more precisely. This selection has been due to a primary hypothesis indicating that some enhancements are needed for structural and technological courses and their prerequisites within the curriculum. Thus, efficiency of structural principals of the curriculum has been examined by means of questionnaires taken from students, interviews with faculty staff members and comparison of this information with other existing curricula and disciplines. The results are some general propositions for ensuring the proper implementation of structural principals within architecture curricula in general and also architecture curriculum of EMU.

Within the suggested items, Information Technology and its potentials for enrichment of architecture curricula have been highlighted. It is proposed to use IT facilities for provision of communication and information exchange within the students and also instructors, as well as emphasizing structural principles of architecture. Further developments of this idea can extend the domain of collaboration between students and provide easier access to architectural knowledge.

Keywords: Architectural Education, Structural Principals, Curriculum, Structure Courses, Information Technology.

ÖZ

Mimarinin en ilginç disiplinlerinden birisi bina tasarımının yapısal ve teknolojik konularıdır. Geçmişte binaların yapımı ve tesarımı bu işin estetik, teknik ve yapısal sorumluları olan yapı ustaları tarafından yapılırdı. Fakat Sanayi Devrimi ve yeteneklerin ayrılmasından sonra mimari ve yapısal mühendislik iki farklı meslek olarak görüldü. Bunun birçok getirisi olmasına rağmen, bazı mimari projeler mimarların yapısal disiplinlere olan ilgisini azaltırken yapı bileşenleri arasında uyumsuzluğa da yol açtı.

Mimari eğitim sistemleri öğrencilerin yapı bilgisi edinmelerinde önemli ve kritik bir rol oynadığı için mimari eğitimdeki yapısal ve teknolojik prensipler bu araştırmaya dahil edilmiştir. Sonuç olarak, bazı mevcut edebiyat ve müfredat seçilmiş ve çalışılmıştır. Çalışılan müfredat için Doğu Akdeniz Üniversitesi mimari müfredatı seçilmiştir ve incelenmiştir. Bu seçim, yapısal ve teknolojik gelişimin ve bunların müfredattaki önşartlarının göstergesi olan baş hipotezler için yapılmıştır. Böylece, müfredattaki yapı prensiplerinin etkinliği, öğrencilerle yapılan anketler, fakülte üyeleriyle yapılan mülakatlar ve bu bilgilerin mevcut diğer müfredat ve disiplinlerle karşılaştırılması yoluyla inceleye tabi tutulmuştur. Sonuçlar, genel mimari müfredatında ve DAÜ müfredatında yer alan yapısal prensiplerin düzgün bir şekilde yürütülmesini sağlayabilecek olan bazı genel önerilerdir.

Önerilen unsurlar içinde, Bilgi Teknolojileri ve onun mimari müfredatını geliştirebilecek potansiyeli vurgulanmıştır. Mimarinin yapısal prensiplerinin vurgulanmasının yanı sıra, iletişimin sağlanması ve öğrenci-öğretmen bilgi aktarımı için BT imkanları önerilmiştir. Bu fikrin ilerideki gelişimi öğrenciler arasındaki uyumun alanını genişletebilir ve mimari bilgiye ulaşımı kolaylaştırabilir.

Anahtar Kelimeler: Mimari eğitim, Yapı prensipleri, Müfredat, Yapı dersleri, Bilgi teknolojisi.

To my parents (Fariba & Amir),

who have always supported and motivated me by their unconditional love.

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INTRODUCTION

Architecture education is a topic which has a direct relationship with quality of our surrounding environment. Training of architects who are able to deal with architectural design and its disciplines properly, will lead the built environment toward having better qualities and serving adequate functions for the users.

Architects have been always supposed to deal with various aspects and features in architectural design. Aesthetic values, site conditions, functional requirement, formal configuration and structural and constructional issues are some of the items, which architects should know, consider and be attentive to them. Within this diversity of disciplines, integration of structural and technological issues with other aspects of design seems as a challenging debate. Paying improper amount of attention to one of them may result in losing the values of the other one and consequently, negative imbalances in architectural design.

In the recent years, architects are more in the risk of falling into this situation than before; this is due to the fact that development of building industry and complexity of market requests have demented more specialists in building industry (Raftopoulos, 1999). Some duties of architects in respond to structural and technical aspects of design become neglected by them and remain unsolved to the structural engineers. This will negatively affect the integrity of building design.

Considering and regarding the negative results of inadequate attention to structural issues of design draws attention to the necessity of contribution of architecture education in training of architects who have the ability of critical thinking and simultaneously solving the different aspects of design.

Furthermore, this concern is attended by Unay (2006). He emphasizes the critical role of design studios and their structural taught in architectural studies and mentions that the artistic and scientific requirements of design courses should be supported by theoretical courses of architecture as well.

1.1 The Main Aims and Objectives and the Consequences Toward Achieving them

The main objective of this research is to clarify the necessary applications for proper implementation of structural principals within architecture curricula. This research emphasizes the importance of having transparency and clearance in policies of architecture schools in relation to structural and technological issues.

Three main items which are considered to be referred to achieve the goals are;

- Study of some current architecture curricula from universities around the world
- Investigation of some existing literature related to architecture education and its structural and technological principles
- Setting the view points of some architecture students and some suggestions made by some architecture instructors[1]

In order to get more tangible information and practical results about application of structural principals in architecture curricula, one of the studied curricula in this research has been taken as a case study. Architecture curriculum of Eastern Mediterranean University (EMU) in North Cyprus is the main case study of the

[1] Some comments and suggestions from architecture students and instructors of Eastern Mediterranean University (EMU) in North Cyprus are used in this research.

research. This selection has been done according to an initial hypothesis based on personal observations of the author and comments of some other students and instructors of architecture faculty in Eastern Mediterranean University indicating that structural principles offered by the faculty are not sufficient and respondent to the whole needs of students. Thus, this initial hypothesis has been put into a research question in order to examine the level of adequacy of the EMU architecture curriculum.

Consequently, some questionnaires taken from students and interviews done with the instructors have been arranged to determine the level of efficiency of the curriculum and level of satisfaction of students from the performance of the faculty. Since the obtained results have indicated some missing and lacking points within the curriculum in terms of presentation of structural principles, some further procedures have been considered in the research to propose solutions to enhance the teaching quality of the current curriculum. Although, some of the proposed items may have already existed within the curriculum, their implementation and application into practical issues of teaching have not been achieved properly. So restatement and rearrangement of them will clarify the schools policies and simplify the supervision of the faculty on their accurate accomplishment. On the other hand, these announcement and proposal for enhancement of EMU architecture curriculum might be useful and effective for other architecture curricula, because similar problems and missing points are probable for other architecture schools as well. Thus, the suggested items are introduced in general as “some proposals to insure the implementation f necessary structural principles within architecture curricula”.

Within the proposed items for enhancement of architecture curricula and specially architecture curriculum of EMU, potentials and facilities of Information

Technology is specifically attended in this research. In today's architecture IT can be used as a tool for communicating architectonic concepts without losing the already available traditional methods of data representation in architecture. New media (especially computer) can act as an instrument for the analysis and reconstruction in architecture (Frohburg, 2006 in Vasquez de Velasco 2006).

1.2 Methods and Approaches in Collection and Evaluation of Data and the Achieved Results in Each Section of the Research

There are some important points which seem important and necessary to be explained and highlighted here about suggested results and enhancements methods of architecture curricula. Although, some of the general methods are already explained, a more detailed explanation about every section of the research is presented here.

The main outlines of the thesis and their relative methodologies are as following;

- Chapter 3: in this chapter the main necessities and abilities which architecture students should have in relation to structural design are separately mentioned in the items of the questionnaire and the quantitative data taken from the questionnaires have been calculated, converted to percentage and illustrated on some diagrams in order to give clear ideas about weaknesses and problematic points. Level of satisfaction of students and level of effectiveness of theoretical courses of structures are two main considerations while analyzing the data, which are expressed numerically.

  On the other hand, existing situation of other universities and also comments from review of existing literatures are collected which are mainly providing qualitative expressions. Finally, interpretations of the quantitave collected data and compiled qualitative data from the literature has led the research toward proposing a set of proposals and suggestion for enhancement of EMU curriculum.

- Chapter 4: This chapter is a continuation or a supplementary part for the chapter 3. In fact, one of the suggested items of the research for enhancement of architecture curricula in general and architecture curriculum of EMU as a specific case is focused and emphasized in this section. The role of information technology is discussed in this chapter and according to the potentials of computer facilities for enhancement of architecture education; an online virtual environment is proposed to be used for design courses (ALEST- Architectural Learning Environment for Structural Training).

  This proposition includes just functions and capabilities, which are offered for online learning environment of ALEST (flow chart definition), and the technical computer programming issues are excluded from this research.

- Chapter 5: This chapter focuses on one of the subtitles of the chapter 4. The proposed online environment of the chapter 4 includes many items and explanations about structural systems and their specifications. Providing detailed explanations and information for the whole items of the online program is excluded from this research and requires another specific research, but one part of it is chosen and focused in the chapter 5 and that is classification of structural systems.

This research can be called an action research since it contains a comparative attitude in obtaining the results. In fact, comparisons of the collected data with the information taken from the case study of the research have led the researcher toward making some suggestions for providing balance in the structural principles of architecture curricula. This issue can be done by some interdisciplinary considerations and collaborations between the two field of architecture and structural engineering.

1.3 Further Expectations from the Research

Apart from suggestions which are made here for the increasing the quality of architecture curricula (and specifically architecture curriculum of EMU), the compiled information of this research is supposed to have another function for students as well. Presenting and explaining the policies and objectives of schools toward providing proper structural teachings for students, can make them conscious and aware of the considered benefits for them. Hence, they can contribute in achieving the considered goals themselves.

Chapter 2

REVIEW OF STRUCTURAL PRINCIPALS OF ARCHITECTURE WITHIN EXISTING LITERATURE AND CURRICULA

2.1 Background and History of Application of Structural Concepts in Architectural Design

According to existing documents and data, throughout history architectural design has been always dealing with structural design. Even architecture and structural engineering had been considered as the same profession for many years. There are many cases showing the presence of architecture and structural design together, both in terms of formal arrangement of buildings and also profession issues.

From the ancient time, Egyptian mathematician Imhotep, who is known as the first engineer in history, is supposed as the architect of the Step Pyramids of Djoser (Humbert, 2003). For many years building makers were expert in both architecture and structural engineering; they were called master builders and it was in industrial revolution time when, the divide between the two professions initiated and grew in the first part of the 20^{th} century.

There are many examples from different historic eras in which architectural approach is integrated with structural design of the buildings to create landmark and remarkable structures. Gothic style which was popular during the high and late mediaeval is a good example of this integration. As Torpiano (2009) explains, “The structural form of Gothic construction is used to perfect effect to create lightfilled spaces of a particular quality and verticality, while the structural elements (flying buttresses, rib vaulting, pointed arch) express a highly particular aesthetic". A famous Gothic example, which indicates structural approach in expressing ideas in architecture, is the dome of Sta. Maria del Fiore in Florence designed by Brunelleschi. In this 15 century dome an octagonal plan erected by bricks is used to achieve 42m span (Florence Cathedral, 2009).

In contemporary architecture the idea (combination of architectural thoughts and structural concepts) is highly attended. Contemporary architect Piano (2001) claims," I can hardly see a separation between shape, function, structure, technology, technical equipment and science; between science and art there can not be a barrier; they speak the same language and require the same energy", (Torpiano, 2009).

A general survey in existing literature reveals the fact that there is no doubt in necessity of considering structural concepts into architectural design of buildings, specially remarkable and notable ones. Moreover, a question raises here; who is the responsible person for integrating structural and architectural thoughts. The answer can be ***architect***, ***structural engineer*** or ***both***. This question is analyzed and discussed in the following subtitle.

2.2 The Architect and the Engineer- Duties and Responsibilities in Structural Design

The rapid development of construction and technology in early 20th century and extensive use of new materials and complicated structural calculations, have defined different professions in building design industry. Architecture and structural engineering are the two main professions in this regard.

Architects are mainly dealing with aesthetics, planning and sociology, whereas structural engineers manage technical subjects. Peter Rice (1994) distinguishes architect and engineer by stating that architect's response is primary creative, despite the engineer' is essentially inventive.

Since consideration of Gestalt theory: "The whole is more important than some of its parts" (Holism, 2009), is essential to achieve a successful design project, it seems necessary for both architects and engineers to collaborate and bridge the gap between art and technology. Furthermore, one of these two persons should act more of the other one; whether the engineer should become more of an architect or the architect more of an engineer. Salvadori (1963) in his book 'Structure in architecture' introduces architects as the main persons responsible for this regard; as he claims, "The architect is the leader of the construction team; the engineer is just one of its members. The architect has the responsibility and the glory, the engineer but a service to render, creative as it may be".

On the other hand, structural engineers can play important roles in incorporating structural design with aesthetic aspects of buildings, but as a general rule architects have the main duty of these kinds of incorporations; Edwards (2008) argues that, although in some cases structural engineers are mentioned as artists, but as a concept 'Aesthetic' would not be the forefront of most engineers minds.

Regarding the duties of architects in relation to structural design, there is an important point to be attended; architects are supposed to design geometrical aspects of structures. They should design the structures as functional and geometrically stable layouts. Complicated calculations of structural members are excluded from architects' responsibilities. As Gauld (1991) points out, "… good structural design ‘for architects’ is related to common sense rather than complex mathematical equations”.

2.3 Potentials of Structure to Enrich Architecture

In the previous section some of the duties of architects and structural engineers were emphasized and the discussion concluded with the necessity of architects’ contribution to enrich structural design. Furthermore, it is important to pay attention to consequent results of these contributions, especially in contemporary architecture.

In today’s architecture iconic buildings play important roles to provide symbolic values to the viewers; this is due to the fact that they can contribute to define the qualities of vistas in urban spaces as well as influencing the quality of their interior life. Since building structure is one of the main elements in defining form and architectural arrangement, it can be said that structure plays a critical role in transferring the ideas and creating expressive features. As Collins (1998) claims, it would not be an exaggeration to say that (structural expression) is the idea which offers the most fruitful prospects for the future development of modern architectural thinking.

Nowadays structure can act as a language to express architectural values. As Charleson (2006) states; “Structure no longer remains silent, but is a voice to be heard”. He also argues that, as architects we can let structure talk and be heard, or change the metaphor, it can be designed in a way that its viewers not only watch it, but also read it passionately.

One of the contemporary vanguard architects, who have created notable iconic structures, is Santiago Calatrava. He describes himself as architectural engineer and believes in using architecture as an expression of structural study. As design concepts he has used muscular forms illustrating load paths and exuding strength in some projects (Ward, 2009).

2.4 Situation of Structural Concepts and their Implementations in Architectural Education

Up to here the survey in literature has revealed the fact that contribution of architects in structural design to enrich architecture is a necessary issue. Furthermore, position of architectural education to prepare architects for this essential regard will be discussed. “It is clear that our built environment has not got the qualities that we think it should have. Education is an excellent way of improving our expectations for changes in the right direction” (Thronberg, 2006).

Some important points related to architecture education and structural concepts are highlighted below:

2.4.1 EAAE (European Association for Architectural Education)

One of the authorized and well known organizations, which have been established for the purpose of “the exchange of ideas and people within the field of architectural education and research”, is EAAE. There are some basic principles defined by EAAE to achieve a successful architectural design system as listed bellow (EAAE, 2006):

1- “1- An ability to create architectural designs that satisfy both aesthetic and technical requirements.
2- An adequate knowledge of the history and theories of architecture and the related arts, technologies and human sciences.
3- Knowledge of the fine arts as an influence on the quality of architectural design.

4- An adequate knowledge of urban design, planning and the skills involved in the planning process.

5- An understanding of the relationship between people and buildings, and between buildings and their environment, and of the need to relate buildings and the spaces between them to human needs and scale.

6- An understanding of the profession of architecture and the role of the architect in society, in particular in preparing briefs that take account of social factors.

7- An understanding of the methods of investigation and preparation of the brief for a design project.

8- An understanding of the structural design, constructional and engineering problems associated with building design.

9- An adequate knowledge of physical problems and technologies and of the function of buildings so as to provide them with internal conditions of comfort and protection against the climate.

10- The necessary design skills to meet building users' requirements within the constraints imposed by cost factors and building regulations.

11- An adequate knowledge of the industries, organizations, regulations and procedures involved in translating design concepts into buildings and integrating plans into overall planning."

2.4.2 Exploration of Some Key Words Related to Building Structure in Architectural Education

It is not possible to specify some of the EAAE principles (2.4.1) as specific structural and technological requirements, because they are interrelated to each other in a design project and cannot be considered separately, but some of them are directly related to structural and technological concerns of design, such as the first, second and the eighth principle; some important key words and phrases used in these explanations are highlighted here:

- structural design
- construction
- engineering
- technology
- association with building design

Since combination of these 5 key words indicates the fundaments of structural design in architectural education, some existing literature related to them is explored and studied in following statements.

In recent years, contemporary architecture has experienced some significant changes in all of its aspects. Extremely fast development of digital media and information technology have provided new methods in generation process of architectural products such as new presentation and simulation techniques. Parallel to these changes, construction industry and production of new building material have become more technical and require specific knowledge. Hence, architectural education needs to respond to some basic requirements to be able to adapt with recent contemporary changes. Genoa faculty of architecture (Voyat, 2009) believes that, "… (the recent architectural demand) not only influences the contents of the subject areas taught in architectural curricula, but also the whole system of studies, as it is responsible for the coherence of the education offered and the integrity of the competences to be fulfilled".

Nordemann (2009) in his article "profession/ professions" emphasis that, the truths which enable architects to draw, design and create in accordance with contemporary demands in architecture are not standardized construction process or predefined techniques, but he draws attention to the necessity of interdisciplinary knowledge for architects in present time; as he claims, executing an architectural project for an architect does not require to be a geographer to understand site conditions, a sociologist to realize the number of population and their needs, an engineer to distinguish full technical issues, an economist to estimate costs and …, but executing a project does mean how to draw and apply main elements, allowing systems and logic to emerge and bringing them together in synergy.

2.4.3 Analyze and Investigation of some Existing Book Contents in Relation to Structural Concepts within Architectural Education

In relation to existing database and documents there are some books and references, which can be used for architects and architectural students to get some ideas about principles of stability and load transformation through structural members. Some of them are mentioned and explained here to provide an overview about the contents and approaches of existing databases.

- *Structure in architecture (Salvadori, 1963)*: This book tries to eliminate the gap between theory and practice in structural design. Salvadori believes in necessity of having both intuitive and mathematical knowledge of structural design for inventing structures. This book only studies the intuitive aspects of structural design and mathematical explanations are totally excluded in this book.
- *Structural Design in Architecture (Salvadori, 1967):* In this book Salvadori emphasizes on necessity of structural knowledge for architectural students from early education stages and introduces his book, firstly by appealing to the intuitions that we all gain from our daily experience and secondly by

manipulative knowledge of mathematics to be able to "figure out" quantitative answers.

- *Structures for architects (Gauld, 1991)*: This book tries to give the knowledge of estimating structural members' size to architects. There are practical examples and mathematical calculations to indicate this aim, but they are more based on 'rules of thumbs' rather than complicated calculations of strength of material.
- *The structural basis of architecture (Sandaker, 1992)*: This book is aimed to give the reader a basic knowledge of structural theory in order to understand how structures work. Many diagrams, figures and sketches are used as well. Most of the definitions of this book are intuitive and mathematical explanations are limited to basic and simple formulas.
- *Structural Design for Architecture (Macdonald, 1997*): Macdonald in his book has accumulated a reference on architectural structures for students and practicing structural engineers. In this book he explains the structural behavior of different forms and materials. Mathematical and calculative explanations are excluded from this book, instead theoretical concepts and case studies are mentioned.
- *Structure as architecture (Charleson, 2006)*: This contemporary book is intended to explore the potentials of structure and raise architects' perception of structure as an integral element of architecture rather than just an applied technology. The approach of this book is to achieve the mentioned goals by illustrating many photos from case studies and explaining their structural system away from mathematical calculations.

2.4.4 Some Current Curricula from Universities Around the World

In this literature survey some universities are selected from the countries around the world to be studies in order to get general ideas about the main principals covered within their curricula and also their attitude toward presentation of structural and technological disciplines.

Selection of the universities has been done in a way that the chosen universities have the best rankings in their countries, and even some of them have the highest rankings of the world. The universities are located in USA, Europe and Middle East. Study of the universities from Middle East can reveal some teaching experiences from the same region where the main case study (EMU) of this research is located and provides the opportunity of comparing the results taken from the case study with existing results in similar conditions. On the other hand, curricula of American and European universities indicate some experiences from overseas areas and offer the opportunity of comparing the case study with universities located in different geographical situations and consequently different social, economical and cultural needs and requirements. These variations generalize the obtained results and make them applicable for various universities as basic and minimum structural requirements in every architecture curricula.

Since majority of the references for accessing to the information of architecture curricula in this research is the website of the universities, there have been some limitations for the author in order to have access to more university curricula. In some websites the information are not available in English Language or the course lists are presented for the current semester and are not presented annually. On the other hand, time limitations of the research have caused some restrictions in this regard for the author. For the future researches and investigations on architecture curricula, it is suggested to study more universities from other parts of the world such as Far East or central Asia.

The main teams and topics covered in curricula of the mentioned case studies are summarizes and categorized in some tables[2].

Study and investigation in the collected data indicated that:

- Minimum 10%-15% of the main topics covered in bachelor degrees are directly related to structural concepts.
- Minimum 20%-30% of the main topics covered in bachelor degrees are directly related to technical and technological issues in architecture.
- There are some critical topics included in the curricula, which are not directly related to the structural and technological concepts, but are indirectly including the mentioned topics.
- In some universities design studio focus in some semesters is given specifically to the mentioned topics.

[2] The tables are drawn by the author, by referring to official websites of the universities.

Studied Curriculum 1-

MIT (Massachusetts Institute of Technology) - USA

Bachelor of Science in Architectural Design (BSAD Degree Chart)

Table 1: Main themes of architecture curriculum of MIT, (MIT, 2009)

part A	General Institute Requirements (GIRs)	
	Science Requirement	• Chemistry • Physics • Calculus • Biology
	other Requirement	• Laboratory (LAB) Requirement • Restricted Electives in Science and Technology (REST) Requirement • Humanities, Arts, and Social Sciences Requirement
	42–60 units	

part B	Department Requirements			
	Freshman year	Sophomore year	Junior year	Senior year
	core subjects for all architecture majors: • Experiencing Architecture Studio • Integrated Architecture Design Studio • Foundations in the Visual Arts for Majors • Introduction to Building Technology • Introduction to Design Computing • Introduction to the History and Theory of Architecture		By the beginning of junior year, students begin concentrating in one of the five disciplines: Architectural Design Building Technology Computation Visual Arts History, Theory and Criticism of Architecture and Art	
	180–198 units			

Bachelor of Science in Architectural Desig

Note: part B in some cases may specify some of the part A subjects.

Undergraduate Education in MIT School of architecture:

1- Bachelor of Science: degree is granted once all General Institute Requirements (GIRs) and all departmental requirements have been met. This course is designed for students who are intellectually committed to subjects within the Department of Architecture but have educational objectives that cross departmental boundaries.

   With the approval of the department, a student may plan a course of study that meets his or her individual needs. The resulting program must incorporate fundamental areas within the department.

2- Bachelor of Science in Art and Design: The degree is granted once all General Institute Requirements (GIRs) as well as the department requirements have been completed. The Bachelor of Science in Art and Design (BSAD) is the predominant undergraduate degree of the Department of Architecture. By the beginning of junior year, students begin concentrating in one of the five disciplines:

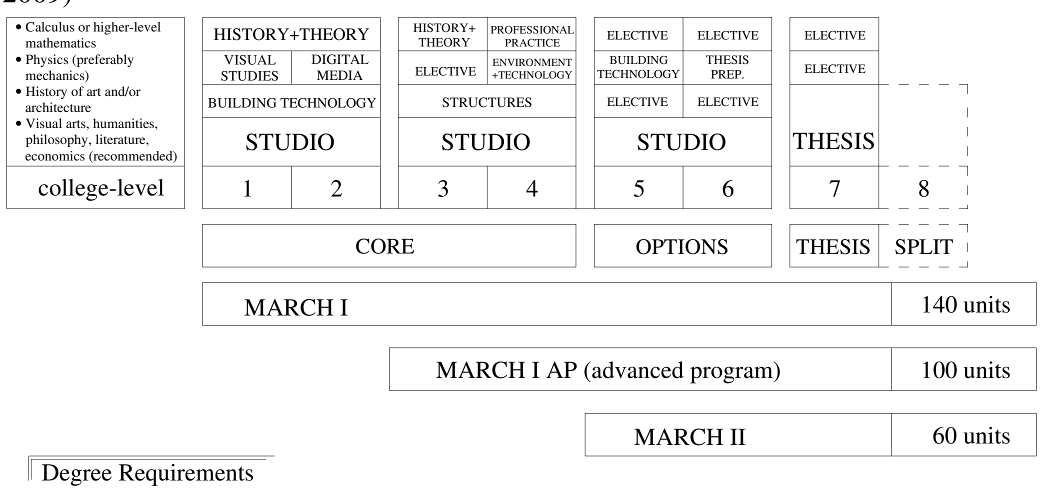
- Architectural Design
- Building Technology
- Computation
- Visual Arts
- History, Theory and criticism of Architecture and Art

Studied Curriculum 2-

HARVARD University-USA- Master of architecture

Graduate School of Design (Degree Requirements chart)

Table 2: Main themes of architecture curriculum of Harvard University, (Harvard, 2009)



The Department of Architecture in Harvard University offers the following degree programs:

1. MARCH I: The program leading to the Master in Architecture as an accredited professional degree is intended for individuals who have completed the bachelor's degree with a major other than one of the design professions or with a preprofessional undergraduate major in one of the design professions.

2. MARCH I AP (advanced program): Individuals who have completed a preprofessional four-year bachelor of arts or bachelor of science degree with a major in architecture or environmental design may be eligible for admission with advanced standing, subject to the review of the admissions committee.

3. MARCH II: The program leading to the Master in Architecture as a postprofessional degree is intended for individuals who have completed a five-year undergraduate professional program in architecture or its equivalent.

Note: For MARCH I & MARCH I AP applicants a minimum of two semesters of college-level survey courses in the history of art and/or architecture, preferably covering the ancient to modern periods, is also required. Applicants must achieve a grade of B or better in each of these courses. Please note that while the GSD requires only one semester of each for admission, it is strongly recommended that applicants complete one year of calculus and physics. Preparation in the visual arts is desirable and may include drawing, sculpture, and/or graphics. Courses in the humanities, philosophy, literature, and economics are also recommended but are not required.

Studied Curriculum 3-

Jordan University of Science & Technology (JUST) - Jordan

B. Sc. Of Architectural engineering

Table 3: Main themes of architecture curriculum of JUST, (JUST, 2009)

<table>
<tr><td rowspan="6">A+B= B.Sc. of Architectural engineering</td><td colspan="2">A= University Requirements</td></tr>
<tr><td>• Language and communication skills
• Computer skills
• Military science</td><td>• Biology
• Environmental Protection
• Health Related Courses
• Psychology
• Sociology
• History
• Music
• …</td></tr>
<tr><td>University Compulsory Requirements</td><td>University Elective Requirements</td></tr>
<tr><td colspan="2">B= Faculty & Departmental Compulsory Requirements</td></tr>
<tr><td>• Math- Calculus
• General Physics
• Drafting, Visual Communication, Computation & CAD
• Technical writing & Verbal communication
• Surveying</td><td>• Structural & Technological issues *
• Drawing abilities (CAD, Descriptive geometry, Drafting, …)
• History & Conservation
• Urban & Landscape
• Human behavior
• Interior design</td></tr>
<tr><td>Faculty Compulsory Requirements</td><td>Departmental Compulsory Requirements</td></tr>
</table>

Total duration of study for the bachelor degree is 5 years

Note * - Structural & Technical issues: The main courses in this section cover the following topics:

- Building construction system
- Building Material
- Mechanical systems
- Engineering mechanics
- Structural analysis and system
- Professional practice

- Geographic in formation system
- Construction management
- Building design and energy consumption

Studied Curriculum 4-

Shahid Beheshti University (SBU) - Iran

B. Sc. In Architecture

Table 4: Main themes of architecture curriculum of SBU, (SBU, 2009)

B.Sc. in Architecture	Construction	Structure	
	• Introduction to technology of building material • Building elements • Building components • Building workshop & Site management	• Mathematics for architecture • Statics • Strength of material, Building structure • New forms & Regulations	
	Environmental control	**Theoretical courses**	**Trainings & Electives**
	• Climatic design • Mechanical building services for architects • Electrical building services for architects	• Introduction to architectural theory • Process of design • History of the world architecture • History of Iranian Islamic architecture • History of contemporary architecture • Urban design	• Presentation technique 1 • Presentation technique 2 • English language in architecture • Elective 1 (related to art or general knowledge) • Elective 2 (related to architecture) • Trainings • Sketch

Studied Curriculum 5-

University Of Cambridge- UK

Bachelor of architecture

Table 5: Main themes of architecture curriculum of Cambridge University, (Cambridge, 2009)

College	Recommended topics (not compulsory): • History of Art • Combination of arts and science subjects • Mathematics at A level (or equivalent)
Part IA (year 1)	**Design** emphasis is on understanding and developing proficiency in traditional modes of architectural representation - models, collage, perspectives, elevations, plans and sections. Basic CAD skills are also tought.
	Lectures • Introduction to Architectural History • Introduction to Architectural Theory • Fundamental Principles of Construction • Fundamental Principles of Structural Design • Fundamental Principles of Environmental Design
	There is a trip to Rome, which includes visits to and lectures on the famous buildings of the city and its surroundings.
Part IB (year2)	**Lectures** • Studies in Architectural History • Theories of Architecture • Urbanism and Design • Principles of Construction • Principles of Structural Design • Principles of Environmental Design Part IBEmphasis is on integrating the following 3 thoughts: • technical skills learnt in Part IA • studio output • ongoing lectures
Part II (year3)	• Advanced Studies in Historical and Theoretical Aspects of Architecture and Urbanism • Introduction to the Principles of Professional Practice • Advanced Studies in Construction Technology Structural Analysis • Environmental Design Related to Case Studies Architectural Engineering

Studied Curriculum 6-

TU Berlin (Technical University of Berlin) - Germany

Master of Science in Architecture

Table 6: Main themes of architecture curriculum of TU Berlin, (TU/Berlin, 2009)

A: Course plan for Bachelor Degree
Design and construction
• Design & construction 1,..., 5
Sociology, History & Theory of Architecture
Appearance and design
• Visual Arts • Descriptive Geometry • Introduction to CAAD
Social Foundations
Scientific and technical bases
• Structural Theory I,II • Structural Theory III • Teaching Materials & Building Physics • Technical Building Equipment
Bachelor thesis
Elective & Free choice

B: Course plan for Master Degree	
Study Profile I: Architecture in general	**Profile Study III: Location and Development**
• Integrated Design II • Integrated Design and PIV III • Theory and History • Law and Economics • Sociology • Elective & Free choice	• Integrated Design II • Design and project management III • Theory and History • City and real estate economics, urban sociology • Private construction law and economics • Public Construction Law and Project Management • Elective & Free choice
Profile II study: Architecture in stock	**Profile Study IV: Structure - Energy**
• Integrated Design II • Draft inventory (Integrated Design III) • Theory, History and Building • Historical Building Construction and Materials • Economics, law and sociology • Urban Design and Historic • Elective & Free choice	• Integrated Design II (energy-optimized architecture / Buildings of the health care system) • Structural Design III • Theory and History • Historical Building Construction and Materials • Law and Economics • Elective & Free choice

A+B= Master Degree

Note: TU Berlin offers a consecutive master program in architecture, which consists of the 6-semester Bachelor's degree where students learn the basics and a 4-semester Master's program.

Studied Curriculum 7-

Eastern Mediterranean University (EMU) - North Cyprus

Bachelor of Architecture

Table 7: Main themes of architecture curriculum of EMU, (EMU, 2009)

Freshman Year	• Design studio (Farch 191; 192) • Graphic Communication • Introduction to Art and Design • Math & Geometry for Designers • English language	Sophomore Year	• Architectural Design Studio (Arch 291; 292) • Human & socio-cultural Factors • History & Theories (I, II) • Tectonics of Structural Systems (I, II) • Construction & Material • Tectonics of Flextural Systems (I, II) • CAD • Energy & Environmental issues • Urban Design Theories
Junior Year	• Architectural Design Studio (Arch 391; 392) • Conservation & Restoration • Tectonics of Form Resistant Structures • Construction & Material • Design Theories • Environmental Systems in Architecture	Senior Year	• Architectural Design Studio (Arch 491; 492) • Economic & Managerial Issues in Architecture • Professional Issues and Portfolio Preparation
* Elective courses normally start from the 5th semester			

***

Table 8: Summary of structural principles within architectural curricula of the selected universities

#	UNIVERSITY NAME	THE OFFERED DEGREE	DURATION OF STUDY	TECHNOLOGICAL & STRUCTURAL TOPICS AND THEIR PREREQUISITES WITHIN THE COURSES
1	MASSACHUSETTS INSTITUTE OF TECHNOLOGY (USA)	BACHELOR OF SCIENCE IN ARCHITECTURAL DESIGN (BSAD)	5 → 1 year colleague → 4 years: year 1&2 → year 3&4 →	• Science requirements: Chemistry, Physics, Calculus, Biology • Introduction to building technology • Focus of one specific branch of architecture ; one of the branches in Building Technology
2	HARVARD UNIVERSITY (USA)	MASTER OF ARCHITECTURE (MA)	5 → 1 year colleague → 4 years: year 1 → year 2 → year 3 → year 4	• Calculus or higher-level mathematics • Physics (preferably mechanics) • Design studio focus is on building technology • Design studio focus is on building structure • Offering elective courses in building technology
3	JORDAN UNIVERSITY OF SCIENCE & TECHNOLOGY (JORDAN)	BACHELOR OF SCIENCE OF ARCHITECTURAL ENGINEERING (BSAE)	Back ground studies in mathematics and physics in high school (prerequisite) + 4 years	• Math, Calculus, General Physics, Biology • Structural & technological courses e.g. construction and material, structural analysis, professional practice, engineering mechanics, mechanical systems
4	SHAHID BEHESHTI UNIVERSITY (IRAN)	BACHELOR OF SCIENCE IN ARCHITECTURE (BSA)	Back ground studies in mathematics and physics in high school (prerequisite) + 4 years	• Building material, building components • Site management • Mathematics for architecture • Statics & strength of material • Building services • Construction & regulations
5	UNIVERSITY OF CAMBRIDGE (UK)	BACHELOR OF ARCHITECTURE (BA)	4 → 1 year colleague → year 1 → year 2 → year 3 →	• Mathematics at A level (or equivalent) • Fundamental principles of construction • Fundamental principles of structural design • Principles of construction • Principles of structural design • Main emphasize is on integration of: 1- technical skills learnt in 1st year 2- studio output 3- ongoing lectures • Professional practice • Advanced studies in construction technology and structural analysis
6	TECHNICAL UNIVERSITY OF BERLIN (GERMANY)	MASTER OF SCIENCE IN ARCHITECTURE (MSA)	5 → 3 years in bachelor level → 2 years in master level →	• Design & construction • Structural theory • Building material & physics & equipment • Historical construction & material • Public construction law & project management • Structural design
7	EASTERN MEDITERRANEAN UNIVERSITY (NORTH CYPRUS)	BACHELOR OF ARCHITECTURE (BA)	4 → year 1 → year 2 → year 3 → year 4 →	• Math & Geometry for Designers • Tectonics of Structural Systems (I, II) • Construction & Material • Tectonics of Flextural Systems (I, II) • Tectonics of Form Resistant Structures • Construction & Material • Economic & Managerial Issues in Architecture • Professional Issues and Portfolio Preparation

2.4.5 Current Movements Toward Integration of Structural Concepts with Architectural Education

In addition to compilation of databases, some practical decisions have been taken to include more structural knowledge into architectural education as well; such as establishment of architectural engineering field in some universities. " Architectural engineering is the application of engineering principles and technology to building design and construction" (Architectural Engineering, 2009). Architectural engineers are able to deal with mechanical and electrical design of the buildings as well as structural and constructional.

2.5 Investigation of some Structural Design Related Softwares

There are some computer softwares which are designed specifically to design and analyze of building structures or to help students to have better structural knowledge. A couple of these kinds of softwares are chosen to be studied and investigated in this research; firstly, SAP 2000 and secondly, Dr Structure.

2.5.1 SAP 2000

"SAP2000 is a structural analysis program by Computers and Structures, Inc. Currently in its 14th edition, it is frequently used by civil engineers in the design and analysis of bridges, buildings, dams, etc. SAP stands for Structural Analysis Program." (SAP 2000, 2009)

"The Advanced Analytical Techniques (provided by SAP 2000) allow for Step-by-Step Large Deformation Analysis, Multiple P-Delta, Eigen and Ritz Analyses, Cable Analysis, Tension or Compression Only Analysis, Buckling Analysis, Blast Analysis, Fast Nonlinear Analysis for Dampers, Base Isolators and Support Plasticity, Energy Methods for Drift Control and Segmental Construction Analysis." (SAP 2000, 2009)

2.5.2 Dr Structure

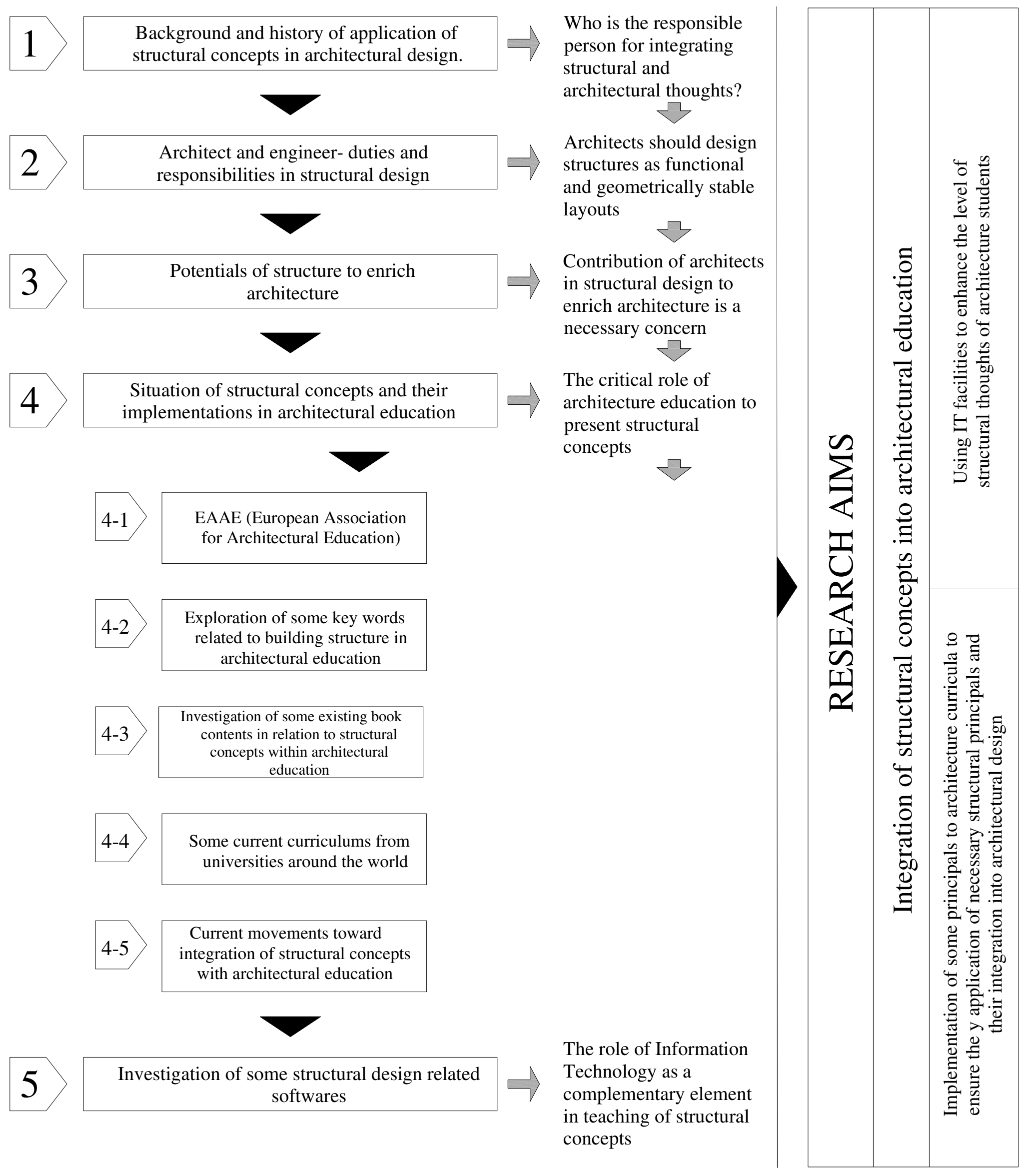
This software is an educational tool to assist structural engineering students to learn detailed steel structural design. It was used in 1999 for the first time in George Mason University in USA. Since structural engineering courses used to be disintegration into structural analysis courses (too abstract) and into the structural design courses (too pragmatic), this software was designed and used to eliminate the problems.

Dr Structure works as double purpose software; it acts as a design and learning tool, which explains structural concepts for students in a categorized way and on the other hand, assists students to accomplish the design process and perceive and control the whole design sequences and complexities. (Arciszewski & Lakmazaheri, 2001)

2.6 Schematic Structure of the Literature and Curriculum Survey

The diagram sketched below (Table 9) shows the summary of the results of studying existing curricula and literature, which has clarified the research objectives and the research gap that this thesis is aimed to fill in.

Table 9: Procedure of the literature and curriculum survey



As it is pointed in the table 9, study and investigation of the existing literature shows the fact that thought history architecture and structural principals have been always mentioned together and architects have been considered as persons responsible for design the structures as functional and geometrically stable layouts. In fact, **integrating of structural principals into architectural design** is a necessary concern for architects and neglecting of it will cause improper and unbalanced outcomes; unfortunately, this have become more probable in the contemporary age, because nowadays more specific professions and experts exist in the building industry and some of the duties of architects in relation to structural design might be left to structural engineers.

Architectural education systems play critical roles in training of architects who are able to consider structures as an integral element for design. Some principals considered by architecture education organizations, curricula from different universities, some books related to structural concepts in architecture and some current movements have been studied in this research. All of these studies reveal the **importance of architecture education role in structural knowledge of architecture students**.

Thus, it seems necessary to clarify the required principals for integration of structural concepts into architecture curricula to ensure their proper application into practice. The role and position of Information Technology and its new potentials for achieving this integration is highlighted and specifically attended in this research as well.

In order to achieve the mentioned clarification it seems useful to study one curriculum in terms of the efficiency in presentation of structural principals, in the next chapter curriculum of Eastern Mediterranean University (EMU) is considered as a case study. As it is understood from the studies of this chapter, architecture curriculum of EMU has similar amount of structural courses to other studied curricula, but as it will be discussed in detail (in chapter 3) integration of structural principals into design courses has some problems which have caused some low efficiencies within the curriculum.

Chapter 3

STRUCTURAL AND TECHNOLOGICAL PRINCIPLES WITHIN ARCHITECTURE CURRICULA

Every school of architecture has some objectives, which are considered for the benefit of students and enrich their knowledge and skills. The attitude of a faculty to the considered aims and the process to reach to the objectives are reflected to the curriculum of that faculty. Presentation and arrangement of the courses through different semesters, contents of the courses, number of credits given to each course and relationship between the presented courses are some factors that influence the overall efficiency of the curricula.

There are some standards and necessities which should be included in every faculty of architecture. These standards and requirements are defined by different organizations. However, it is not possible to consider the same requirements and courses for all faculties of different countries or even one country. This is due to the fact that each architecture faculty requires its own specifications in respect to the cultural, economical and regional specifications (Neuckermans, 2009).

Structural and technological principals within architecture curricula are one of the necessary disciplines in every architecture curriculum. As it is mentioned before the same structural concepts and technological issues cannot exist in all architecture curricula, but referring to students needs and demands, using the experience of architecture instructors and also studying the necessary structural principals for architecture curricula defined by authentic organizations can give a definition of minimum requirements that should be applied in the curricula. In order to get more information about practical implementation of these requirements and not just study the theoretical bases, it seems helpful and effective to consider one curriculum as a case study and evaluate its current situation and compare it with other existing solutions. This approach will help to the better application of structural principals within architecture education.

In this research curriculum of faculty of architecture in Eastern Mediterranean University (EMU) is considered as a case study. According to personal observations of the author and comments from some students and instructors of EMU, a basic hypothesis was generated about EMU architecture curriculum. The hypothesis demonstrated some missing abilities related to technological and practical aspects of architectural design in students. Hence, this selection has been subjected to this research.

Analysis and evaluation of EMU architecture curriculum as case study is aimed to reveal the positive and negative aspects of structural principles within the curriculum. The consequent result of these analysis and findings are some proposed principles to increase the quality of teaching structural concepts within the curriculum and achieve a sufficient teaching program with high efficiency and a logical balance between all aspects of architecture pedagogy. These proposal are some general comments applicable for every curricula since they do not refer to specific situations of EMU and just focus on general and basic structural requirements of each architecture curriculum.

There are three main references which are used to accomplish the process; firstly comments and ideas of EMU architecture students on the architecture curriculum of EMU, secondly results of interviews with instructors of EMU faculty of architecture and thirdly comparison of EMU architecture curriculum with architecture curriculum of some other universities around the world and existing information within the available literature.

3.1 Structural Principals within Architecture Curricula from the Point of View of Students (Architecture Students of EMU)

To explore and realize the expectations, needs and ideas of EMU architecture students in relation to structural and technological concepts covered within the curriculum a questionnaire[3] is prepared. Quantitative and statistical information which are taken from these questionnaires are guidelines to fill in the gaps and compensate the missing points of the curriculum. Since the respondents are supposed to have the experience of dealing with the majority of topics covered in the curriculum, they are chosen from the 7th semester (arch 491), 8th semester (arch 492), master and PHD students who are graduated from EMU. Total number of respondents of the questionnaire is 110 persons.

There is a list of questions mentioned in the questionnaire, answers given by the respondents and interpretation and comments of the researcher presented here as following:

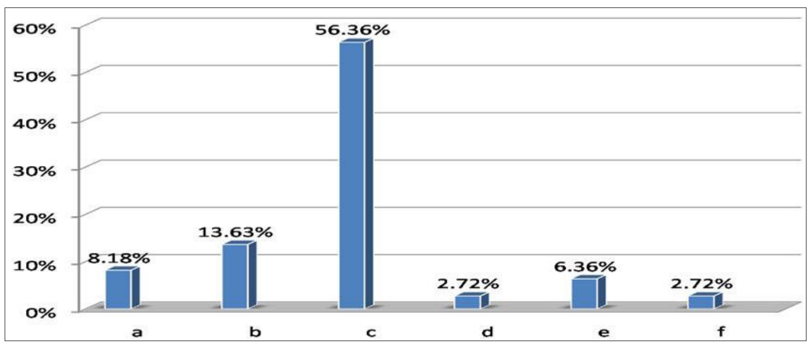
[3] The questionnaire is presented in "Appendix 1".

Comments on form, function and structure

1- Preference of students on the sketched proposal diagrams for architectural design process;

Table 10: Function -Form -Structure

a	b	c	d	e	f
STEP 1 FORM STEP 2 FUNCTION STEP 3 STRUCTURE	STEP 1 FUNCTION STEP 2 FORM STEP 3 STRUCTURE	FUNCTION FORM STRUCTURE	STEP 1 STRUCTURE FORM STEP 2 FUNCTION	It depends on the situation	None of them
8.18%	13.63%	56.36%	2.72%	6.36%	2.72%



<u>Interpretations and comments:</u>

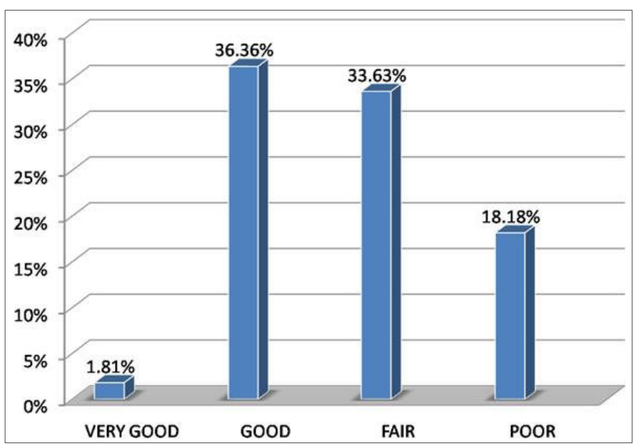
- Option (a) and (d) are mainly used for creation of landmark and symbolic structures.
- Option (b) is generally used in design of buildings with technical requirements such as hospitals and factories.
- Option (c) indicates a simultaneous consideration of form, function and structure in a design process.
- Option (e) and (f) mention the possibility of considering other options according to special conditions and situations.

According to the presented diagram majority of students (56.36%) believe in parallel attention to form, function and structure in a design process (option c). Since architectural projects which are given to students in different semesters are not always focused on one aspect of architecture like symbolic principles (option a and d) or technical requirements (option b), it is expected to consider the diagram of option (c) for the general approach of an architecture curriculum. Hence, the expected results coincide with the majority of answers from the respondents.

The next three questions of the questionnaire examine the satisfaction of students from the three major components of the design process.

2- Student's votes on quality of teaching of concepts related to **<u>function</u>** in EMU faculty of architecture;

Table 11: Students' votes- Function



Very good	Good	Fair	Poor
1.81%	36.36%	33.63%	18.18%

<u>Interpretations and comments:</u>

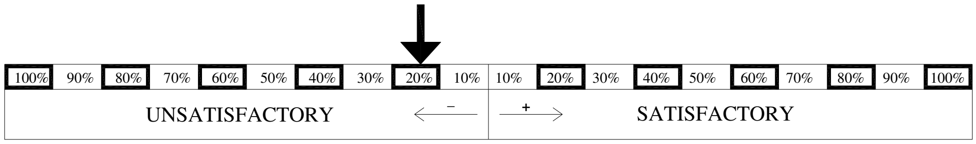
- The highest comment = GOOD

Level of Satisfaction[4]:

[4] In order to have a visual, numerical, clear and tangible presentation of the results, "**Level of Satisfaction**" is introduced here as:

- Satisfaction over 50% ($S_{>50\%}$): (VERY GOOD + GOOD) = 38.17%
- Satisfaction bellow 50% ($S_{<50\%}$): (FAIR + POOR) = 51.81%
- Level of Satisfaction (L_S) = ($S_{>50\%}$) - ($S_{<50\%}$)= -13.64%

Diagrammatic presentation of Level of Satisfaction:



3- Student's votes on quality of teaching of concepts related to **form** in EMU faculty of architecture;

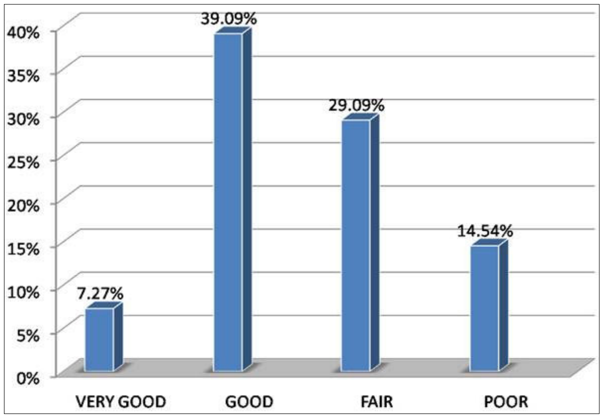
Satisfaction over 50% ($S_{>50\%}$) = VERY GOOD + GOOD
Satisfaction bellow 50% ($S_{<50\%}$) = FAIR + POOR

Level of Satisfaction (L_S) = (Satisfaction over 50%) – (Satisfaction bellow 50%)

POOR	FAIR	GOOD	VERY GOOD
0% - 25%	25% - 50%	50% - 75%	75% - 100%

satisfaction bellow 50%   satisfaction over 50%

Table 12: Students' votes- Form

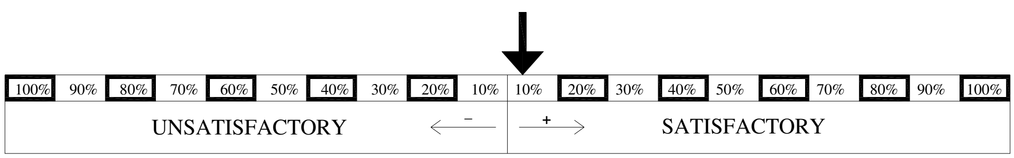


Very good	Good	Fair	Poor
7.27 %	39.09%	29.09 %	14.54 %

Interpretations and comments:

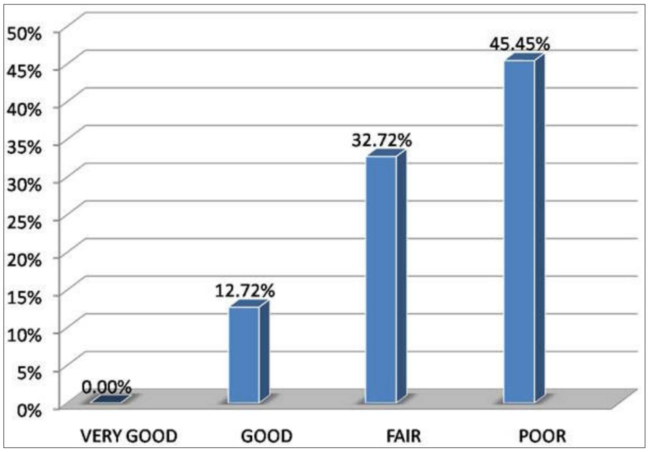
- The highest comment = GOOD
- Satisfaction over 50% ($S_{>50\%}$): (VERY GOOD + GOOD) = 46.36%
- Satisfaction bellow 50% ($S_{<50\%}$): (FAIR + POOR) = 43.63%
- Level of Satisfaction (L_S) = ($S_{>50\%}$) - ($S_{<50\%}$)= +2.73%

Diagrammatic presentation of Level of Satisfaction:



4- Student's votes on quality of teaching of concepts related to **structure** in EMU faculty of architecture;

Table 13: Students' votes- structure

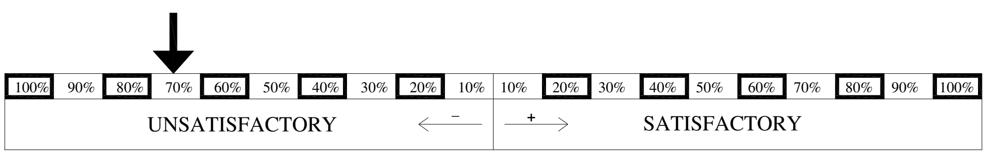


Very good	Good	Fair	Poor
0.00 %	12.72%	32.72%	45.45 %

<u>Interpretations and comments:</u>

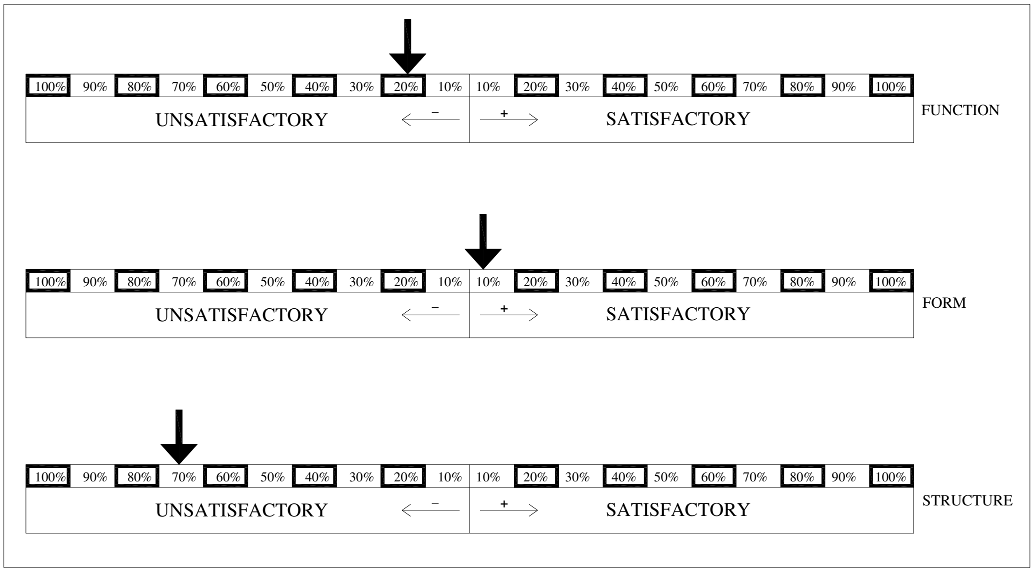
- The highest comment = POOR
- Satisfaction over 50% ($S_{>50\%}$): (VERY GOOD + GOOD) = 12.72%
- Satisfaction bellow 50% ($S_{<50\%}$): (FAIR + POOR) = 78.17%
- Level of Satisfaction (L_S) = ($S_{>50\%}$) - ($S_{<50\%}$)= -65.45%

Diagrammatic presentation of Level of Satisfaction:



Ranking of the level of students satisfaction from thought concepts related to **<u>function</u>**, **<u>form</u>** and **<u>structure</u>** in EMU faculty of architecture:

STRUCTURE << FUNCTION < FORM

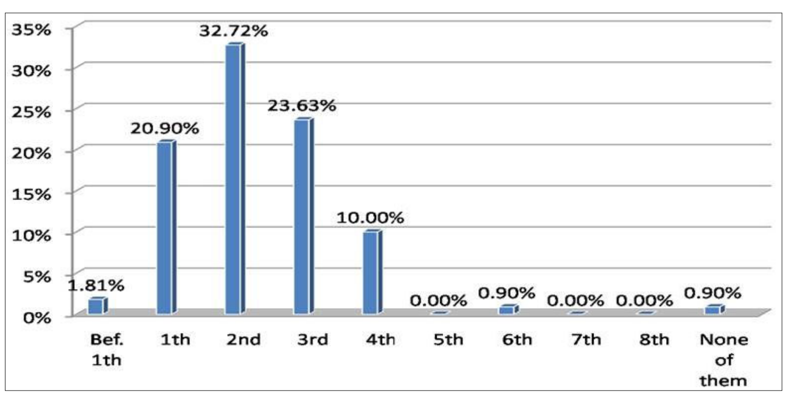


Curriculum (teaching program) of architecture

5- The best starting semester for teaching of structural concepts to undergraduate architecture students from the point of view of EMU students;

Table 14: The best semester to start structural concepts

Before first semester (e.g. Colleague period)	1th	2nd	3rd	4th	5th	6th	7th	8th	None of them
1.81%	20.90%	32.72%	23.63%	10.00%	00.00%	0.90%	00.00%	00.00%	0.90%



Interpretations and comments:

- The highest comment = 2nd
- The first three highest comments: 1th < 3rd < 2nd
- Total number of respondents on 1st, 2nd and 3th semester: Total= 77.25%

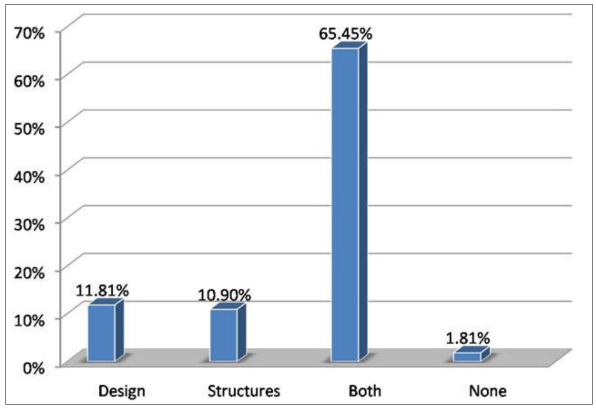
According to the majority of students' comments (77.25%), the first three semesters are the preferred time to start teaching of structural concepts to undergraduate architectural students. On the other hand study and analysis of architecture curricula from other universities (2.4.3) which are explained in detailed in chapter 2 indicate that in most of the universities teaching of structural concepts to undergraduate students specifically starts from 2nd semester. Thus second semester is a proper time to start structural concepts in the curriculum.

Although, teaching of structural concepts should start specifically from 2nd semester, there are some information and thoughts which are prerequisites of those concepts and students are supposed to be familiar with them from college period or their previous backgrounds; basic mathematical and physical rules and calculations are the fundaments of structure specific courses. These kinds of knowledge are indirectly useful for design and other courses as well as structural courses, because they give the students the ability of investigation, comprehension and analysis of problems which lead them to better solutions and results. Considering qualification exams for entering to architecture or a minimum required grade for college courses which are prerequisites of structural courses, can be a sufficient solution to achieve this goal.

6- Architectural students should learn their structural thought …………..

Table 15: Learning of structures thought

From design courses	From structure specific courses	Both previous options	None of them
11.81%	10.90%	65.45%	1.81%



<u>Interpretations and comments:</u>

Majority of the students (65.45%) prefer to learn the structural thoughts from both structural courses and design courses, which means integration of design studios with other courses. Through the existing literature this integration is highly recommended for the arrangement of architectural teaching systems; relative detailed information is discussed in (2.4). Hence, according to students' comments and review of existing literature integration of structural principles of technical courses with design studios is an inevitable fact. Therefore, the following questions are designed to discover the level of application of this principle into architecture curriculum of EMU.

7-Evaluation of the teaching quality of:

Mathematics

Physics

Structural courses

Construction courses

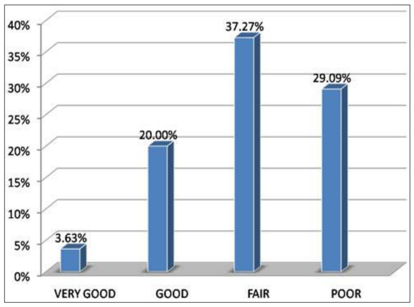
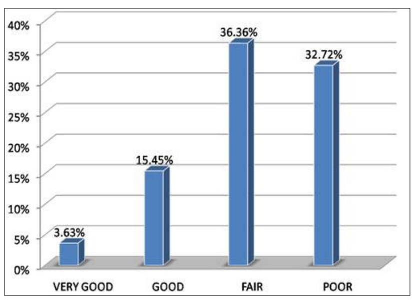
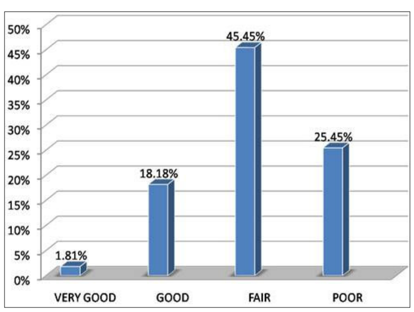
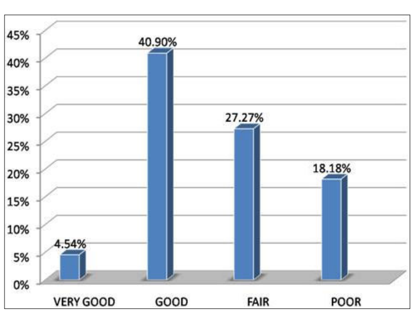
in EMU faculty of architecture from the point of view of students;

	Very good	Good	Fair	Poor
Mathematics	3.63%	20.00%	37.27%	29.09%
Physics	3.63%	15.45%	36.36%	32.72%
Structural courses	1.81%	18.18%	45.45%	25.45%
Construction courses	4.54%	40.90%	27.27%	18.18%

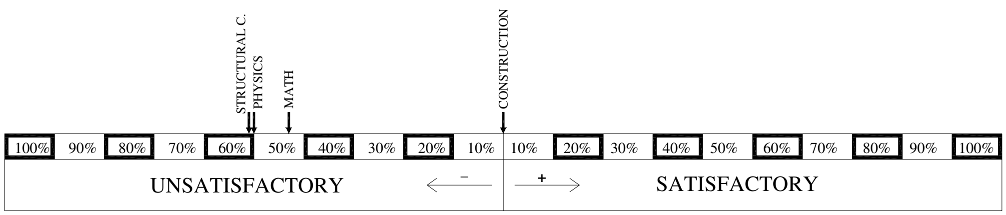
Note: In order to analyze the results, "Level of Satisfaction[5]" is introduced and used here.

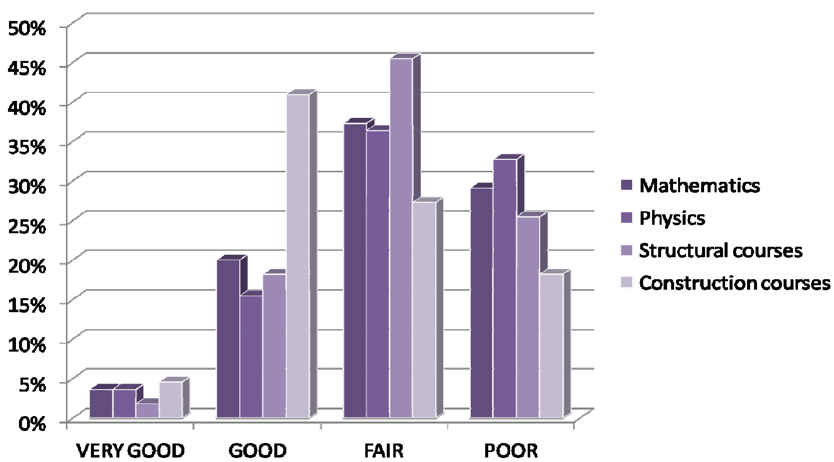
[5] Satisfaction over 50% ($S_{>50\%}$) = Very good + Good
Satisfaction bellow 50% ($S_{<50\%}$) = Fair + Poor
Level of Satisfaction (L_S) = ($S_{>50\%}$) - ($S_{<50\%}$)

Table 16: Evaluation of students from teaching quality of some courses

Mathematics 	• The highest comment = FAIR • (S>50%) = 23.63% • (S<50%) = 66.36% • Level of Satisfaction (LS) = -42.73%
Physics 	• The highest comment = FAIR • (S>50%) = 19.08% • (S<50%) = 69.08% • Level of Satisfaction (LS) = -50.00 %
Structural courses 	• The highest comment = FAIR • (S>50%) = 19.99% • (S<50%) = 70.90% • Level of Satisfaction (LS) = -50.91%
Construction courses 	• The highest comment = GOOD • (S>50%) = 45.44% • (S<50%) = 45.45% • Level of Satisfaction (LS) = -0.01%

STRUCTURAL C. < PHYSICS<MATHEMATICS<CONSTRUCTION





According to the diagrams and statistics level of satisfaction of students from quality of teaching of Mathematics, Physics and structural courses are low. Since math and physics can indirectly influence the students' thoughts about structural concepts and structural courses are directly related to structure, low quality of teaching in these two types of courses will have negative results on structural aspects of design projects of students.

Construction courses from the point of view of students have better level of teaching (the highest comment is good, and the Level of Satisfaction is higher than the three other courses), but still there is need for improving and increasing the quality of construction courses because they are very effective for the students' design projects and also professional life of students in the future.

8- Level of Effectiveness of:

- Mathematics
- Physics
- Structural courses
- Construction courses

into design studio taught, from the point of view of EMU students;

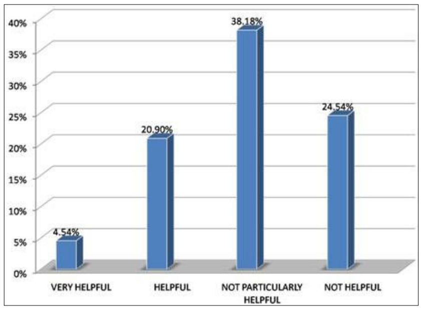
	Very helpful for design studios	**Helpful** for design studios	**Not particularly helpful** for design studios	**Not helpful** for design studios
Mathematics	0.00%	17.39%	39.13%	34.78%
Physics	0.00%	13.04%	30.43%	43.47%
Structural courses	26.08%	30.43%	26.08%	4.34%
Construction courses	30.43%	21.73%	30.43%	8.69%

Note: In order to analyze the results, "Level of Effectiveness[6]" is introduced and used here.

[6] Effectiveness over 50% ($E_{>50\%}$) = Very helpful + Helpful
Effectiveness bellow 50% ($E_{<50\%}$) = Not particularly helpful + Helpful
Level of Effectiveness (L_E) = ($E_{>50\%}$) - ($E_{<50\%}$)

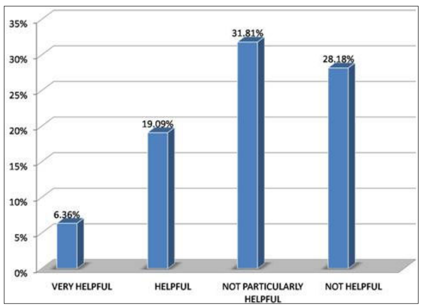
Table 17: Level of effectiveness of Math, Physics, Structural courses and Construction courses for design studios from the point of view of students

Mathematics



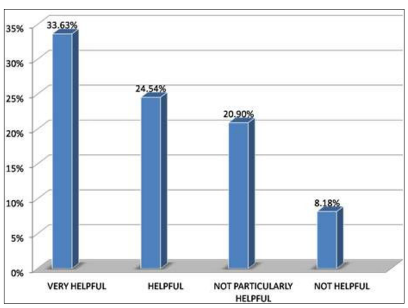
- The highest comment = NOT PARTICULARLY HELPFUL
- (E>50%) = 25.44%
- (E<50%) = 62.72%
- Level of Effectiveness (LE) = -38.28%

Physics



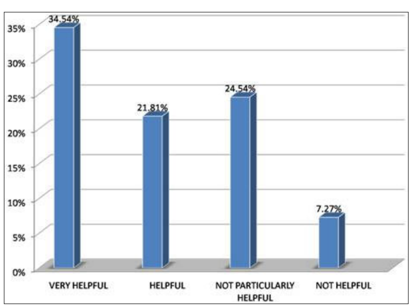
- The highest comment = NOT PARTICULARLY HELPFUL
- (E>50%) = 25.45%
- (E<50%) = 59.99%
- Level of Effectiveness (LE) = -34.54%

Structural courses



- The highest comment = VERY HELPFUL
- (E>50%) = 58.17%
- (E<50%) = 29.08%
- Level of Effectiveness (LE) = % +29.09

Construction courses



- The highest comment = VERY HELPFUL
- (E>50%) = 56.35%
- (E<50%) = 31.81%
- Level of Effectiveness (LE) = % +24.54

Level of effectiveness of the courses for the design studios:

MATHEMATICS < PHYSICS < CONSTRUCTION < STRUCTURAL C.

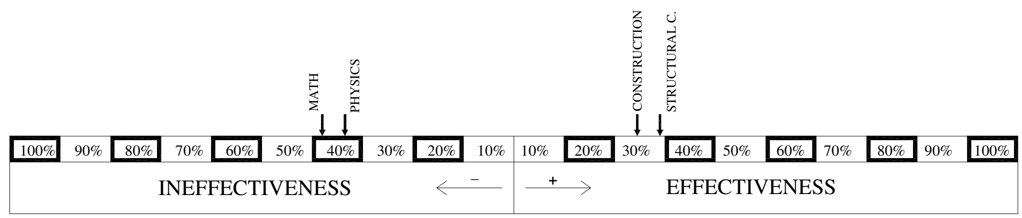
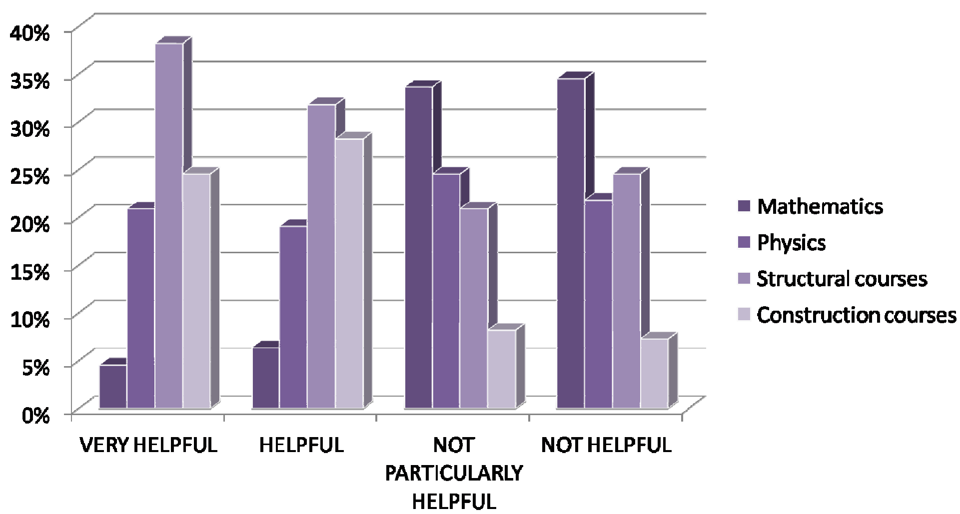


Table 18: Level of effectiveness from the point of view of students



The diagrams are showing the fact that students of architecture in EMU do not believe in mathematics and physics as effective courses for design studios, but they believe that structural and construction courses have effective roles in design projects. Although math and physics are prerequisites to understand the structural and construction courses and are consequently effective for design courses, students are not aware of this fact and do not pay enough attention to it. On the other hand, every course or topic which is presented to architecture students by the faculty is supposed to improve the quality of the design projects, while the current teaching methods of math and physics do not correspond to this principle.

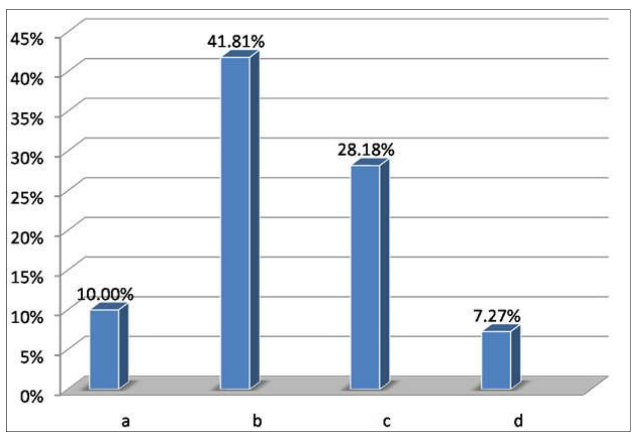
All of these problems have probably risen from the presentation of structural courses, structure prerequisite courses (math and physics) and also application of these two types of courses into design studios.

Ability of students to solve structural problems of their design projects

9- Evaluation of the respondents on existence of structural resource books for architects and architectural students to get enough knowledge of structural design which can help them in design projects;

Table 19: Existence of structural resource books

a	There are enough resource books from this type.	10.00 %
b	There are some books from this type, but they are not respondent the whole questions of architects.	41.81 %
c	There are some structural resource books, but they are mainly useable for structural engineers and not architects.	28.18 %
d	There is not any book from this kind.	7.27 %



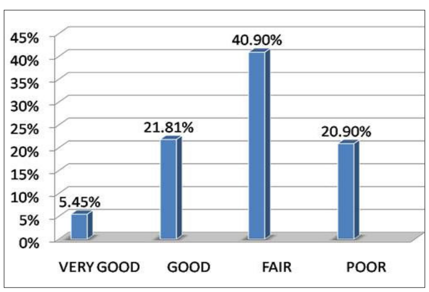
In this question the option (a), (b) and (c) are indicating that students of architecture have difficulty in access to structure reference information, and the option (a) mentions that there is no problem to attain structural information from the resource books.

Since only 10% of the students have chosen option (a) and the rest have chosen the other options, it can be thought that architecture students have difficulty and trouble in finding enough structural resource information.

10- Evaluation of the respondents on ability of EMU architecture students to define the following items in design studios;

		Very good	Good	Fair	Poor
a	Selection of suitable structural system for the selected forms	5.45%	21.81%	40.90%	20.90%
b	Selection of suitable materials (e.g. steel, concrete, wood, composite material) for the selected forms	1.81%	22.72%	36.36%	33.63%
c	Defining the approximate size of structural members (e.g. size of beam, column, slab thickness, space frame depth and cantilever length)	4.54%	23.63%	25.45%	35.45%

Table 20: Selection of suitable structural system for the selected forms (a)



- The highest comment = FAIR
- (S>50%) = 27.26%
- (S<50%) = 62.80%
- Level of Satisfaction (LS) = -34.54%

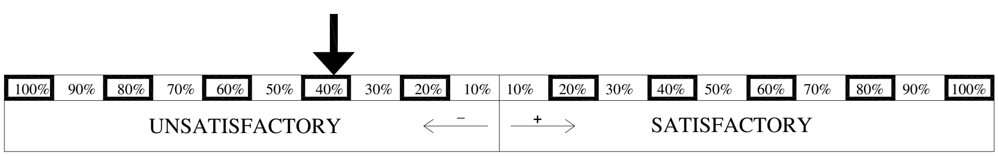
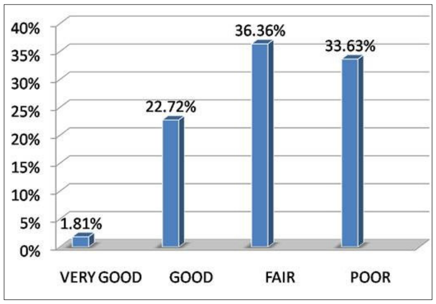


Table 21: Selection of suitable material (e.g. steel, concrete, wood, composite material) for the selected forms (b)



- The highest comment = FAIR
- (S>50%) = 24.53%
- (S<50%) = 69.99%
- Level of Satisfaction (LS) = -45.46%

Level of satisfaction:

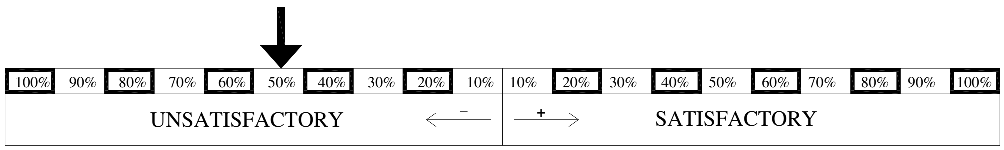
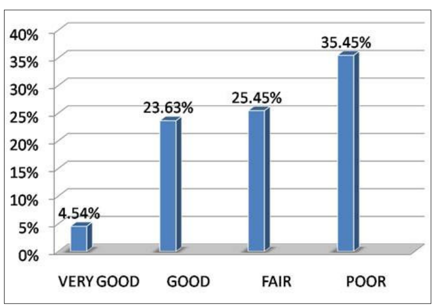
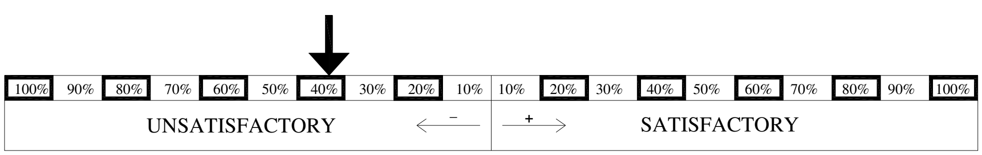


Table 22: Defining the approximate size of structural members (e.g. size of beam, column, slab thickness, space frame depth and cantilever depth), (c)



- The highest comment = FAIR
- (S>50%) = 28.17%
- (S<50%) = 60.90%
- Level of Satisfaction (LS) = -32.73%

Level of satisfaction:



As it is understood from the charts and diagrams level of satisfaction of respondents from ability of students in selection of structural systems, selection of structural material and approximation of structural members' size is not in a satisfactory level. All of these three factors are below the level of satisfaction. Hence, some revisions in the curriculum to improve the ability of students in these areas are needed.

3.2 Comments of EMU Architecture Instructors on Structural Principals within Architecture Curricula (Interview Results with some Instructors of EMU Architecture Department)

In order to understand the necessary level of attention to structural principals within architecture curricula, some interviews have been done with EMU architecture instructors. Some questions are specifically asked about level of attention of structural concepts in EMU architecture curriculum. Their view points, expectations and suggestions are mentioned here. The interviewed instructors are chosen from persons who have experience in various branches of architecture; such as structure, construction, urban design, landscape design, environmental control and architecture history .Thus, the interview results come from persons with various opinions.

Prof. Dr. Ibrahim Numan (Dean of faculty of architecture- EMU) - (Numan, 2009)

- How do you evaluate the quality of teaching concepts related to **form**, **function** and **structure** in design studios in faculty of architecture? Is there a sufficient balance or one or two of them are more attended?

It depends on the title of the projects and teaching method of every instructor. There is not a single specific answer to this question.

- Teaching of structural concepts to undergraduate architectural students should start from which semester?

2nd semester

- How do you evaluate the teaching quality of Mathematics, Physics, structural courses and construction courses? & how do you evaluate the integration of these courses with design studios?

They are generally not in a satisfactory level; they can be mentioned as poor or fair. / They are not well integrated.

- How do you evaluate the ability of EMU architecture students to define the necessary structural systems, material selection and estimation of structural members' size in design studios?

Fair- Not sufficient.

- How do you evaluate the existence of structural resource books for architects and architectural students to get enough knowledge of structural design which can help them in design projects?

There are very useful and well compiled books from this kind, architecture students can refer to those and benefit from them.

- Did you pass mathematical, physical, structural, constructional courses in your student life? / If yes, how they were integrated with design studios?

Yes we had courses from these types like calculus, physics, statics, strength of material, reinforced concrete, construction methods and materials. / We were asked to apply the thought topics from these courses into our design projects. For example we were asked to do some structural calculations and estimation of structural members' size in our design projects.

Assoc. Prof. Dr. Yonca Hürol- (Hürol, 2009)

- How do you evaluate the quality of teaching concepts related to **form**, **function** and **structure** in design studios in faculty of architecture? Is there a sufficient balance or one or two of them are more attended?

I am more involved with structural courses and concepts; structural knowledge of students in many cases are not enough and adequate for solving the problems of design projects.

- Teaching of structural concepts to undergraduate architectural students should start from which semester?

It is better to start from the beginning semesters.

- How do you evaluate the teaching quality of technical and technological courses (e.g. Mathematics, Physics, structural courses and construction courses)? & how do you evaluate the integration of these courses with design studios?
- How do you evaluate the ability of EMU architecture students to define the necessary structural systems, material selection and estimation of structural members' size in design studios?

The answer can be discussed in the new and the old curriculum of EMU. Sine in the old curriculum there were some complains and criticisms about some mathematical and structural courses, the new curriculum were suggested to eliminate the problems. The criticizers believed that these courses are unnecessary and over focused on mathematical calculations. Hence, in the new curriculum the amount of these courses are reduced and instead some courses related to architectonics and intuitive structural concepts are added. These new courses are aimed to provide the ability of solving structural problems in design projects for architecture students, but still there are some problems remained unsolved. It is not easy to compare the two curricula and comment on the efficiency of the old and the new curriculum in EMU, but the obvious fact is that students are still unable to solve many structural problems. They have **dimension problems** and lack of knowledge of **estimation of structural members' size**.

Collaboration between faculty of architecture and department of civil engineering can be a very helpful attitude to give the knowledge of structure and reality of the projects to architecture students. Providing some group works for architecture and civil engineering students is also a good idea. Some special softwares can also be used for architecture students in this regard such as, SAP 2000.

- In general how do you evaluate the structural knowledge of EMU students?

  Week

- How do you evaluate the existence of structural resource books for architects and architectural students to get enough knowledge of structural design which can help them in design projects?

There are very good books from this type. Some of them explain the approximate methods for estimation of the size of structural members. They can be very helpful for students.

- Did you pass mathematical, physical, structural, constructional courses in your student life? / If yes, how they were integrated with design studios?

In the Middle East technical university we had courses related to math and physics. We also has statics, strength of material, structural analysis course, reinforced concrete, design of form resistant structures and some elective structural course.

Some topics related to earthquake resistance in buildings were covered in these courses. During the undergraduate studies we used to work with computer softwares related to structural design as well as passing theoretical courses, which were very useful. / We were not officially asked to apply the topics of these courses into the design projects, but I used to do this practice personally.

Assist. Prof. Dr. Halil Zafar Alibaba- (Alibaba, 2009)

- How do you evaluate the quality of teaching concepts related to **form**, **function** and **structure** in design studios in faculty of architecture? Is there a sufficient balance or one or two of them are more attended?

Structure is not attended enough, just after midterm juries students start to work on structural aspects. Timing arrangement of the design classes has some problems; therefore, there is not a suitable balance in teaching of form, function and structure; form is the most attended issue, function is in the second level of attention and structure is the least attended one. The students do not prepare phase 2 drawings.

- How do you evaluate the teaching quality of mathematical, physical, structural and construction courses and their integration with design studios?

Math and physics are taught in a beginner level and it is enough for architecture students. Teaching of structural courses needs some revisions and rearrangements. Construction courses are taught in a medium level. Since structural and construction courses are not well integrated with design studios the efficiency of design studios is low in terms of construction and structure outcomes.

- Did you pass mathematical, physical, structural, constructional courses in your student life? / If yes, how they were integrated with design studios?

Yes, construction and structure courses were integrated and parallel with design courses.

- How do you evaluate the existence of structural resource books for architects and architectural students to get enough knowledge of structural design which can help them in design projects?

There are useful books from this kind.

Prof. Dr. Mesut Ozdeniz- (Ozdeniz, 2009)

- How do you evaluate the quality of teaching concepts related to **<u>form</u>**, **<u>function</u>** and **<u>structure</u>** in design studios in faculty of architecture? Is there a sufficient balance or one or two of them are more attended?

  In the 7th semester design studio (arch 491) which I am involved, students are asked to think about form, function and structure simultaneously and from the first week of the design studio.

- Teaching of structural concepts to undergraduate architectural students should start from which semester?

First semester

- How do you evaluate the teaching quality of technical and technological courses in EMU (e.g. Mathematics, Physics, structural courses and construction courses)? & how do you evaluate the integration of these courses with design studios?

The quality of teaching these courses are in a satisfactory level but still there are many problems in design projects of students, which are related to lack of attention from students. There are students with very good level of structural knowledge and also there students with very poor level of knowledge. The structural and construction courses are integrated with design courses because the same teachers from the same faculty (architecture) are teaching these courses, but the problems are low attempt from students.

- Do you believe that some prerequisite courses or abilities are necessary to enter the faculty of architecture? (e.g. Mathematics, physics, …)

It is important to consider some prerequisites for entering to faculty of architecture, but not necessarily math and physics; general knowledge of students should be tested and examined before entering to architecture field. All of the other necessary knowledge can be given to students within the curriculum, so curriculum can be extended to 5 years instead of 4 years.

- How do you evaluate the existence of structural resource books for architects and architectural students to get enough knowledge of structural design which can help them in design projects?

There are very good and useful books from this type.

- Did you pass mathematical, physical, structural, constructional courses in your student life? / If yes, how they were integrated with design studios?

Yes we had all of these course as well as descriptive geometry which were very useful. / Since the teachers of these courses were architects (not engineers) and were instructors of design studios as well, there were integration between the mentioned courses and design.

- In general how do you evaluate the current structural knowledge of EMU students?

Poor

Assoc. Prof. Dr. Nacie Doratli- Urban Planner- (Doratli, 2009)

- How do you evaluate the quality of teaching concepts related to **form**, **function** and **structure** in design studios in faculty of architecture? Is there a sufficient balance or one or two of them are more attended?

There is not a balance between these three items. The less attended one is the structure.

- Teaching of structural concepts to undergraduate architectural students should start from which semester?

2^{nd} semester

- Did you pass mathematical, physical, structural, constructional courses in your student life? / If yes, how they were integrated with design studios?

No. Since from the first year I started to study in the department of urban planning, I did not pass any of these courses.

- How do you evaluate the ability of EMU architecture students to define the necessary structural systems, material selection and estimation of structural members' size in design studios?

The ability of students in these topics is low and not sufficient. This is thought from other instructors' comments during the juries and also there are some obvious problems distinguishable with every teacher and not just the structure expert ones.

- How do you evaluate the existence of structural resource books for architects and architectural students to get enough knowledge of structural design which can help them in design projects?

I have no idea.

- In general how do you evaluate the current structural knowledge of EMU students?

Poor

Assist. Prof. Nicholas Wilkinson- (Wilkinson, 2009)

- How do you evaluate the quality of teaching concepts related to **form**, **function** and **structure** in design studios in faculty of architecture? Is there a sufficient balance or one or two of them are more attended?

Form and function are more attended, structure is left behind and not enough attended.

- Teaching of structural concepts to undergraduate architectural students should start from which semester?

3th semester (arch 291)

- How do you evaluate the teaching quality of technical and technological courses in EMU (e.g. Mathematics, Physics, structural courses and construction courses)? & how do you evaluate the integration of these courses with design studios?

I have no idea about mathematical courses. About structure and construction although there are some missing points, there are courses with high quality and sufficient efficiency. The main problem of structure and construction courses is that they are not well integrated with design and they are not well applied into design studios.

- How do you evaluate the existence of structural resource books for architects and architectural students to get enough knowledge of structural design which can help them in design projects?

I do not think that there are enough books from this type.

- Did you pass mathematical, physical, structural, constructional courses in your student life? What were the prerequisites of entering to architecture in your school?

Yes we had these kinds of courses; but they did not include detailed and complicated mathematical topics. / The prerequisites to enter to architecture were an interview, sketch exam, portfolio submission and …. The main focus and consideration of the faculty was ability of students in sketching. During the whole architecture studies **sketch abilities** were highly attended.

- How do you evaluate the ability of EMU architecture students to define the necessary structural systems, material selection and estimation of structural members' size in design studios?

Their knowledge in this case is not enough and satisfactory.

Assist. Prof. Dr. Munther Moh'd- (Moh'd, 2009)

- How do you evaluate the quality of teaching concepts related to **form**, **function** and **structure** in design studios in faculty of architecture? Is there a sufficient balance or one or two of them are more attended?

There is not a balance. Form is the most attended one, the second level of attention goes for function and structure is the least attended one.

- Teaching of structural concepts to undergraduate architectural students should start from which semester?

2^{nd} semester

- How do you evaluate the teaching quality of technical and technological courses in EMU (e.g. Mathematics, Physics, structural courses and construction courses)? & how do you evaluate the integration of these courses with design studios?

Teaching level of these courses in EMU faculty of architecture is low, especially level of structural courses which are very poor./ and there is not adequate integration with design courses.

- How do you evaluate the existence of structural resource books for architects and architectural students to get enough knowledge of structural design which can help them in design projects?

There are some books which explain structural concepts and act as structural hand books for architects; but they include either mathematics and calculations or mathematical and geometrical concepts and ideas. Hence, students are not able to have efficient use of those books themselves and they need explanations and introductions from the teachers to achieve deep understandings about structural thoughts. Students should first start designing and face with the problems and then deal with structural concepts by using the hand books and consulting with the teachers.

- Do you believe that some prerequisite courses or abilities are necessary to enter the faculty of architecture? (e.g. Mathematics, physics, …)

Yes, students need to have the background of some scientific subjects in mathematics (e.g. calculus), physics and chemistry; otherwise, they will have difficulty in learning some architectural issues. For example to understand acoustics and lighting from environmental courses knowledge of physics is necessary. To distinguish building material properties chemistry is needed. Math and geometry are also prerequisites to understand structural concepts.

- Do you believe in effectiveness of collaboration between faculty of architecture and other faculties like civil engineering?

Yes, collaboration between faculty of architecture and civil engineering will be helpful for students of both faculties. Architecture students will be familiar with reality of construction and also duties of civil engineers and can design buildings which are feasible for constructions; on the other hand, civil engineering students can have more knowledge about building forms. Currently students in the EMU civil engineering department are just able to do structural analysis and have no contribution in defining the buildings' form, this level of knowledge is not enough and respondent to the whole needs of structural engineering students, sometimes they are not even able to deal with design projects of architecture faculty in arch 291.

- In general how do you evaluate the current structural knowledge of EMU students?

Very poor

3.3 Debates on Structural Principles within Architecture Curricula

Structural and technological principles in architecture curricula are the key principles of training architects with practical skills. In order to achieve successful architecture curricula, it is important to attend and supervise the proper application of these principles into practice. Thus, clarification and elucidation of some key principles, which can assure this important issue seems necessary.

This research is supposed to find and explain the mentioned key principles. The approach to this aim is to explore and excavate the following three items and to consider and evaluate their results simultaneously;

- Some existing curricula from universities around the world
- Referring to some existing literatures related to the topic
- Studying EMU curriculum as a case study

Extensive variety of principles and disciplines which are necessary to be applied in architecture curricula, may cause inadequate attention to the structural principles, and this is probable for every university. Selection of one curriculum and study its situation in terms of application of structural principles can reveal the reasons and causes of these kinds of problems. In fact this selection can introduce a frame work to discover the causes of the problems.

As it is mentioned at the beginning of this chapter, EMU is considered as a case study according to personal observations of the author and comments from some students and instructors of EMU demonstrating the fact that structural principles are not well achieved in EMU.

A couple of tables are illustrated here (24 & 25) to show the main highlights and key points taken from EMU members (students and staffs).

Table 23: Summery of structural principles within architecture curricula from the point of view of students (architecture students of EMU)

#	QUESTIONS	PREFERRED OPTIONS BY THE RESPONDENTS	KEY RESULTS
1	Process of design	FUNCTION – FORM – STRUCTURE 56.36%	Integration of function, form and structure in a design process
2, 3, 4	Quality of teaching ...	Structure < Function < Form Level of Satisfaction (Ls)* : -65.45% < -13.64% < -2.73%	Necessity of revision of structural concepts within the curriculum of EMU
5	Starting semester for structural concepts should be...	1th < 3rd < 2nd 20.90% < 23.63% < 32.72%	2nd semester
6	Learning of structural concepts should be from ...	Both design courses & structure specific courses 65.45 %	Necessity of integration of design and structural courses
7	Quality of teaching ...	Structural courses< Physics< Mathematics< Construction (Ls): -50.91% < - 50.00% < - 42.73% < -0.01%	Necessity of revision of structural & construction courses and their prerequisites
8	Effectiveness of courses in design studios	Mathematics <Physics <Construction <Structural c. (L_E)** : -38.28% < -34.54% < +29.09% < +24.54% A contradiction is seen here in students comments; they believe in effectiveness of structural and construction courses for design, but they do not believe in effectiveness of prerequisites of these courses in design studios.	
9	Existence of structural source books	• 10% of the respondents have no problem in this regard • 90% of the respondents have some problems in this regard	Providing an electronic resource book to assist students in solving the structural problems
10	Ability of EMU students to define the following items	• Selection of suitable structural systems for selected forms (Ls) = -35.54 • Selection of suitable material for selected forms (e.g. steel, concrete, wood, composite material (Ls) = -45.46 • Defining the approximate size of structural members (e.g. size of beam, column, slab thickness, cantilever length) (Ls) = -32.73	Provision of structural & technical skills in students (Enabling students to deal with real projects)

*POINT:

- Satisfaction over 50% (S>50%) = Very good + Good
- Satisfaction bellow 50% (S<50%) = Fair + Poor
- Level of Satisfaction (L_S) = (S>50%) - (S<50%)

**POINT:

- Effectiveness over 50% ($E_{>50\%}$) = Very helpful + Helpful
- Effectiveness bellow 50% ($E_{<50\%}$) = Not particularly helpful + Helpful
- Level of Effectiveness (L_E) = ($E_{>50\%}$) - ($E_{<50\%}$)

Table 24: Summery of comments of EMU architecture instructors on structural principals within architecture curricula

	TITLE OF COMMENTS	KEY RESULTS
1	Comments on level of teaching of structural courses	• Poor, fair, not in a satisfactory level, low ⟶ 85.72% • Taught in a satisfactory level ⟶ 14.28%
2	Comments on positive points	• Students are asked to think about form, function and structure simultaneously from the first stages of design. (commented on a specific design studio) • There is integration between structural courses and design courses, because teachers who teach structural courses go to design studios as well. (not a general comment- commented on specific cases) • There are many useful taught concepts in structural courses.
3	Comments on problematic points	• Structural courses are not well integrated into design courses. • Although, there are some useful topics taught in structural courses, still there are many missing points and students are not able to deal with structural problems of design studios well. • Students have problems about dimensions and estimation of structural members' size. • Timing arrangement of the design classes has some problems; just after midterm juries students start to work on structural aspects. • There is not a suitable balance in teaching of form, function and structure. Form and function are more attended and structure is left behind. (imbalance)
4	Suggested solutions	• Collaboration between faculty of architecture and civil engineering, this can be done by some courses in department of architecture which are taught by civil engineers also arranging some group projects for students of the two faculties can be useful. • Implementation of some structural softwares in architectural teaching. • Students should be asked to reflect their knowledge from structural courses into their design projects.
5	Suitable starting semester for structural concepts	• 2nd ⟶ Majority of answers • 1th • 3th
6	Existence of structural source books for architects	• No idea ⟶ 14.28% • There are not enough source books ⟶ 14.28% • There are enough source books ⟶ 71.42%

The important points of interviews with EMU architecture instructors are summarized and mentioned here in the table above.

3.3.1 Essential Structural Principles in Architecture Curricula

In the recent years, education in different countries have been faced with some new needs and requirements; providing diversity and flexibility for the students is one of these issues which will lead architects and architecture students to collaborate with each other and provide exchange of knowledge and information between the profession members in all parts of the world. These kinds of new communications can have positive effects on professional life and job issues of architects as well.

3.3.1.1 Minimum Requirements in Architecture Curricula

Since various schools offer different subjects and diplomas, provision of an educational environment which provides communication opportunities can not be achieved without **"redefinition of the minimum requirements"** for an architect education. Thus, some programs and applications have been arranged in this concern; one of them is the Qualification Directive 2005/36/EC of the European Parliament and Council. This directive sets out rules for the reciprocal recognition of around 800 diplomas among the 27 EU countries (Directive, 2005).

Since there is no standard education profile for architecture education within the European countries, the Qualification Directive specifies some items as basic requirements to be fulfilled by European universities in order to have their diploma recognized reciprocally by the other members as an architectural diploma (Neuckermans, 2009). Some of the items mentioned by this directive are the 11 competences mentioned in the architects Directive 85/384/EEC of EAAE (European Association for Architecture Education) as competences for academic architectural diplomas (in chapter 2 the items are marked and structural and technological points of them are specifically highlighted 2.4.1).

Another organization which has attended the minimum requirements of architecture education is the National Architectural Accrediting Board (NAAB) in USA. "The NAAB is the only agency which is recognized by registration board in the United States to accredit professional degree programs in architecture" (NAAB, 2004). Some of the items defined by NAAB, which are related to structural and technological issues of architecture, are quoted here;

"For the purpose of accreditation, graduating students must demonstrate understanding or ability in the following areas:

…

- *Structural Systems*

Understanding of principles of structural behavior in withstanding gravity and lateral forces and the evolution, range, and appropriate application of contemporary structural systems

- *Building Materials and Assemblies*

Understanding of the basic principles and appropriate application and performance of construction materials, products, components, and assemblies, including their environmental impact and reuse

- *Construction Cost Control*

Understanding of the fundamentals of building cost, life-cycle cost, and construction estimating"

The other definition from minimum requirements of architecture curricula is given by TU/e (Technical University of Eindhoven) in Netherlands, which lists the necessary abilities for architecture students (Meijers, 2005) as following:

- Capability to analyze
- Capability to synthesize

- Capability to abstract
- Capability to concretize

3.3.1.2 Proposition of some Principles to Insure the Implementation of Essential Structural Principles in Architecture Curriculum of EMU

In this section some suggestions are made to enhance the teaching quality of structural principles within architecture curriculum of EMU. As it is mentioned before, these proposals are given for EMU curriculum by referring to existing literature and curricula and also some comments from EMU members. But they are general suggestions and applicable for every curriculum, because the problematic points of EMU curriculum (as a sample of an architecture curriculum) are probable to happen for every architecture curriculum.

The main references of these suggestions are the following items;

- Minimum requirements of architecture curricula defined by authorized architecture education organizations (such as EAAE ,NAAB and TU/e mentioned in 3.3.1.2)
- Comments and remarks available in existing literature and also existing curricula (discussed in 2.4.4)
- Comments of EMU students and staffs (as example of persons who are dealing and using an architecture curriculum) on general structural requirements which should be fulfilled by architecture curricula and also architecture curriculum of EMU

Analysis and consideration of these three factors and the consequent proposals are explained in the following items;

a- Structural principles within the design studios:

In all of the architecture curricula which are surveyed and studied in this research (table 8) structural principles are seen; but in some of them like Harvard University (table 8, item2) there are some special attitudes. In Harvard University the design studio focus of the second year of architecture study is specifically given to building structures. This helps students to get familiar with structural and practical issues of design within the design process, and not just experience them in theoretical courses. Another application toward integration of structural principals into design studios is seen in Cambridge University curriculum. In this university, the main emphasize of the studies in the second year is on integration of technical skills, studio output and ongoing lectures (table 8, item5). By this attitude students are supposed to do two important issues in design studios in the second year. Firstly, application of their structure, construction and technical knowledge (obtained from structure and construction specific courses of the first year of study) into design projects; secondly, integration of ongoing lecture courses into their design training.

The two mentioned attitudes are parallel to structural and technological requirements that should be fulfilled by architectural schools and have been emphasized by some organizations such as EAAE, TU/e and NAAB (explained in 3.3.3.2).

A similar attitude is proposed for EMU;

- Having one year of design studio focus on building structures is suggested. Integration of structure and construction knowledge of students into design projects within this year is required. Arrangement of assignments and home works related to structural details and construction drawings for design courses will be helpful in this period of study. Consideration of building regulations while doing designs is also required.

b- Incorporation of theoretical structure and construction courses into design studios:

According to (table 24, item10) EMU students have some problems and difficulties in selection of suitable structural systems and structural materials for their design projects. They also have problems in estimating the size of structural members. Thus, it is necessary to consider some requirements to solve these kinds of problems. Moreover, some topics are discussed and some suggestions are made:

- Interviews with instructors indicate that majority of them believe that there are enough structural source books for architects and they are adequate to respond students' questions (table 25, item6), while most of the EMU students (90%) are not able to solve their structural problems by referring to the source books (table 24, item9); so teaching and focusing on contents of structure hand books of architecture and inquiring relevant home works and assignments during the theoretical courses of structure and construction is proposed.
- Some of the structural problems of students come from fragmentation of structure and construction courses from design studios (instructors' comments, table 25, item3). To compensate this separation and have more integration between these two types of courses, it is suggested to give special attention to information about classifications of structural systems and materials and also methods of estimation of structure members' size in theoretical courses (mentioned suggestion by EMU instructors, table 25, item4). This means that students should practice these taught as some home

works and assignments of theoretical structure and construction courses on their own design projects.

c- Prerequisites of structural and technical aspects of design:

To avoid an architectural project from becoming just the outcome of inspiration, the logical analysis must be the first consideration. This viewpoint began with the methodology of architectural design by theoreticians Christopher Alexander (1964) and Geoffrey Broadbent (1971), oriented in a rationality composed of three stages: analysis, synthesis and appraisal[7]. This systematic technique provides a precise evaluation of the conception and building processes, and unites logical analytic judgment and emotional creative intentions. This comment has been argued by (Consiglieri, V.; Consiglieri, L., 2003) in a research emphasizing the importance of existence of mathematical studies in architectural curricula. As it is indicated in that research, it is necessary to enrich the theoretical knowledge in students together with the capacity of application of mathematics in architecture curricula.

Within the studied curricula in this research (table 8), application of mathematical and analytical topics are seen. There are some courses which are directly or indirectly related to mathematics, such as; calculus, physics and chemistry. In some of the universities such as MIT, Harvard and Cambridge the mentioned studies are included in college studies. This means that studying and passing of those courses are the prerequisites to enter to the field of architecture. In some other universities like SBU and Jordan University having the background of mathematical and physical studies from high school is the essential prerequisite to

[7] This idea is very close the proposed items by TU/e Technical University of Eindhoven) as minimum requirements that an architecture curriculum should provide in students: capability to analyze, synthesize, abstract and concretize (3-3-1-1)

enter to architectural studies. These abilities are tested through qualification exams to enter to the university.

Eventually, by referring to all of the mentioned points a suggestion is made to ensure the fulfillment of necessary structural and technological courses in EMU architecture curriculum;

- Insertion and addition of some concepts related to mathematics (especially calculus), physics and chemistry into some course outlines. The best courses for this purpose are structure and construction courses.
- Testing the ability of students in handling mathematical and analytical topics through qualification exams before the first semester of architectural study (revision of entrance regulations of EMU).

d- Duration of bachelor architecture education studies:

As it is defined by Qualitative Directive (2005), **"the minimum duration"** of full time bachelor architectural education is **4 years**. Minimum duration of architectural study has been attended by others as well; the architectural education community of ACE[8] (2009) has advocated 5 years of study as a minimum duration for the education of an architect, which is accepted by UIA (International Union of Architects) and UNESCO as well (Colin, 1996).

According to the mentioned references above and also some comments from EMU instructors such as (Ozdeniz, 2009)[9], four years of study in architecture is the minimum possible duration and the optimum period of study is 5 years[10].

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[8] Architects' council of Europe
[9] Prof. Dr Mesut Ozdeniz, Instructor of EMU faculty of architecture
[10] In some universities 5 years of study includes one year colleague study which presents some prerequisites of structural concepts.

On the other hand, addition of some structural topics and their prerequisites to the curriculum is already proposed, which requires enough time. Consequently, the following proposition is given;

- Extension of duration of architecture curriculum of EMU from 4 years to 5 years (10 semesters of study), this can be done by the addition of one year colleague study.

e- Starting semester for structural studies in architecture curricula:

In most of the architecture curricula studied in this research, the starting semester for structural topics is 2nd semester, such as Harvard, Cambridge, SBU and TU/Berlin.

On the other hand according to comments given by majority of EMU students and instructors teaching of structural concepts to architecture students should start from 2nd semester (table 24 item5 & table 25 item5). Thus, the following proposal is given;

- Starting the structure related courses from the 2nd semester of the architecture curriculum[11]

f- Knowledge of structural and practical issues of design in EMU architecture instructors:

Since instructors should have enough structural, technical and practical knowledge of design to be able to teach properly to students and encourage them to integrate structural and technical issues of design with other aspects, the following suggestion is made:

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[11] Currently structural courses start from the 3rd semester in EMU.

- Considering minimum 2 years of practical training in an architectural office or dealing with construction of real projects, for the applicants of instructorship in EMU, as a necessary condition

g- Information Technology (IT) and the new potentials in architecture pedagogy:

In today's pedagogy, information technology can play important and effective roles in increasing the quality of teaching. Maier (1998) in the book "Using technology in teaching and learning" emphasizes the role of technology on enhancement of the university programs. As he claims, provision of better access to learning sources is one of the benefits of IT in education.

As it is highlighted in (table 24, items 9 & 10), in this research two of the important results obtained from the evaluation of EMU students abilities based on the questionnaire are:

- Necessity of assisting students in using the structural resource books
- Necessity of provision of structural, technical and practical skills in students

Already there have been some implementations toward solving similar problems in students and assisting them in learning structural taught and skills by using IT and computer facilities (discussed in 2.5). Although, they are mainly used by students of structural engineering field, the concepts and ideas which are used in arrangement of these facilities can be beneficial and applicable for architecture.

Ultimately, the two following proposals are given;

- Preparation of an online learning environment for architectural education as a supplementary teaching tool. (this proposition is explained in detail in chapter 4). This online facility should include information of structural hand books for architects, supported by examples illustrations and animations in order to offer the structural information to students in a tangible and understandable way. Within the presented information there should be a special attention to methods of approximation of structural members' size. This can be more emphasized by provision of a software within this online environment as an assisting instrument for students.

h- Clarification of architecture schools' policies in relation to structural principles within the curricula

Since according to new conditions and requirements of architecture faculties, various changes might happen in arrangement of curricula thought time, it seems necessary to clarify the main policies of schools and present them as ***statutes*** to be referable for every new decision or change in the faculties.

On the other hand, this clarification is one way to assure that necessary and basic requirements are included within the curricula[12]. Structural and technological

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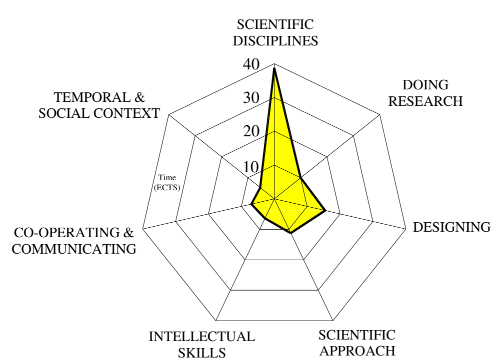
[12] One of the methods of clarification and presentation of existing disciplines in curricula is the radar plot diagram, which is a visual and diagrammatic explanation of the contents included in a curriculum. This method was proposed by Meijers (2005) for the first time. An example of a radar plot is shown below for the Technical University of Eindhoven (TU/e) in Netherland.
Technical University of Eindhoven in Netherland- Competences Profile



- The diagram is sketched based on the amount of study time (ECTS) spent on a particular area of competence.
- (ECTS): The European Credit Transfer System is the common trade-off measurement unit for the time devoted to a subject: 1 ECTS credit = 25 to 30 hours' student workload.(Neuckermans, 2009)

Radar plot as well as helping schools to define and express the main school policies for the users and advertisement issues can help different universities to compare their policies and specifications in distributing workloads with each other. Thus, they can make sure that sufficient balance is provided within the contents of the curricula.

principals are one of the disciplines which should be regarded in the defined statute. Thus, concisely it is proposed to;

- Clarifying the school policies which one of its items would be the role and level of structural principles and practical issues within the curricula.

Chapter 4

PROPOSITION OF A SUPPLEMENTARY ONLINE LEARNING ENVIRONMENT FOR STRUCTURAL TRAINING

In today's pedagogy, information technology can play important and effective roles in increasing the quality of teaching. Maier (1998) in the book "Using technology in teaching and learning" emphasizes the role of technology on enhancement of the university programs. As it is claimed in this book computer facilities develop new strategies in teaching for larger group of students and provide better access to learning sources and communicate with and between students.

In the previous chapter the role and importance of information technology within architectural education was highlighted. Limitations and missing points in teaching of architectural subjects might occur because of restrictions in time or facilities and this can be compensated by the sufficient use of information technology. One of the specific areas in architecture teaching which can be integrated with information technology and its new opportunities is the structural principles of building design. This integration seems useful and effective for design courses and their relevant structural taught. Thus, this research is aimed to propose some solutions for enhancement of quality of teaching of structural principles within architecture curricula by means of Information Technology (IT) facilities. To achieve this aim some probable problems of architecture curricula in relation to structural and technological principals are stated and also some potentials of IT for improvement of the efficiency of educational systems are marked. Consequently, some proposals and suggestions are made.

4.1 Some Probable Problems Related to Structural Principles within Architecture Curricula

In order to provide solutions based on information technology, current problems of the EMU curriculum (explained in Chapter 3) are restated here as sample problems which architecture students might be faced with. According to the questionnaire taken from undergraduate students of faculty of architecture (discussed in detail in 3.1) and interview with EMU architecture instructors (3.2), some of the problematic points of the curriculum are categorized below:

- Structural taught are less attended than form and function in design studios.
- Majority of students have problems and difficulties in using structural resource books and achieving standard data of structures.
- Students have some problems with selection of suitable structural systems and structural materials and estimation of structural members' size in their design projects.
- Fragmentation of design studios with theoretical structure courses and construction courses

4.2 Information Technology and New Learning Environments

In the recent years, increasing use of information technology has provided some new potential in educational facilities through online services. "**Web-assisted courses**" and "**Web-based courses**" are two important outcomes of information technology on educational systems; they are explained as following (Learning Online Glossary, 2009);

- Web-assisted Courses: are traditional face to face courses which are supplemented with online materials and courses. Interaction between faculty and students may or may not take place online. The courses use web technology to provide access to course contents and resources from the web.
- Web-based Courses: Are courses in which instruction and interaction are based on the available technologies from the internet and the World Wide Web. In a web base class, students are enrolled with their instructor and other classmates through class discussions and internet based communications. Course meeting places is focused from the classroom to an online environment.

Three of examples of online learning environments are selected and explained here to provide more clear explanation about online courses. Study of these examples are supposed to lead the research toward suggesting some IT based solutions for improving the quality of teaching of structural principle within design studios. Since this research has planned to propose supplementary learning facilities and not to suggest a fundamental change in the teaching system, the selected examples are chosen from "*web-assisted*" type of online courses.

4.2.1 Online Learning Environment for Steel Design (OLE Steel)

The first selected example is "OLE Steel". It is an experimental learning environment designed and developed in civil engineering department of Catholic University of America. This online environment is useful for self directed learning and project based collaboration for civil engineering students. Ole Steel works as a supplementary tool for engaging students in outside classroom learning. It provides access to definitions, examples, illustrations and database of steel design. Each example or illustration is linked to a database of information. When the students need more explanation than the available database or intended to ask frequent questions, they can submit their questions to the instructor electronically and receive feedbacks later. Consequently, the program compiles the questions and answers, so the whole users can benefit from this archived information (Arcisewski, 2001).

4.2.2 Engineering Mechanics Digital Library

This is an online learning environment designed and produced for civil engineering students in Catholic University of America. This online electronic library has provided access to explanation of concepts, sample solved problems and course modules for students. Some video clips and pictures exist as well to give deeper understandings to the users. A question and answer system is also considered within the library which enables students to ask their questions from their instructors (Arcisewski, 2001).A couple of examples of this library pages are illustrated bellow (Figure 1&2):

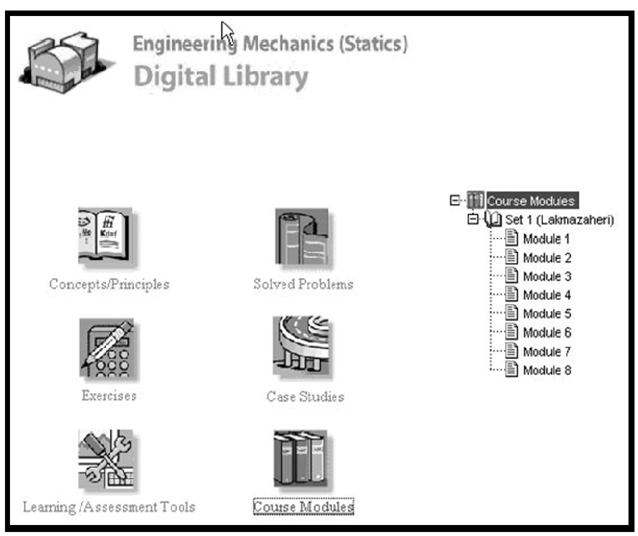


Figure 1: Engineering Mechanics Digital Library of instructional material, (Arcisewski, 2001)

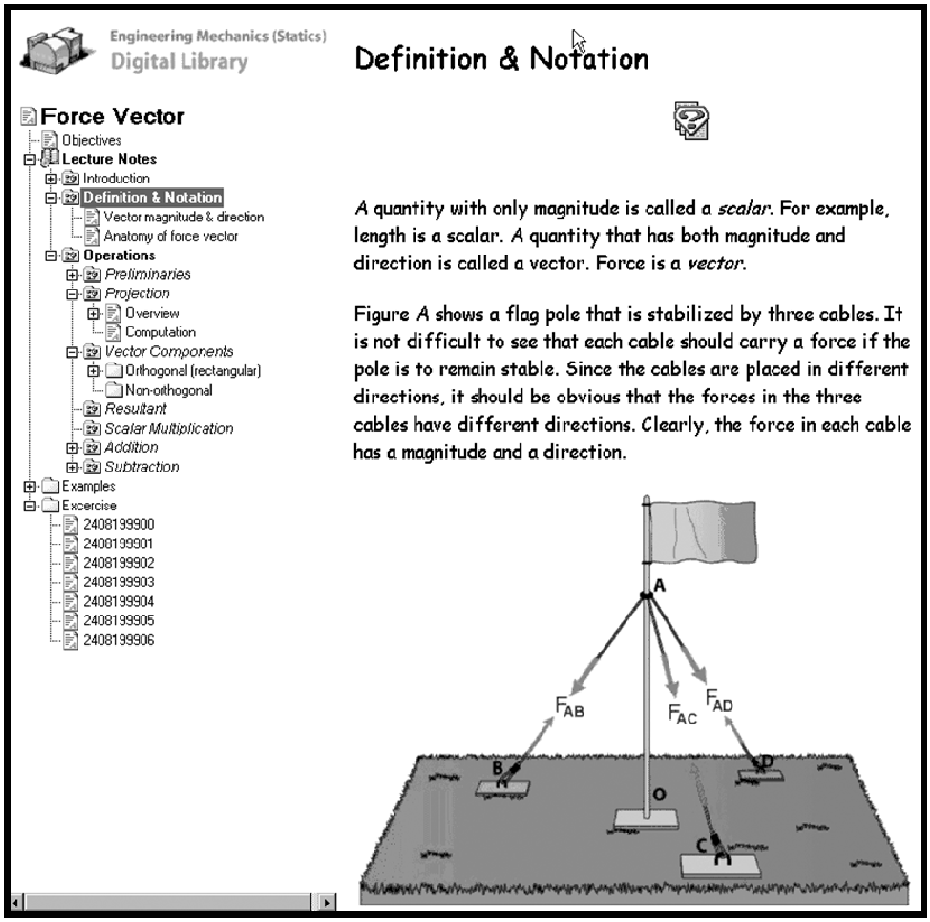


Figure 2: A sample explanation page from the library, (Arcisewski, 2001)

4.2.3 Modular Object-Oriented Dynamic Learning Environment (Moodle)

Another example of an online learning environment is *Moodle*. “Moodle is a Course Management System (CMS), also known as a Learning Management System (LMS) or a Virtual Learning Environment (VLE)” (Moodle, 2009). It is used for making internet-based courses which provide social frameworks in education. All universities or educational systems can use Moodle to provide supplementary learning environments for their courses.

The word Moodle stands for Modular Object-Oriented Dynamic Learning Environment. It's also a verb; as it is described in Moodle documents (2009), Moodle means, “… the process of lazily meandering through something, doing things as it occurs to you to do them, an enjoyable tinkering that often leads to insight and creativity".

General layout of a Moodle environment is shown here as a schematic diagram (Figure 3). Students are supposed to register to the system and choose a user name and a password to be able to enter to the website and use its facilities.

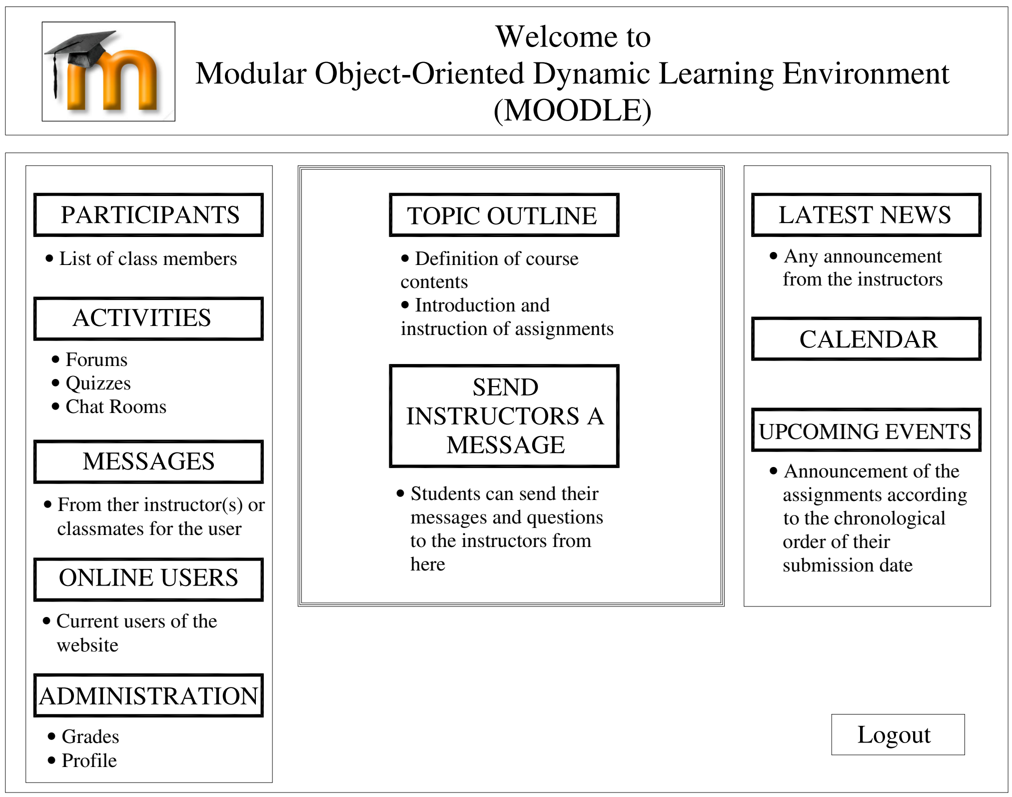


Figure 3: General layout of a Moodle environment, (Mokhaberi, 2009)

Components of a Moodle environment are:

- PARTICIPANTS: This part includes a list of class members and let the participant know each other and communicate easier.
- ACTIVITIES: Students can enter to chat rooms from here and have discussions, they can also enter to the forums and comment on the topics which are already defined by the instructors; by definition of the instructor(s)

this may result in getting some points or grades for the students. Some brief quizzes also might be planned by the instructors here for the students.

- MESSAGES: Every user of the website can see his/her messages from other students or teachers from here.
- ONLINE USERS: This part shows the current users of the website
- ADMINISTRATION: For every user of the website, total semester grades and personal profile is visible from here.
- TOPIC OUTLINE: The main topics and requirements of the course are explained here by the instructor(s). Definitions, examples and useful websites are introduced here to the students by the teachers.
- SEND INSTRUCTOR A MESSAGE: Contact with the instructors and sending messages for them are provided here.
- LATEST NEWS: Instructors can leave their public announcement for students here. It may include the dead line of assignments, jury dates or grade announcements.
- CALENDAR
- UPCOMING EVENTS

4.3 Proposition of a Supplementary Online learning Environment for Design Courses of Architecture Curricula

Investigation of the existing problems of EMU in terms of teaching of structural principles within the design studios of faculty of architecture and exploration of some existing online learning environments has led the author toward proposition of a supplementary online learning environment for design studios of architecture teaching. This suggested online environment has been called:

"*Architectural Learning Environment for Structural Training* ***(ALEST)"***.[13]

ALEST focus is on structural aspects of architectural design. It works as a counselor or assistant for students in solving their structural problems. Students can refer to ALEST as a reference or electronic document and find their desired answers. On the other hand it works as an environment in which students can share their thoughts and ideas and have collaboration and consultation with each other. In fact, ALEST presents an architectural environment for **learning structural concepts** while having **transparency**, **clarity** and **visibility** of information for every one.

Function of online learning environment of ALEST and its components

Online services of ALEST can be provided and managed by Moodle services (explained in 4.2.3) from the "http://moodle.org/", or it can be produced independently by every university. In both cases the ideas and functions of the ALEST would be the same.

A schematic diagram is shown here (Figure 4) to explain the ALEST components and their functions.

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[13] This proposition includes only architectural programs and facilities which are offered by this online learning environment (flow chart proposition). In other words, it is away from technical computer programming issues, which requires knowledge of computer software creation.

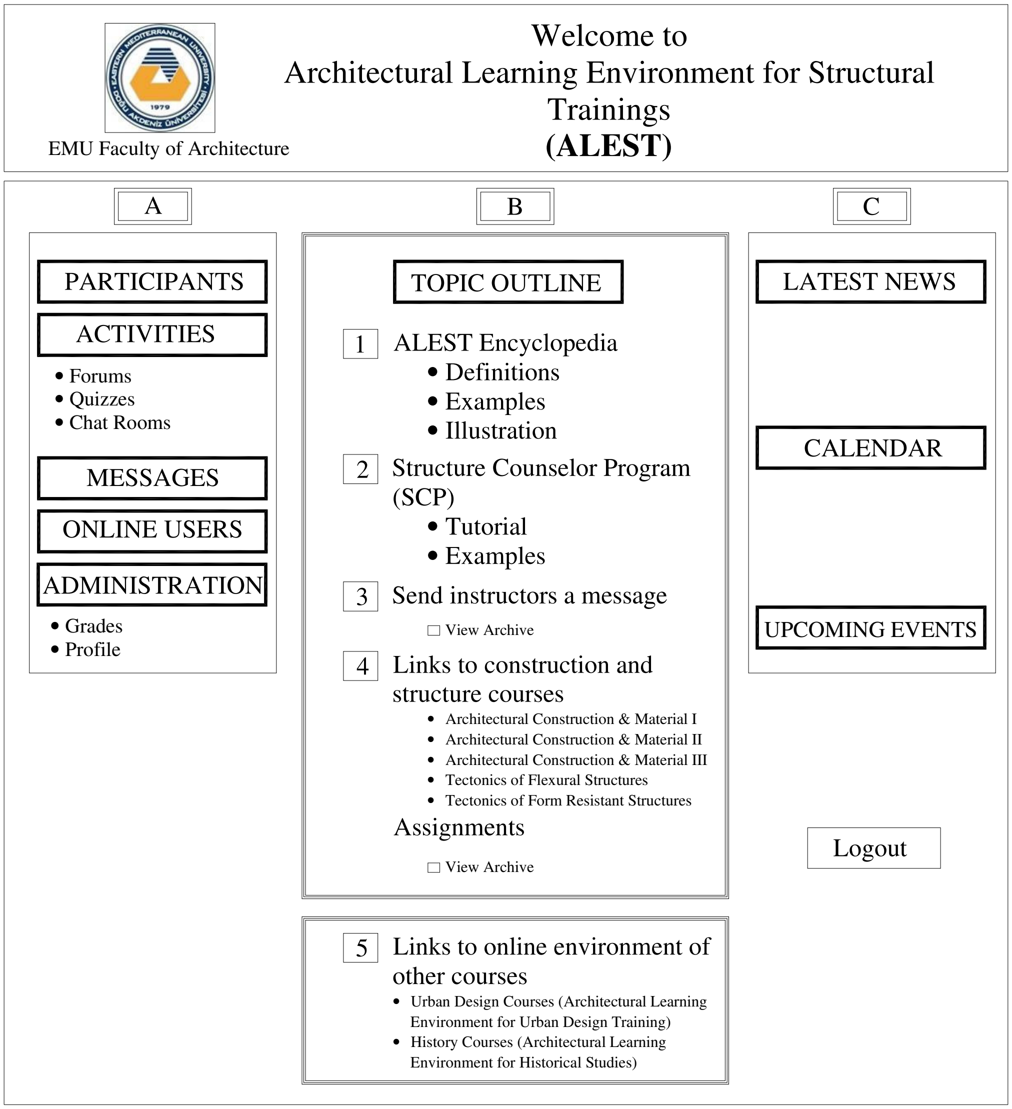


Figure 4: A typical web page of the ALEST, (Mokhaberi, 2009)

Functions and facilities which ALEST offer for its users are indicated in the three columns of the figure 4 (A, B and C). The A and C columns serve the same functions as Moodle environments do (4.2.3). Items of the column A (Participants, activities, messages, online users and administration) are informative for the users and provide communication between students and teachers. Items of the column C let the instructors to have public announcements for the class members.

Column B is the core and the most important part of the ALEST. The main objectives and policies of ALEST are supposed to be achieved by the items of this part. The components of this part are explained as following;

1- ALEST ENCYCLOPEDIA:

This item works as a structural electronic reference or hand book for architecture students. A collection of definitions, examples and standard data of structural systems and materials are accessible from here. The compiled information of this section are supported by illustrations and video clips to provide intuitive explanations of the concepts (More information and explanation about contents of this part of ALEST is given in the chapter 5).

2- STRUCTURE COUNSELOR PROGRAM (SCP):

One of the necessary skills which architecture students need to attain during their undergraduate studies is the estimation of structural members' size. This will help them to develop more realistic and practical ideas and design the buildings which are feasible to construct. Gauld (1991) emphasis this fact; as he mentions, methods of approximation of structural members' size are the most important structural information at the **detailed planning stage**. He also argues that despite experienced architects and engineers who have intensive feeling for structural form, the students have to refer to a number of rules of thumb.

Since the questionnaires taken from EMU undergraduate students (3.1) have revealed the fact that majority of students do not have enough knowledge of estimation of structural members' size, this research has made a suggestion to assist students in this regard. THE ***SCP*** (Structural Counselor Program) is proposed to help students to use proper size and dimensions for their design projects.

The SCP computer software can be offered to students in two different ways. Firstly, students can install this program on their own computers and use it independent from online environments. Secondly, they can use it as an online program within the virtual environment of ALEST.

The advantage of existence of SCP in ALEST is that students can have access to SCP from any computer (even the ones which do not have the program installed). On the other hand, students and instructors can share their findings, samples and experiences about the program through ALEST environment.

Two types of items exist in SCP; user items and program items (Figure 5). User items are data which are given to the program by the users and program items are the data which are produced by the program for the users.

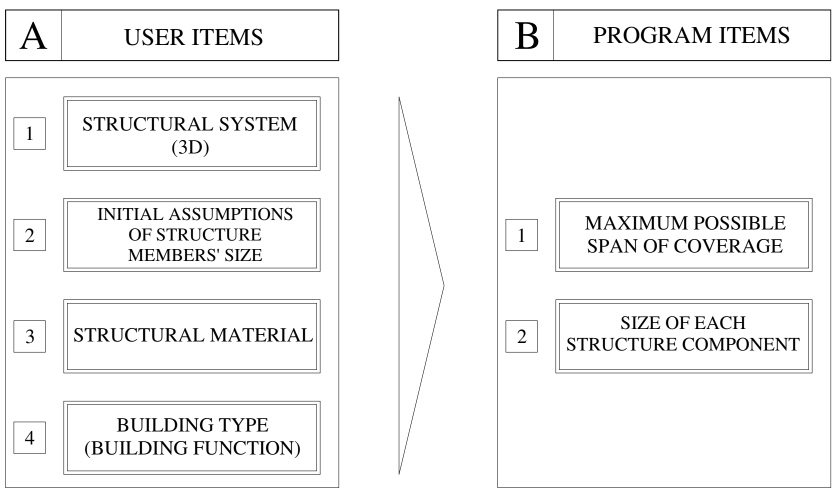


Figure 5: Different items exist in SCP, (Mokhaberi, 2009)

The instruction of using the program is explained for a user as following:

1A-Structural system (3D): Insert a pre designed three dimensional model of your structural system into the program. (It can be drawn be Auto CAD or other softwares.).

2A-Initial assumption of structural members' size: Obviously, components of the inserted 3D model have dimensions and size, which are called initial assumptions of structural elements' size. They may later change according to the program proposals.

3A-Structural Material: Define your desired structural material for the selected structural system (from the material list of SCP). Steel, reinforced concrete, wood or combination of these can be some items of your probable selection.

4A-Building Type (Building Function): Determine the type of building that you need (from the function list of SCP). This is required in order to define the live load of the building.

1B-Maximum possible span of coverage/ Size of each structure component:

Now your data are ready to be analyzed by the program. Click on the analyze option and get:

- Maximum possible span of coverage on each span of your 3D model.
- Comments of the program on your initial assumption of structural members' size; such as beams and columns size. You can understand whether they are correct or not.
- Furthermore, you can get some proposed dimensions and proportions for the 3D model members.

2B-Rearrangement of the structural model: If the current dimensions of your 3D model are wrong and not providing structural stability for the building, you may change your 3D model according to the program proposals. If the program proposals are disturbing for your functional arrangements of the plan, you can change the 3d model arrangement and repeat the procedure of the SCP program from the beginning until obtaining an optimized result.

After accomplishing the whole steps of SCP instruction, users are expected to:

Obtain an adequate design in which structural members' size, structural spans and plan functioning are all properly achieved and optimized.

3- SEND INSTRUCTOR A MESSAGE:

From this item students can write their questions about structural topics and send them to the instructors and receive responds. According to the decision of the instructor the questions and answers might be kept in the archived and become available and visible for the whole ALEST users.

4- LINKS TO CONSTRUCTION AND STRUCTURE COURSES:

As well as the instructors of the design studios, instructor of structure and construction courses can observe the ALEST environment and contribute to it. They should put a link in ALEST from their courses, including course outlines and explanation of the course contents. This will provide more transparency between students, instructor of design courses and instructors of structure and construction courses. It also helps the curricula to increase the integration of design studios into structure and construction courses; because:

a) Instructors of design courses and structure and construction courses who are all informed about the course contents of each other can move toward achieving common or parallel aims and they can accordingly, define the home works and assignments of students.
b) On the other hand, ALEST users can have simultaneous access to all design, structure and construction courses and be aware of their parallel aims and perform better.

5- LINK TO ARCHITECTURAL LEARNING ENVIRONMENT OF OTHER ARCHITECTURE COURSES:

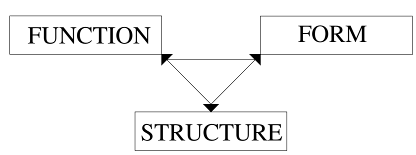
It is suggested to design and arrange some other learning environments similar to ALEST for online training of other aspects of architecture education such as Urban Design and History courses. There can be a link from ALEST environment to those environments or from those to ALEST.

Chapter 5

CLASSIFICATION OF STRUCTURAL SYSTEMS

As it has been mentioned in chapter 4, an online learning environment called ALEST[14] is proposed to assist architecture students in solving and dealing with structural concepts and problems. In this chapter a prototype of this online environment with its functions and offered information for students is presented.

In chapter 3, the importance of integration of form, function and structure in architectural design projects was discussed. On the other hand, according to existing literature and curricula (chapter 2), this integration seems an essential fact. Hence, in this chapter by considering and regarding some information from standard architectural data related to building types and also building structures, a series of data classifications are provided to help students in integration of the three important factors: function, form and structure. In fact standard data of building types and structural systems are compiled and put together in this chapter to help students think simultaneously about function, form and structure[15];



[14] Architectural Learning Environment for Structural Training
[15] Majority of information of this chapter are compiled from existing literatures, a new kind of interpretation and arrangement of data has been added by the author to be used in ALEST environment.

5.1 Building Types and Adequate Structural Systems

Some common building types are selected and mentioned here from Neufert Architects' Data (1980). Consequently, some structural systems from the book "Structure Systems" by Engel (1999) are proposed to be used for these building types. This proposition and combination, which has been done by the author is supposed to be a part of ALEST environment and help architecture students in selection of appropriate building structure for architectural design projects.

Table (26) shows the possible structural systems for each building type. The proposed items are the most usual approaches although in some special cases there can be other solutions than the ones mentioned in the table.

Various subtypes of the mentioned structural systems in the table (26) can cover different ranges of spans. But in general the span of coverage of each structural system is as following;

Form active > Vector active > Surface active > Section active

This fact has been considered in arrangement of the table.

Table 25: Adequate structural systems for each building type[16]

Building Type \ Structural System		1- FORM ACTIVE	2- VECTOR ACTIVE	3- SECTION ACTIVE	4- SURFACE ACTIVE	5- HEIGHT ACTIVE	5- HYBRID
Residential building	Houses		●	● ●	●		○
	Flats and apartments		●	●	●	● ●	●
Educational spaces		● ●	● ●	●	●	○	●
Hospitals			●	●	●	●	○
Religious spaces		● ●	●	●	●		●
Shops and stores				● ●	●		●
Restaurants				● ●	●	○	
Hotels				●	●	●	●
Office buildings			●	● ●	●	●	○
Banks			●	●	●	●	○
Airport		● ●	●	●	●	○	●
Industrial buildings		● ●	● ●	●	●	○	●
Laboratories			●	●	●		
Farm building		●	●	●	●		
Sport halls		● ●	● ●	●	○	○	○
Theatres and cinemas		● ●	● ●	●			
Museums		●	●	●	●	○	●

● ●	Very commonly used
●	Commonly used
○	Less commonly used

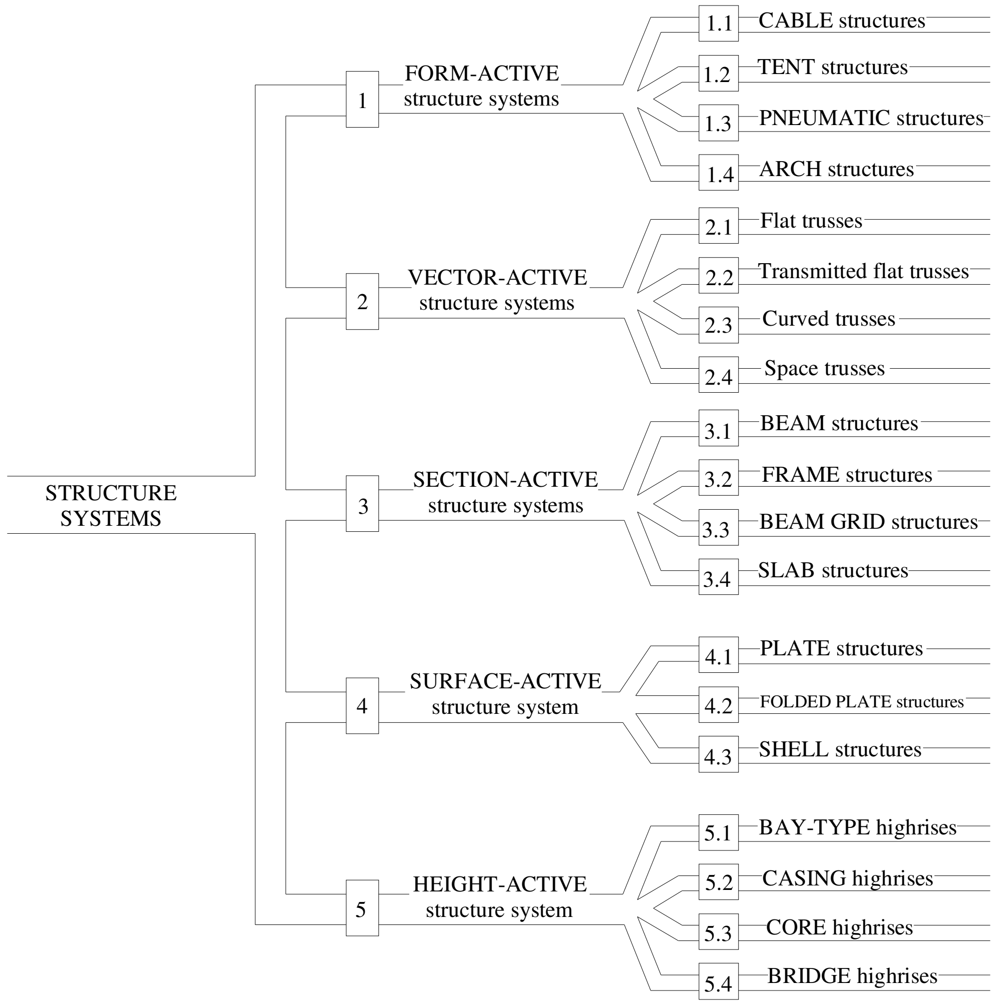
[16] This proposed table is an initial assumption or a prototype to show the authors' ideas about arrangement of information in ALEST environment. Accurate propositions in this concern need indebt analysis and precise attention to the relationship of function and structure. This can be a suggestion for further studies on completion of ALEST environment.

5.2 Classification of Structural Systems in Buildings (Engel, 1999)

Table 26: Classification of structural systems in buildings

Structure family		Definition	Structure type	
1	FORM-ACTIVE structure systems	... are systems of flexible, non-rigid matter, in which the direction of forces is effected by particular FORM design and characteristic FORM stabilization.	1.1	CABLE structures
			1.2	TENT structures
			1.3	PNEUMATIC structures
			1.4	ARCH structures
2	VECTOR-ACTIVE structure systems	... are systems of short, solid, straight linear members (bars), in which the redirection of forces is effected by VECTOR partition, i.e. by multi-directional splitting of single forces (compressive or tensile bars)	2.1	Flat trusses
			2.2	Transmitted flat trusses
			2.3	Curved trusses
			2.4	Space trusses
3	SECTION-ACTIVE structure systems	... are systems of rigid, solid, linear elements -including their compacted form as slab-, in which the redirection of forces is effected by mobilization of SECTIONAL (inner) forces	3.1	BEAM structures
			3.2	FRAME structures
			3.3	BEAM GRID structures
			3.4	SLAB structures
4	SURFACE-ACTIVE structure system	... are systems of flexible, but otherwise rigid planes (-resistant to compression, tension, shear), in which the redirection of forces is effected by SURFACE resistance and particular SURFACE form	4.1	PLATE structures
			4.2	FOLDED PLATE structures
			4.3	SHELL structures
5	HEIGHT-ACTIVE structure system	... are systems in which the redirection of forces neccessitated by height extension, i.e. collection and grounding of storey loads and wind loads, is effected by typical HEIGHT- proof structures, HIGHRISES	5.1	BAY-TYPE highrises
			5.2	CASING highrises
			5.3	CORE highrises
			5.4	BRIDGE highrises
6	HYBRID structure system	Two structure systems with dissimilar mechanics of redirecting forces can be locked together to form a single operational construct with new mechanics: hybrid structure system.	Some examples of possible hybrid structural systems: • Superposition of section-active and form-active structure systems • Superposition of form-active and vector-active structure systems	

Table 26: Classification of structural systems in buildings (continuous)



Genealogy of structures in buildings

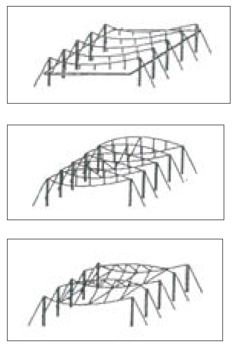
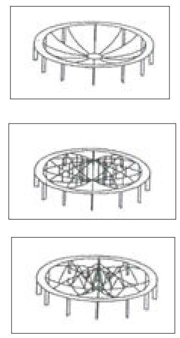
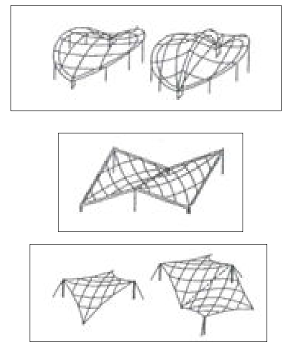
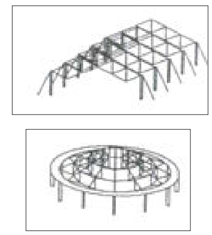
Table 26: Classification of structural systems in buildings (continuous)

- 1.1.1 parallel cable systems
- 1.1.2 radial cable systems
- 1.1.3 biaxial cable systems
- 1.1.4 cable trusses
- 1.2.1 peak tents
- 1.2.2 undulating tents
- 1.2.3 indirect peak tents
- 1.3.1 air-controlled indoor systems
- 1.3.2 air cushion systems
- 1.3.3 air tube systems
- 1.4.1 linear arches
- 1.4.2 vaults
- 1.4.3 thrust lattices
- 2.1.1 top chord trusses
- 2.1.2 botom chord trusses
- 2.1.3 two-chord trusses
- 2.1.4 cambered trusses
- 2.2.1 linear trusses
- 2.2.2 folded trusses
- 2.2.3 intersecting trusses
- 2.3.1 cylindrical trusses
- 2.3.2 saddle-shape trusses
- 2.3.3 dome-shape trusses
- 2.3.4 spherical trusses
- 2.4.1 flat space trusses
- 2.4.2 folded space trusses
- 2.4.3 curved space trusses
- 2.4.4 linear space trusses
- 3.1.1 one-bay beam
- 3.1.2 continuous beam
- 3.1.3 pin-jointed beam
- 3.1.4 cantilever beam
- 3.2.1 one-bay frames
- 3.2.2 multipanel frames
- 3.2.3 storey frames
- 3.3.1 homogeneous grids
- 3.3.2 gradated grids
- 3.3.3 concentric grids
- 3.4.1 uniform slabs
- 3.4.2 ribbed slabs
- 3.4.3 box frames
- 3.4.4 cantilever slabs
- 4.1.1 one-bay plates
- 4.1.2 continuous plates
- 4.1.3 cantilever plates
- 4.1.4 intersecting plates
- 4.2.1 one-way folded plates
- 4.2.2 polyhedral folded plates
- 4.2.3 intersecting folded plates
- 4.2.4 linear folded plates
- 4.3.1 cylindrical shells
- 4.3.2 dome shells
- 4.3.3 saddle shells
- 4.3.4 linear shells
- 5.1.1 framed bays
- 5.1.2 trussed bays
- 5.1.3 stabilized post-beam bays
- 5.1.4 shear wall bays
- 5.2.1 framed casings
- 5.2.2 trussed casings
- 5.2.3 stabilized casings
- 5.2.4 shear wall casings
- 5.3.1 cantilever cores
- 5.3.2 indirect load cores
- 5.3.3 cores combinations
- 5.4.1 girder bridges
- 5.4.2 storey bridges
- 5.4.3 multistorey bridges

Table 26: Classification of structural systems in buildings (continuous)

1 FORM-ACTIVE structure systems	1.1 CABLE structures	1.1.1 parallel cable systems	1.1.1.1 weight stabilization
			2 isoplane cable stabiliz.
			3 staggered cable stabiliz.
		1.1.2 radial cable systems	1.1.2.1 weight stabilization
			2 isoplane cable stabiliz.
			3 staggered cable stabiliz.
		1.1.3 biaxial cable systems	1.1.3.1 boundary arch
			2 boundary beam
			3 boundary cable
		1.1.4 cable trusses	1.1.4.1 parallel alignment
			2 radial alignment
	1.2 TENT structures	1.2.1 peak tents	1.2.1.1 boundary support
			2 interior support
			3 arch support
		1.2.2 undulating tents	1.2.2.1 boundary support
			2 interior support
		1.2.3 indirect support tents	1.2.3.1 exterior construction
			2 interior construction
	1.3 PNEUMATIC structures	1.3.1 air-controlled indoor systems	1.3.1.1 pressurized air
			2 negative pressure
			3 pos. and neg. pressure
		1.3.2 air cushion systems	1.3.2.1 pressurized air
			2 negative pressure
			3 pos. and neg. pressure
		1.3.3 air tube systems	1.3.3.1 structural space envelope
			2 load-bearing skeleton
	1.4 ARCH structures	1.4.1 linear arches	1.4.1.1 funicular arch
			2 two-hinged arch
			3 three-hinged arch
		1.4.2 vaults	1.4.2.1 barrel vault
			2 cross vault
			3 cloister vault
			4 arch-supported vault
			5 pebdentive dome
			6 squinch dome
		1.4.3 thrust lattices	1.4.3.1 flat boundary cut
			2 boundary mesh arch

Table 26: Classification of structural systems in buildings (continuous)

FORM-ACTIVE structure systems			
1.1.1	1.1.2	1.1.3	1.1.4
			
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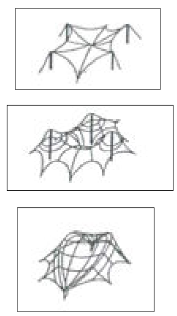
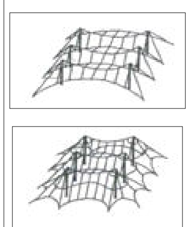
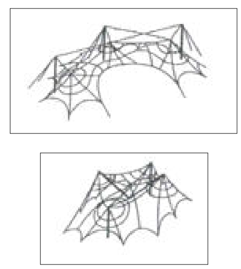
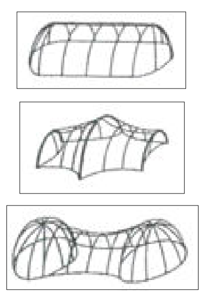
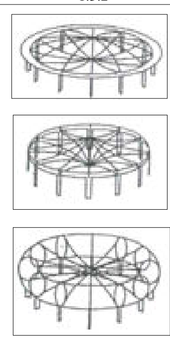
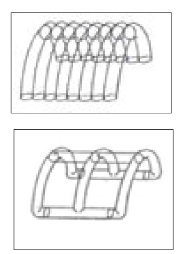
			
1.3.1	1.3.2	1.3.3	
			
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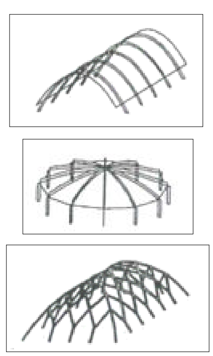
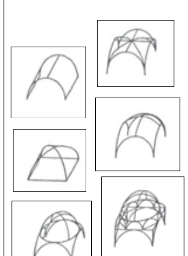
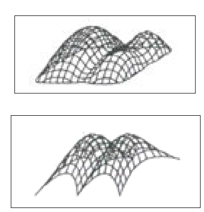
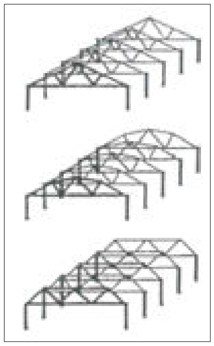
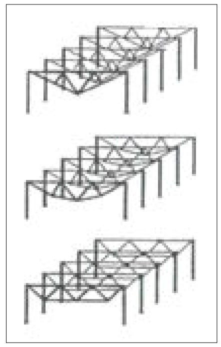
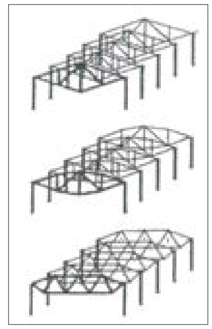
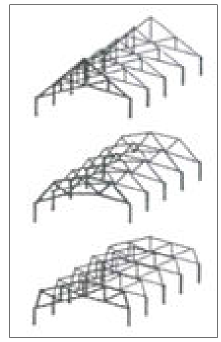
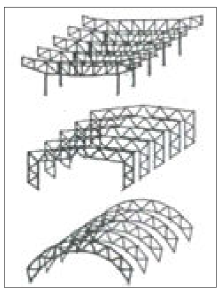
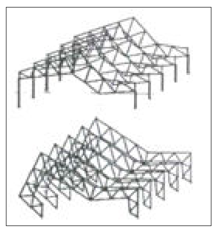
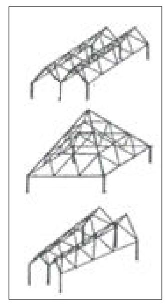
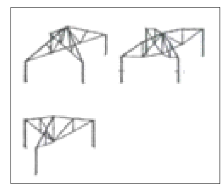
			

Table 26: Classification of structural systems in buildings (continuous)

- 2 VECTOR-ACTIVE structure systems
  - 2.1 flat trusses
    - 2.1.1 top chord trusses
      - 2.1.1.1 double-pitched truss
      - 2 segmental (bow) truss
      - 3 parallel-chord truss
    - 2.1.2 bottom chord trusses
      - 2.1.2.1 inverted two-pitch truss
      - 2 segmental (catenary) truss
      - 3 parallel chord truss
    - 2.1.3 two chord trusses
      - 2.1.3.1 rhombus-shape truss
      - 2 concave-chord truss
      - 3 parallel chord truss
    - 2.1.4 cambered trusses
      - 2.1.4.1 scissors truss
      - 2 croscent (curved) truss
      - 3 mansard truss
  - 2.2 transmitted flat trusses
    - 2.2.1 linear trusses
      - 2.2.1.1 trussed beam
      - 2 trussed frame
      - 3 trussed arch
      - 4 trussed irregular forms
    - 2.2.2 folded trusses
      - 2.2.2.1 parallel folding
      - 2 polyhedral folding
      - 3 tapered folding
    - 2.2.3 intersecting trusses
      - 2.2.3.1 biaxial intersection
      - 2 three-axial intersection
  - 2.3 curved trusses
    - 2.3.1 cylindrical trusses
      - 2.3.1.1 one-way form
      - 2 intersecting form
    - 2.3.2 saddle-shape trusses
      - 2.3.2.1 boundary arch
      - 2 straight boundary beam
    - 2.3.3 dome-shape trusses
    - 2.3.4 spherical Fachwerke
      - 2.3.4.1 Schwedler dome
      - 2 Lattice dome
      - 3 parallel lattice dome
      - 4 Lamella dome
      - 5 Geodesic dome
  - 2.4 space trusses
    - 2.4.1 flat space trusses
      - 2.4.1.1 semi-octahedral packing
      - 2 tetrahedral packing
      - 3 prismatic packing
    - 2.4.2 folded space trusses
      - 2.4.2.1 parallel folding
    - 2.4.3 curved space trusses
      - 2.4.3.1 singly curved
      - 2 doubly curved
      - 3 spherical shape
    - 2.4.4 linear space trusses
      - 2.4.4.1 space truss beam
      - 2 space truss frame
      - 3 space truss arch

Table 26: Classification of structural systems in buildings (continuous)

VECTOR-ACTIVE structure systems			
2.1.1	2.1.2	2.1.3	2.1.4
			
2.2.1	2.2.2	2.2.3	2.2.4
			
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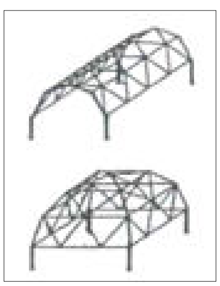	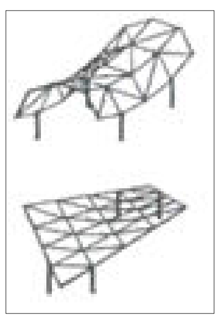		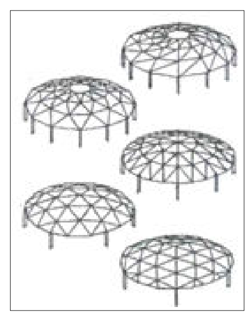
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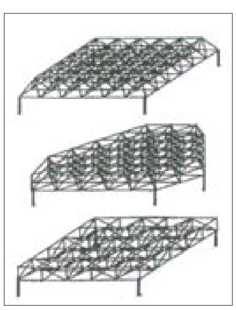	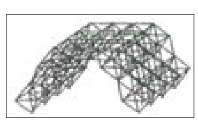	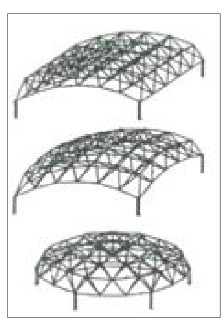	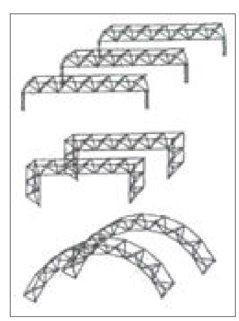

Table 26: Classification of structural systems in buildings (continuous)

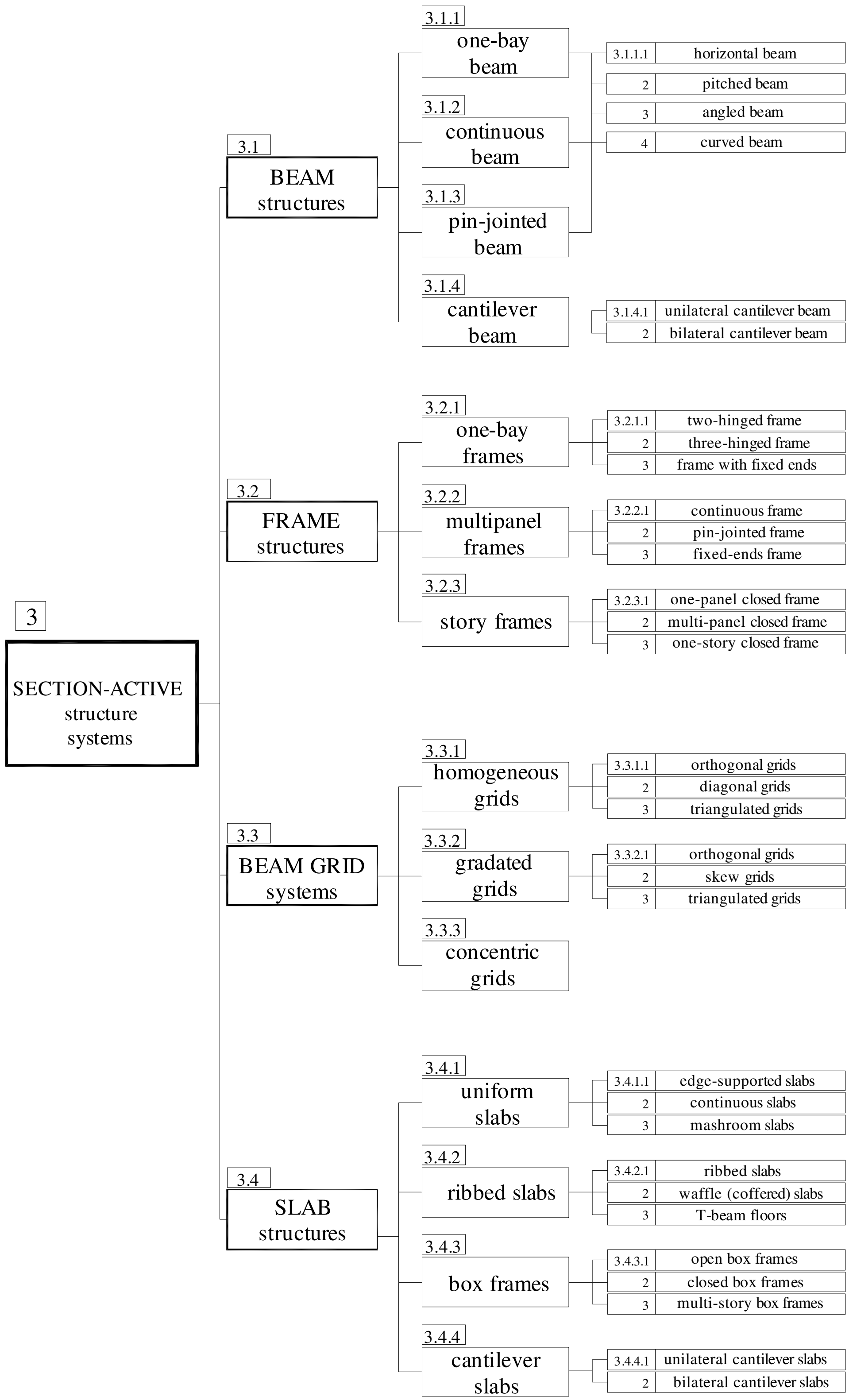

Table 26: Classification of structural systems in buildings (continuous)

SECTION-ACTIVE structure systems			
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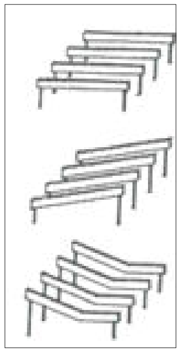
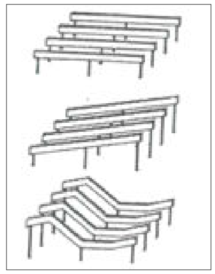
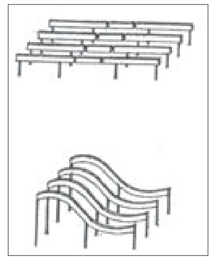
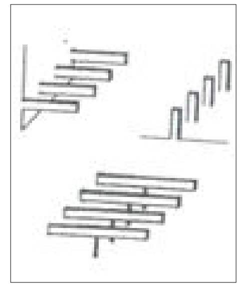
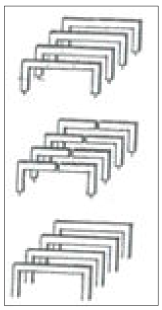
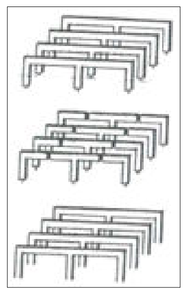
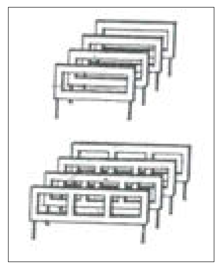
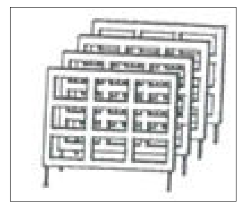
			
3.2.1	3.2.2	3.2.3	3.2.4
			
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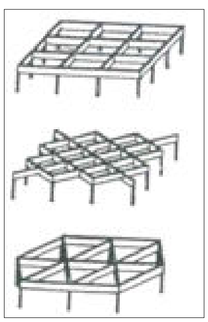		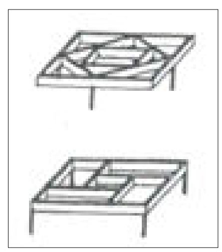	
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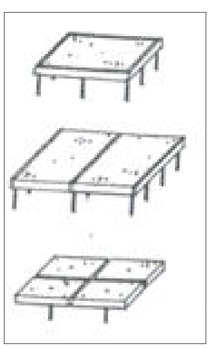		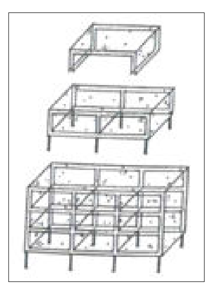	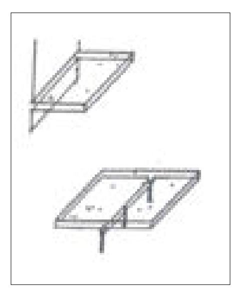

Table 26: Classification of structural systems in buildings (continuous)

4 SURFACE-ACTIVE structure systems	4.1 PLATE structures	4.1.1 one-bay plates	4.1.1.1 rectangular plates
			2 pitched plates
			3 stepped plates
		4.1.2 continuous plates	4.1.2.1 rectangular plates
			2 stepped plates
		4.1.3 cantilever plates	4.1.3.1 unilateral cantilever plates
			2 bilateral cantilever plates
		4.1.4 intersecting plates	4.1.4.1 biaxial intersection
			2 three-xial intersection
	4.2 FOLDED PLATE structures	4.2.1 one-way folded plates	4.2.1.1 folded plate roof
			2 folded box frame
			3 folded barrel vault
		4.2.2 polyhedral folded plates	4.2.2.1 pyramidal folding
			2 triangular folding
		4.2.3 intersecting folded plates	4.2.3.1 biaxial intersection
			2 three-axial intersection
		4.2.4 linear folded plates	4.2.4.1 folded plate beam
			2 folded frame
			3 folded arch
	4.3 SHELL structures	4.3.1 cylindrical shells	4.3.1.1 barrel shell
			2 cone shell
			3 intersecting shell
		4.3.2 dome shells	4.3.2.1 rotational shell
			2 translational shell
		4.3.3 saddle shells	4.3.3.1 rotational shell
			2 translational shell
			3 ruled surface shell
		4.3.4 linear shells	4.3.4.1 shell-type girder
			2 shell-type frame
			3 shell-type arch

Table 26: Classification of structural systems in buildings (continuous)

SURFACE-ACTIVE structure systems			
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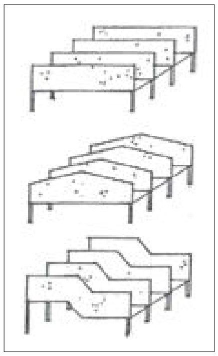
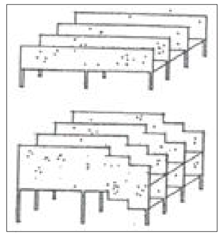
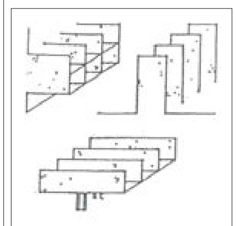
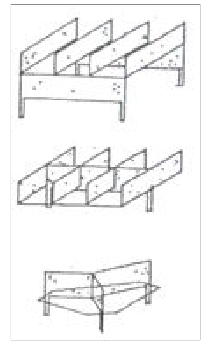
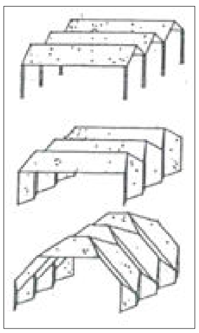
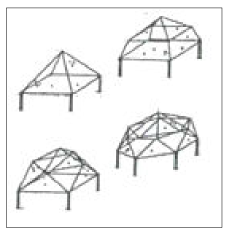
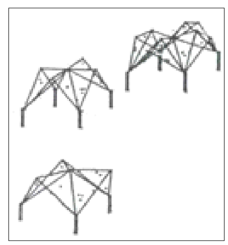
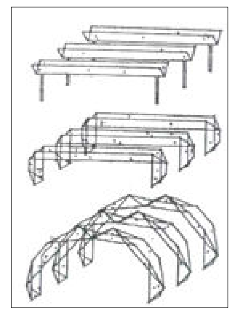
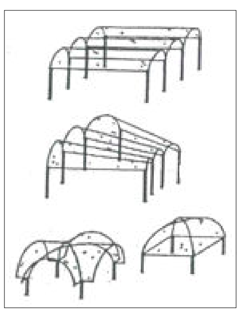
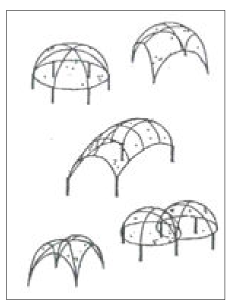
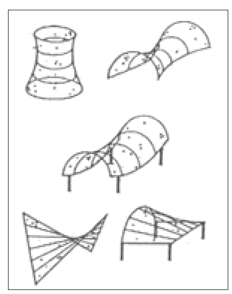
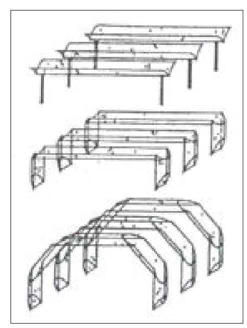
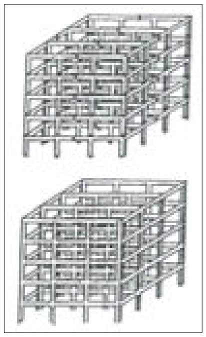
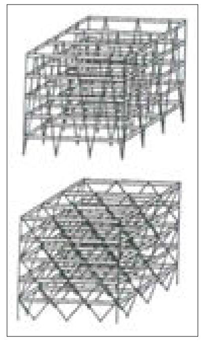
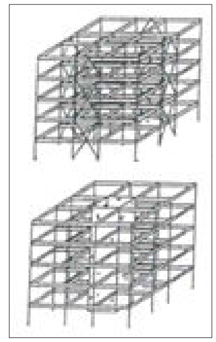
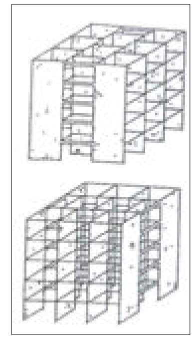
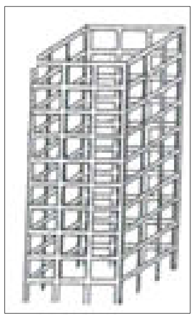
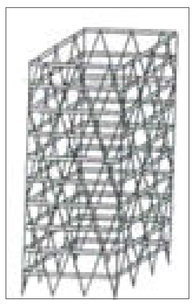
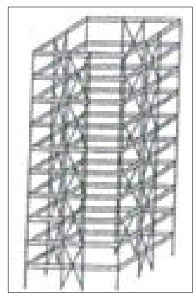
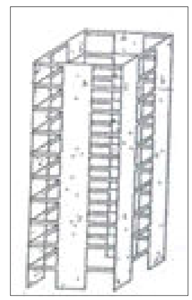
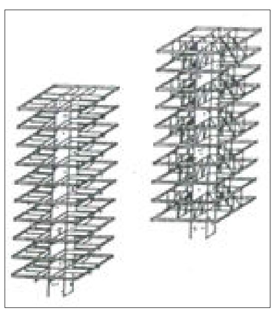
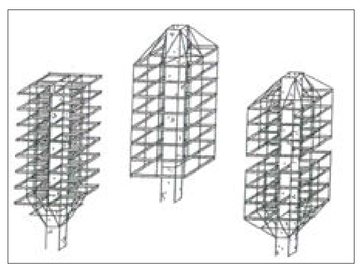
			
4.2.1	4.2.2	4.2.3	4.2.4
			
4.3.1	4.3.2	4.3.3	4.3.4
			

Table 26: Classification of structural systems in buildings (continuous)

- 5 HEIGHT-ACTIVE structure systems
  - 5.1 BAY-TYPE highrises
    - 5.1.1 framed bays
      - 5.1.1.1 stacked hinged frames
      - 2 all-bay through-frames
    - 5.1.2 trussed bays
    - 5.1.3 stabilized post-beam bays
      - 5.1.3.1 single-bay bracing
      - 2 core stabilization
      - 3 shear wall stabilization
    - 5.1.4 shear wall bays
      - 5.1.4.1 longitudinal wall systems
      - 2 cross wall systems
      - 3 two-way wall systems
  - 5.2 CASING highrises
    - 5.2.1 framed casings
      - 5.2.1.1 stacked hinged frames
      - 2 all-bay through-frames
    - 5.2.2 trussed casings
    - 5.2.3 stabilized post-beam casings
      - 5.2.3.1 single-bay bracing
      - 2 core stabilization
      - 3 shear wall stabilization
    - 5.2.4 shear wall casings
  - 5.3 CORE highrises
    - 5.3.1 cantilever cores
      - 5.3.1.1 floor slab cantilever
      - 2 storey cantilever
      - 3 multi-storey cantilever
    - 5.3.2 indirect load cores
      - 5.3.2.1 boundary shoring
      - 2 boundary suspension
      - 3 suspension+shoring
    - 5.3.3 cores combinations
      - 5.3.3.1 core/casings systems
      - 2 core/bay systems
  - 5.4 BRIDGE highrises
    - 5.4.1 girder bridges
    - 5.4.2 storey bridges
      - (5.4.1 and 5.4.2:)
      - 5.4. 1 all-storey mounting
      - 5.4. 2 all-storey suspension
      - 5.4. 3 group mounting
      - 5.4. 4 group suspension
      - 5.4. 5 mount/hang combination
    - 5.4.3 multistorey bridges

Table 26: Classification of structural systems in buildings (continuous)

<table>
<tr><th colspan="4">HEIGHT-ACTIVE structure systems</th></tr>
<tr><td>5.1.1</td><td>5.1.2</td><td>5.1.3</td><td>5.1.4</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>5.2.1</td><td>5.2.2</td><td>5.2.3</td><td>5.2.4</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">5.3.1</td><td colspan="2">5.3.2</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
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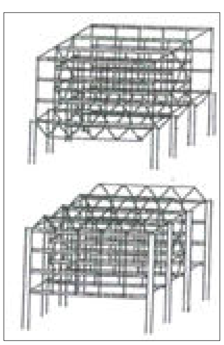
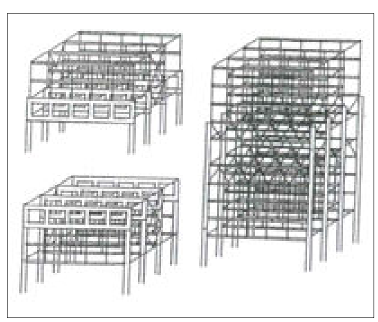
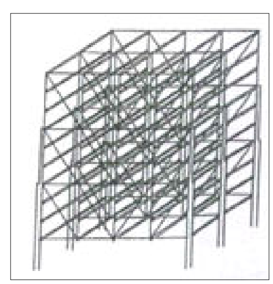
<tr><td></td><td colspan="2"></td><td></td></tr>
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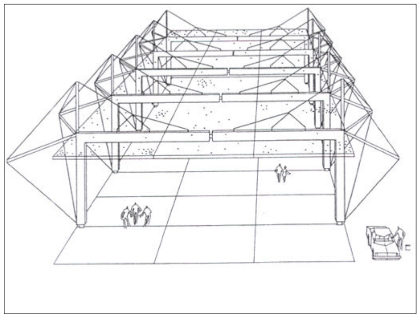
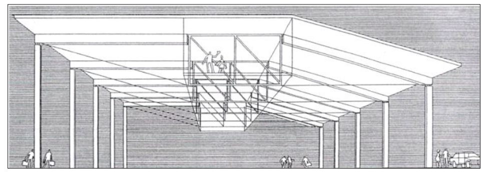
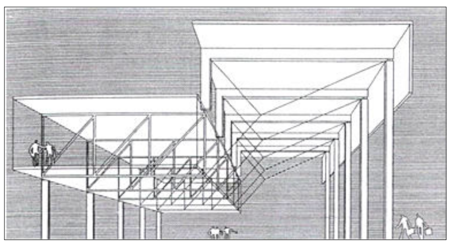
Table 26: Classification of structural systems in buildings (continuous)
/Hybrid-structure systems (The 6^{th} item of classification)



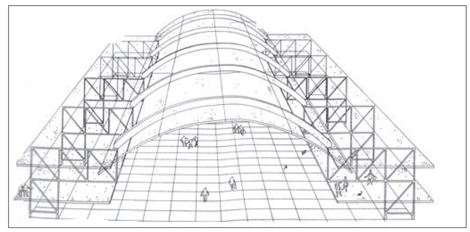
section-active + form-active



central truss connected to lateral beams



truss and cable stabilized rigid frame



form-active + vector-active

Some of the examples of Hybrid structural systems are illustrated above. Hybrid structures are made from combination of other types of structural systems. They are mainly used for creation of free forms and landmark structures.

5.3 The Limits of Spans and Depth/Width Ratio in Structural Systems

Adaptability of the building type and the building structure and also possible structural systems for each building type has been explained in (5.1) and (5.2).

There are two more important structural factors which are necessary to be considered in architectural design. Firstly, limits of spans for each building structure type and secondly, depth/ width ratio of the structural systems. Consideration of these two factors can lead the designers toward making more proper structural decisions.

The limits of spans for each structural system

The limits of spans for some of the various structural systems, which are classified and explained in (5.2), are mentioned here to be used as a reference for the designers in selection of suitable structural systems. (Engel, 1999)

Table 27: Span limits of various structural systems

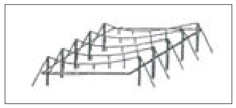
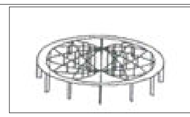
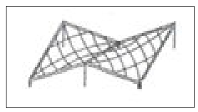
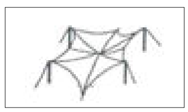
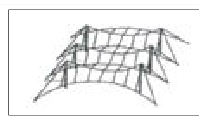
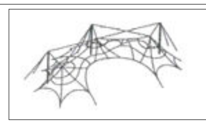
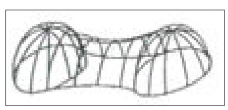
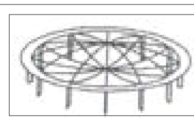
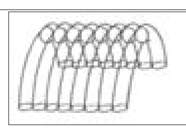
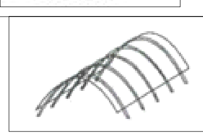
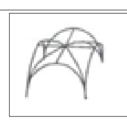
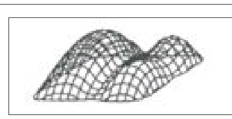
Structural System		Primary Material	Span (m)
1.1 CABLE structures		all metal metal+ R. C.	[80,500]
		all metal metal+ R. C.	[60,200]
		all metal metal+ R. C./+wood	[50,120]
1.2 TENT structures		textile+metal/+wood plastics+metal/+wood	[10,25]
		textile+metal/+wood plastics+metal/+wood	[30,70]
		plastic+metal/+concr. textile+metal/+concr.	[30,80]
1.3 PNEUMATIC structures		plastics+metal	[10,40] ∪ [90,220]
		plastics+metal/ +wood/+concr.	[20,70]
		plastics	[10,50]
1.4 ARCH structures		R.C. Lamin wood metal	[25,70]
		masonary	[8,20]
		metal wood	[20,90]

Table 27: Span limits of various structural systems (continuous)

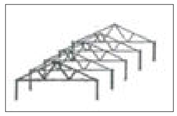
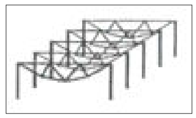
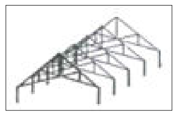
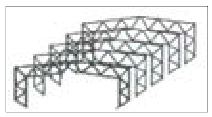
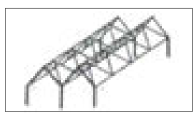
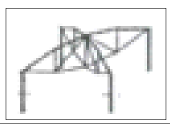
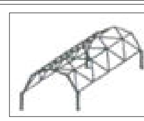
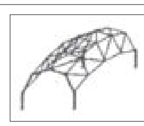
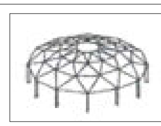
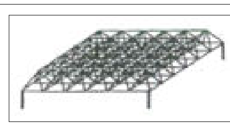
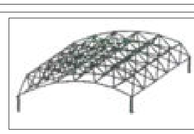
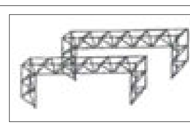
Structural System		Primary Material	Span (m)
2.1 flat trusses		wood metal (steel)	[15,30] [15,30]
		wood metal (steel)	[20,50] [20,80]
		wood metal (steel)	[10,20] [12,25]
2.2 transmitted flat trusses		wood metal (steel)	[20,40] [25,100]
		wood metal (steel)	[12,25] [20,80]
		wood metal (steel)	[15,35] [16,60]
2.3 curved trusses		wood metal (steel)	[12,25] [20,80]
		wood metal (steel)	[12,25] [20,80]
		wood metal (steel)	[40,150] [50,190]
2.4 space trusses		wood metal (steel)	[15,60] [25,100]
		wood metal (steel)	[15,60] [25,100]
		wood metal (steel)	[20,50] [25,120]

Table 27: Span limits of various structural systems (continuous)

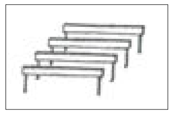
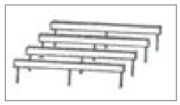
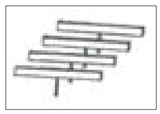
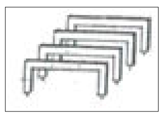
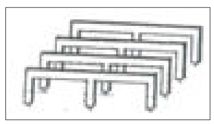
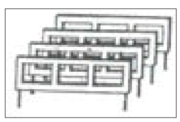
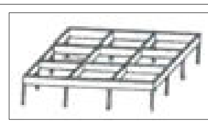
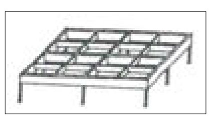
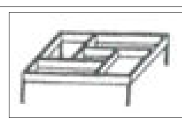
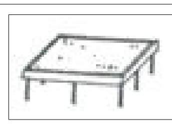
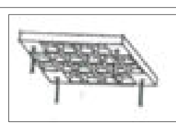
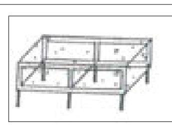
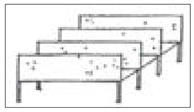
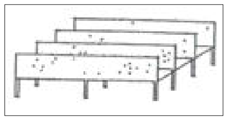
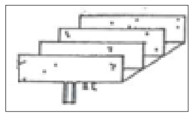
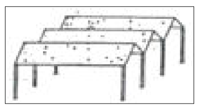
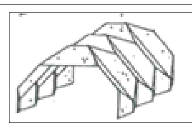
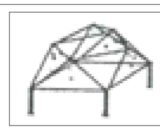
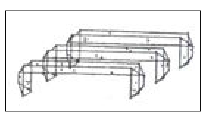
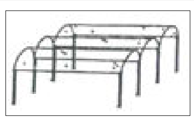
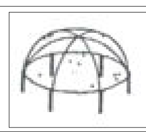
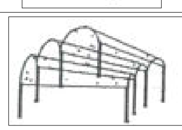
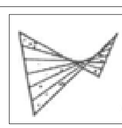
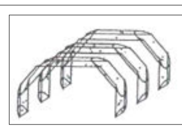
Structural System		Primary Material	Span (m)
3.1 BEAM structures		wood metal R.C.	[4,8] [7,20] [4,10]
		glued wood metal (steel) stressed concr.	[10,30] [8,25] [10,25]
		wood metal (steel) R.C.	[4,8] [7,20] [4,8]
3.2 FRAME structures		glued wood metal (steel) R.C.	[15,40] [15,60] [10,25]
		glued wood metal (steel) R.C.	[15,45] [15,65] [10,25]
		glued wood metal (steel) R.C.	[20,50] [20,70] [15,30]
3.3 BEAM GRID systems		glued wood metal (steel) R.C.	[12,25] [12,25] [8,18]
		glued wood metal (steel) R.C.	[15,30] [15,30] [8,20]
		glued wood R.C.	[10,20] [8,15]
3.4 SLAB structures		wood R.C.	[0,5] [0,6]
		R.C.	[7,15]
		R.C.	[4,9]

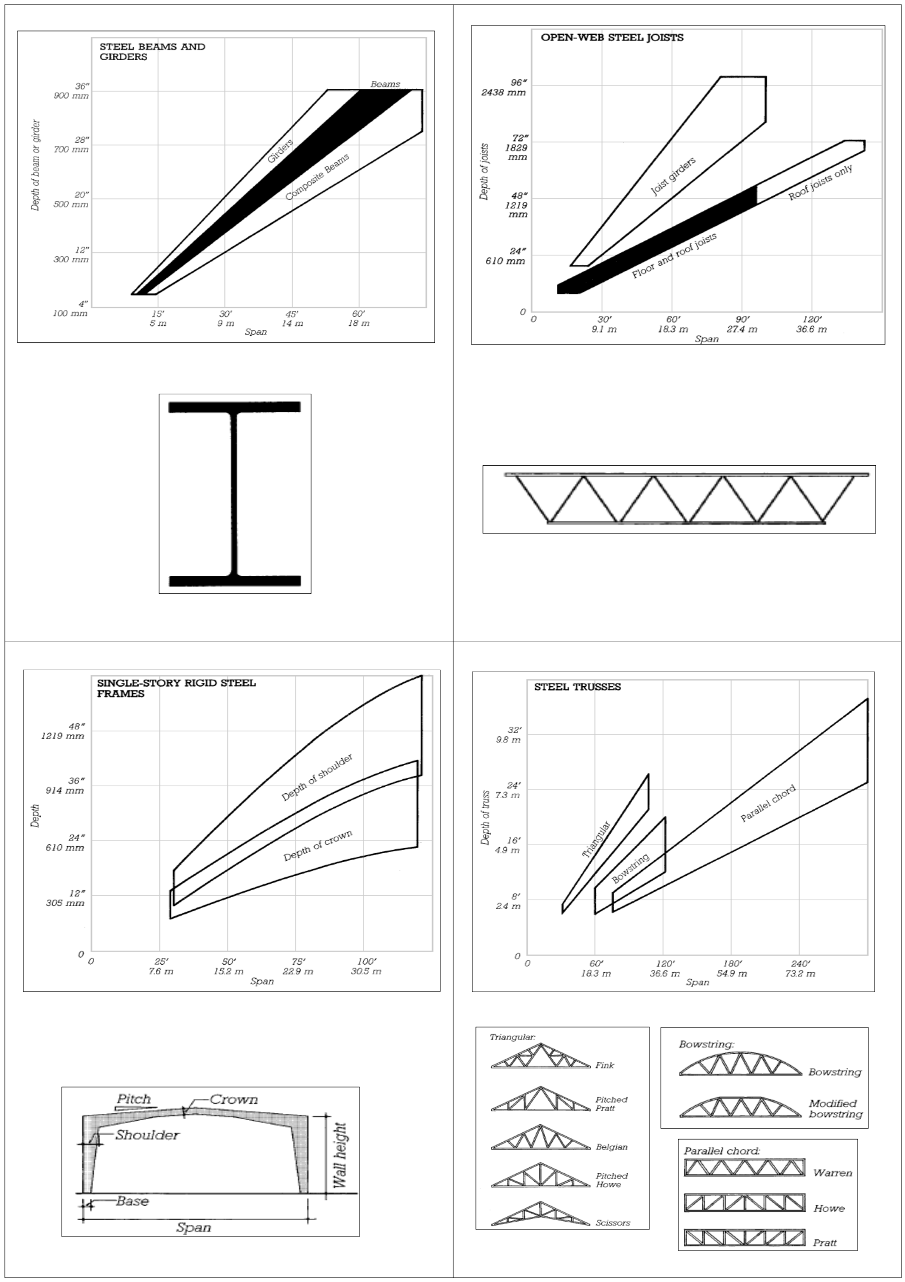
Table 27: Span limits of various structural systems (continuous)

Structural System		Primary Material	Span (m)
4.1 PLATE structures		R.C. wood	[10,40] [8,30]
		R.C. wood	[15,50] [10,40]
		R.C. wood	[8,20] [5,15]
4.2 FOLDED PLATE structures		R.C. wood	[15,50] [10,40]
		R.C. wood	[25,150] [20,120]
		R.C. wood	[25,80] [20,60]
		R.C. wood	[20,70] [15,60]
4.3 SHELL structures		R.C.	[20,60]
		R.C.	[40,150]
		R.C.	[25,70]
		R.C. wood	[25,60] [20,50]
		R.C.	[25,80]

Depth/width ratio in structural systems

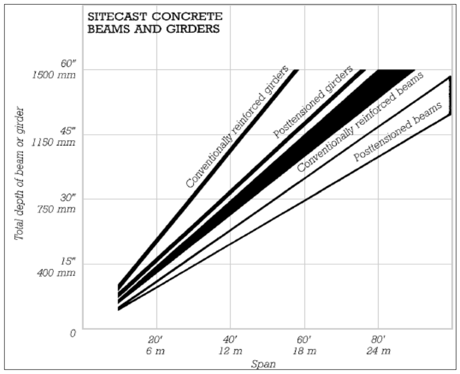
There are some diagrams[17] indicating depth/width ratio in structural systems presented bellow (Allen & Iano, 2002);

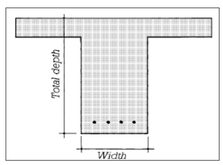
Table 28: Depth/width ratio in structural systems

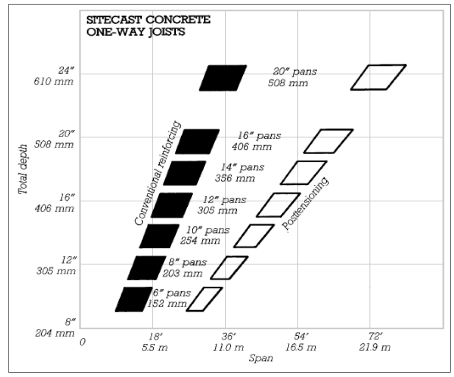


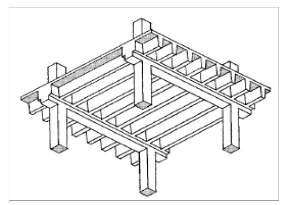
[17] From the book 'The architect's Studio Companion, Rules of Thumb for Preliminary Design"

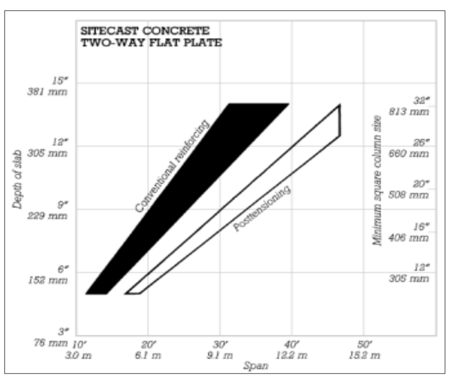
Table 28: Depth/width ratio in structural systems (continuous)

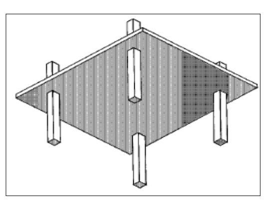


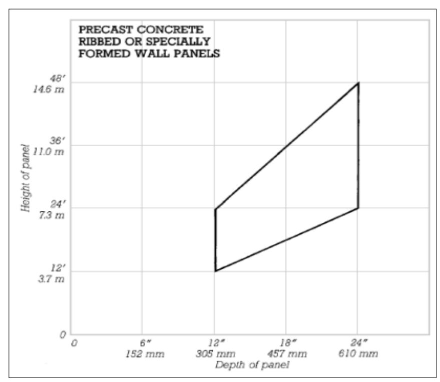


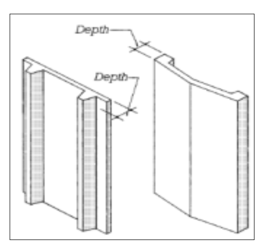












Chapter 6

CONCLUSION

Structural and technological principles of architecture education have been always attended as factors which donate structural stability, constructability, and also beauty to the building design. Considering structural disciplines of design as integral and inseparable design elements provide unity and harmony to architectural projects and ignoring them result in improper projects.

This research argues on essential roles of architectural education systems in giving the necessary knowledge of structural design to architecture students. The investigation has been done with focusing on existing architecture curricula and literature and considering EMU architecture curriculum as a case study. Consequently, a series of suggestions have been made and some clarifications have been done on the school policies in relation to structural taught.

The following list is presenting the suggestions and proposals which are made for enhancement of quality of teaching of structural principles of architecture curricula and insure the implementation of necessary structural principles within architecture curricula;

a- Structural principles within the design studios:

- Specifying one year of design studio focus on structural and practical issues of architecture (this will include integration of structural principles into design concepts. In this period application of regulations into design projects are also required.

b- Integration of theoretical structure and construction courses into design studios:

- Emphasizing and focusing on standard data of building structures which should be attended by architects and encouraging and assisting students to use structure hand books of architecture.
- Teaching different structural systems, structural materials and methods of estimation of structural members' size to students. Then students should be asked to apply these taught into their design projects.

c- Prerequisites of structural and technical aspects of design:

- Insertion and addition of some concepts related to mathematics (especially calculus), physics and chemistry into structure and construction courses.
- Testing the ability of students in handling mathematical and analytical topics through qualification exams before the first semester of architectural study (revision of entrance regulations of EMU).

d- Duration of bachelor architecture education:

- Extension of duration of architecture curriculum of EMU from 4 years to 5 years (10 semesters of study), this can be done by the addition of one year colleague study.

e- Starting semester for structural studies in architecture curricula:

- Starting the structure related courses from the 2nd semester of the architecture curriculum

f- Knowledge of structural and practical issues of design in EMU architecture instructors:

- Considering minimum 2 years of practical training in an architectural office or dealing with construction of real projects, for the applicants of instructorship, as a necessary condition

g- Information Technology (IT) and the new potentials in architecture pedagogy:

- Preparation of an online learning environment for architectural education as a supplementary teaching tool

h- Clarification of architecture schools' policies in relation to structural principles within the curricula:

- Clarifying the school policies which one of its items would be the role and level of structural principles and practical issues within the curricula.

Within the suggested items, the role of Information Technology (IT) in teaching of structural concepts and preparation of an online learning environment is specifically attended. It has been discussed that IT and its new potentials can be effective and beneficial for teaching in design studios and can be advantages for both students and instructors of architecture. Consequently, an online learning environment called ALEST (Architectural Learning Environment for Structural Trainings) is suggested as a complementary teaching tool for design studios. This virtual environment offers the following opportunities for students:

- Students can have access to explanations, tutorials lectures and also standard structural data of structural concepts.
- Opportunities of communication, collaboration and exchange of information between students and instructors through ALEST environment. Having the

chance of asking questions and receiving answers from the teachers and the archive of these data are the benefits provided for students.

- The SCP (Structural Counselor Program) is suggested as a sub function of ALEST environment. This online program acts similar to a structural engineer counselor for architecture students. It helps them to estimate and define the proportions and dimensions of structural elements.
- The most important specification of data presentation in ALEST environment is that information are explained in a classified and organized way. Thus, students can have access to categorized information related to structural topics such as classification of structural systems and classification of structural materials.
- Structural systems classifications (presented in chapter 5) are compiled and mentioned in this research as a sample of classifications in the ALEST environment. The categories and presented items are supported with illustrations to provide more clear ideas for the users.

The main specification of the suggested environment of ALEST is the visibility and transparency of information for the whole users. Information and activities are arranged to be sharable within the students and also instructors.

Ultimately, the suggestions for providing improvements in architecture curricula (including architecture curriculum of EMU) and also the proposition of online environment of ALEST are aimed to enrich structural knowledge and abilities of students.

Suggestions for further researches

In chapter 2 of this thesis some curricula from universities around the world are selected and studied to understand the structural and technological principles covered within their curricula. It is suggested for further studies to select more universities from various parts of the world and study, compile and compare their main themes in order to get more accurate and detailed information and analysis.

Another suggestion for further researches is development of ALEST environment (explained in chapter 4). Preparation of the whole components of online learning environment of ALEST requires precise studies and indebt investigations through existing documents and data. It is suggested for the further researches to concentrate on definitions and classifications of building materials, construction techniques and also structural theories. It is recommended to support the definitions with some video and audio explanations.

As further suggestions for enrichment of ALEST environment, development of the (Table 25) mentioned in chapter 5, is specifically recommended. This table explains the suitable structural systems for each building type. This definition needs further enrichments and supports from existing documents and study of existing building structures.

In order to develop the domain of online training in architecture, some other online learning environments can be proposed as well as ALEST for different architecture curricula; such as online learning environment for Urban Design and History courses. There can be a link from those environments to ALEST as well.

Increasing the domain of usage of ALEST environment to different universities and architecture education organizations through European Union is also suggested for further developments. This can provide the opportunity of collaboration and exchange of information and experience within more number of architects and students.

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APPENDIX

Questionnaire Taken from EMU Architecture Students

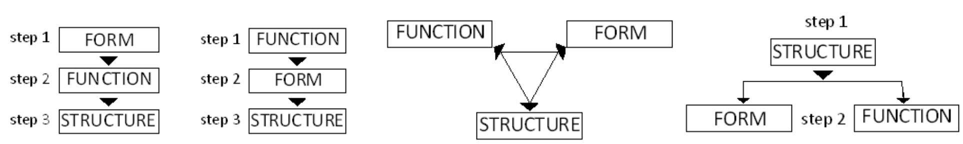
EASTERN MEDITERRANEAN UNIVERSITY
FACULTY OF ARCHITECTURE
MASTER THESIS QUESTIONNAIRE

Thesis title: Structural principles within architectural education
Researcher: Ghazaleh Mokhaberi

This questionnaire is designed to investigate necessities of teaching structural concepts within architectural education in undergraduate level. It also explores the consequent results of these teachings in professional life of architectural students. I would be grateful if you state your ideas and experience by means of this survey.

Comments on form, function and structure

1-The diagrams sketched below are some proposals for architectural design process. Which one do you prefer more to achieve a successful design project?



a-☐ b -☐ c -☐ d -☐

e-☐ It depends on the situation f-☐ none of them

2-How do you evaluate the quality of teaching concepts related to **function** in EMU faculty of architecture?

a- very good b-good c-fair d-poor

3-How do you evaluate the quality of teaching concepts related to **form** in EMU faculty of architecture?

a- very good b-good c-fair d-poor

4-How do you evaluate the quality of teaching concepts related to **structure** in EMU faculty of architecture?

a- very good b-good c-fair d-poor

Curriculum (teaching program) of architecture

5-Teaching of structural concepts to undergraduate architectural students should start from which semester?

Before first semester (e.g. Colleague period) 1st 2nd 3rd 4th 5th 6th 7th 8th

None of them

6-Architectural students should learn their structural thought ………….

From design courses

From structure specific courses

Both above options

None of them

7-How do you evaluate the teaching quality of following courses to architecture students in EMU faculty of architecture? (√ the answer please)

	Very good	Good	Fair	Poor
Mathematics				
Physics				
Structural courses				
Construction courses				

8-How do you evaluate the effect of following courses into design studios in EMU faculty of architecture? (√ the answer please)

	Very helpful for design studios	**Helpful** for design studios	**Not particularly helpful** for design studios	**Not helpful** for design studios
Mathematics				
Physics				
Structural courses				
Construction courses				

Ability of students to solve structural problems of their design projects

9-How do you evaluate the existence of structural resource books for architects and architectural students to get enough knowledge of structural design which can help them in design projects?

There are enough resource books from this type.

There are some books from this type, but they are not respondent the whole questions of architects.

There are some structural resource books, but they are mainly useable for structural engineers and not architects.

There is not any book from this kind.

10-How do you evaluate the ability of EMU architecture students to define the following items in design studios? (√ the answer please)

	Very good	Good	Fair	Poor
Selections of suitable structural systems for selected forms				
Selection of suitable material for selected forms (e.g. steel, concrete, wood, composite material)				
Defining the approximate size of structural members (e.g. size of beam, column, slab thickness, cantilever length)				

THANK YOU FOR YOUR ATTENTION

Additional comments from the respondents: ……….