Journal of Engineering and Applied Sciences 12 (Special Issue 6): 7843-7848, 2017
ISSN: 1816-949X

Practical Concepts of Structure for Architecture Students

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Abstract: As architecture, structural instruction in traditional communities was based on person to person or master and apprentice instruction system. In the late 1940's, by gradual establishment of first architecture school in Iran, traditional methods of architectural instruction were disappeared and "master-apprentice architect" was replaced by "academic architect". So, instruction of technical topics, especially, structure and statics have been always among concerns of universitie's administrators and educators. To design an instructional model, five factors are important: instructional goals, instructional status, instructional contents, instructional method and tools and evaluation. If proper and practical contents are not transferred to students, it will cause confusion and discouragement for learning continuance and a question always will come to student's minds: what are presented subjects by teacher for? Therefor, the main concern of this article is attaining structural practical concepts in architecture. First, current article restates importance of structure at architecture and states structural instruction's problems. Then according to Iran's Ministry of Science confirmed topics, proper and practical structural concepts for architecture students are suggested. The purpose of study is to increase structural instruction's quality for architecture students by presentation of practical contents. The study method for attaining practical concepts in this article is quality-based and it is of case study kind. By analyzing structural and architectural typical samples, structural theories which are practical for architecture design will be derived and these theories can be used as structural instruction basis for architects.

Key words: Structural instruction, structure in architecture, instructional contents, statics, analyzing, traditional

INTRODUCTION

From structuralism point of view, architectural space comes to existence by interaction between human and environment which is considered as a technical or artificial totality. Components of an architectural space are human, form and environment. Generally in this system, structure protects element's form and system totality and it is the main factor of space definition and territory security by the mean of fabric (Engel, 1997). The most important aspect of structure is helping the architecture and then the most important aspect of architecture is its positive influence on human patterns but not to overshadow it. When the structure merges with space in a compatible way, when the engineering improves space's sensational dimensions, then the architecture and the structure merge into each other. The line drawn on paper is a reflection of human's sense which comes to reality at three dimensional space and structural system is a medium to adjust, produce and improve human's senses (Wilson, 1983).

As architecture, structural instruction in traditional communities was based on person to person or master and apprentice instruction system: a slow and longtime instruction, face to face and surely with deep influence of master's behaviors, manners and style on apprentice. Limitations of traditional communities in different fields and also their social circumstances supplied enough time for such long time and of course slow instructions. But by occurrence of vast social and scientific evolutions especially in the 19th and 20th centuries after industrial revolution, instruction methods were also changed. In the late 1940's, by gradual establishment of first architecture school in Iran, traditional methods of architectural instruction were disappeared and "master-apprentice architect" was replaced by "academic architect" (Hojat, 2004). So, instruction of technical topics, especially structure and statics have been always among concerns of universitie's administrators and educators. Nowadays, structural instruction system obviously seems to be inadequate for most architectural students which can have bad consequences. From several aspects,

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importance and necessity of structural instruction and its role in architecture can be considered. Regarding to preparation for facing professional work environment, recent decades can be mentioned that engineering profession has been transformed in all different fields and its consequence was inconsistency and inadequate unity among different engineering groups. Regarding to separation between structure and architecture, Engle's standpoint can be implied; the structure's importance in architecture is stated as the main and unique medium of creating form and space. Because of this feature, the structure is considered as the most basic part of human's environment formation. To be systematic, the structure is in consistent with natural sciences. Therefore, among architectural design's members, the structure is considered as an absolute norm. The structure gets different shapes by its relation to architectural form to be visible. It can be completely hidden by the building's form also it can be the building form, i.e., the architecture, in other hand, the structure gives an identity to designer's creative aim for uniting form, materials and forces (Engel, 1997).

But the necessity of structural instruction regarding to costs and economic matters is also important. For the lack of student's involvement with practical structural topics and lack of their experience in real or half-real environment, they have not enough knowledge at the time of graduation to face professional environment and some of architectural and engineering companies dedicate some time to instruct graduated students which is costly and at massive level it can push unnecessary costs on government (Soleymani, 2012). Lack of attention to structural instruction itself causes fading out of the architect's role. If the architect can't use his structural knowledge in interaction with structural engineer during designing and building, he/she can't adjust space's concept according to structural developments and most activities especially at structure and building fields move to engineer's district which causes improper consequences such as separation between structure and space (Zaekesh, 2005).

The other importance of structural instruction is related to practical structural concepts transformation to students. Proper methods for students contacting scientific topics may be less useful for students with less theoretical studies such as architects. This problem is especially obvious in structural analysis instruction to architecture students. In fact comparing to some other students, architecture students are less interested in mathematics and they mostly use visual, quality-based and creative methods (Pedron, 2006). Therefore, one of the most important factors in structural instruction to architects and causes instructional design's inefficiency if neglected is instructional contents which is considered in this study.

THE PURPOSE OF STRUCTURAL INSTRUCTION

One of the most important concern which structural instruction teachers are always faced by is which topics and concepts of the structure must be instructed to be useful for architecture students. So firstly, a question must be answered: What is the purpose of structural instruction? Or in other words, why architects must be taught about structure? Along with this, different theories have been stated but all of them can be collected in three categories. Structural instruction to architects has three main reasons: first, the architect to be able to solve structural problems; second, the architect to be able converse more intelligently with structural engineers and to discuss better and at last, the architect to be able to use structural theories in architecture designing which results in more logic and beautiful designs (Ochshorn, 1990).

The first reason architects need to solve structural problems such as the determination of tension distribution is calculation of beam and column's dimensions. Regarding this, two points should be mentioned: first, structural problems are really so simple and commonplace that will never be used in real world and second to design simple structures, complicated calculations are not needed, because tables and diagrams of approximate calculations are categorized by structural engineers to this aim, so that, architects can use them for locating and approximate dimensions of structural members in architectural designing process (Ochshorn, 1990). Calculations taught to architecture students in structural lessons, not only don't help architecture students but also cause superficial understanding of structural concepts and merely results in learning of some formulas and as they won't be used on next courses, they will be forgotten (Vaziri, 1991). So, using structural calculations as the main point of structural lesson's contents can't be a proper choice. But in other hand, they can't be completely omitted from instruction process, because to form a structure and to make proportions right, the architect must follow sensational methods by mathematical solutions in some cases (Sha'bani, 2010). Thus, it is better for students to become acquainted with basic calculations such as balance and torque equations and structural stability principles, so, they can be used alongside with main contents of lesson for more creation.

The second reason which structural instruction follows, relates to architect's ability increasing, so that, at

least they can converse with structural engineers in future. As in most building projects, the architect play as designing group's leader, he/she must have enough knowledge about other sciences to he/she can contact with other engineers for designing problems. Architects must at least know about some necessary keywords such as moment,shear, transformation, etc. (Shaeffer, 1980). The last reason of structural instruction to architects is giving the ability of presenting logical and beautiful design. To reach this, first practical structural topics must be determined so that by them increasing aesthetic aspect of architectural fabric and influence on building's form become possible.

STATICS LESSON TOPICS IN IRAN

At first, structural concepts and topics aimed by Iran's Ministry of Science are presented, then parts which can be useful for architectural designing are completely analyzed. According to enactment 365 of programming supreme council meeting, the main purpose of statics lesson is acknowledgment of forces and acquaintance with various treatments and its rules. This council categorizes statics lesson topics in six districts of understanding and applying forces, balance and determination of reactions, determination of internal forces, natural structures and shearing features (Anonymous, 1998).

Understanding and applying forces: Explanation of some definitions on forces understanding topic and introducing force on area and force's resultant, crossover forces on area, undefined forces on area, combination of forces, analyzing of forces, force balance.

The structure: Understanding of structure, bases, balance between two materials, stability, specificity, degree of indeterminacy in different methods of stability determination (truss, arch, frame and compound structures).

Balance and determination of reactions: Understanding various kinds of loads, applying balance equations, using auxiliary equations, determination of reactions in determined structures.

Determination of internal forces: Determination of trus'ss internal forces, shearing and bending forces of beam, drawing beam's shearing and bending diagrams and approximate drawing of the structure.

Natural structures: Consideration of force and form in nature, consideration of force's movement in natural structures, form's analysis in nature and simulation of natural form by statics definitions.

Shearing features: Determination of various surface area, determination of area's center, understanding and calculation of statical moment, understanding and calculation of inertia moment, understanding and calculation of shearing module, understanding and calculation of Radius of gyration.

PRACTICAL STRUCTURAL CONCEPTS

To attain practical structural theories, case sample analysis was used in this study. In this case study, the designer has reached to an exquisite and beautiful form which has structural and economic logic. In this part, applied theorie's study is derived and categorized into five parts:

- Concept of structural member's internal forces
- Center of area and center of gravity
- Inertia moment
- Bending and shearing diagrams of structural members
- Stability of structures

In the following, above mentioned topics will be considered and their practical approaches will be presented.

Student's acquaintance with internal forces of members such as tension, compression, shearing and bending have several advantages, first, if students understand the features of tension, compression and bending members properly, they can use dimensions and proportions of structural members correctly during designing. For instance if the student knows that tension members don't need much thickness, he/she can use this knowledge for parts of designing which need elegance (Moore, 1998). On the other hand, by knowing about tension, compression and bending members in structure, the student can choose proper positions for them in his/her architectural designing. For example, if it is supposed that a ceiling to be carried by a member, two solutions are possible: supporting the ceiling from upward by a tension member or supporting the ceiling by from downward by a compression member such as stud. Now if the student knows that a compression member is prone to buckling and that for solving this problem, the member's dimensions must be increased, he/she can decide more properly for choosing the kind of structural system.

The second topic which can be useful for students is centroid: center of gravity. If the architect knows that the center of gravity and center of rigidity must be near each other so that the building doesn't get torsion, plan's geometry won't trend to a complicated geometry without reason and radically during designing (Ochshorn, 1990). Knowing about the center of gravity in structural

members can be useful when facing forces on structure to have a creative solution. For example in Alamillo bridge's designing, Calatrava neutralized thrust of the bridge's deck supporting cables by expelling the center of gravity of mast from pier (Moore, 1998). Another usage of the center of area is for member's shearing area which shows the neutral axi's crossing point and if the student can recognize approximate point of neutral axis on shearing area, he/she can increase the member's stability creatively during designing of a structural member (William, 1977).

Third part of practical topics for students is concepts of moment of inertia which has two parts: computational and conceptual. To better understanding of the conceptual part of inertia moment, using computational part is need to some extent. From Salvadori's point of view to more completely understanding of structure and its concepts, computational tools must be used (Moore, 1998). One the most important instructions for understanding inertia moment is helping students to choose the best cross section for structural members and at higher level it can cause creation for designing proper and beautiful cross section (William, 1977).

Acquaintance with increasing moment of inertia techniques results in solutions for improving bending stability of structural members and these solutions are unknown till being created by architects during designing. By knowing how the moment of inertia can be increased, students can design structural members with creative and beautiful forms and proportions. One of the most famous samples in which moment of inertia has been used completely creatively to attain structural and architectural desires is the building of Renault factory designed by Norman Foster. By taking advantage of his knowledge and by using bar and cable, Foster has reinforced bending strength of beam from the middle of span. This approach in addition to reinforcing the beam has made the structure better aesthetically and added stylized sense.

One of the most important and significant structural concepts which its usage is obviously seen in architectural designing is understanding of bending and shearing diagrams of structural members. In most cases, prominent architects have reached to optimum and elegant forms from bending diagram of structural members. Like the ceiling of UNESCO Conference Building in Paris which is designed based on bending diagram by Pier Luigi Nervi. The designer has controlled the bending creatively by increasing height of foldable sheet and arching the ceiling in where the bending is maximum (Moore, 1998).

Another famous sample which has been designed by bending diagram pattern is Forth Bridge which is completely designed based on bending diagram (Anonymous, 1890). In Forth Bridge's designing which has several spans, the designer had to draw bending diagram firstly, then wherever the bending was zero, material's mass must had been decreased to change it to a hinge and at last the totality of bridge became like a Gerber structure which is economic in addition to being stable against lopsided subsidence (Fig. 1-4).

The last part of structural concepts which can be useful is structural stability. If the student doesn't know about structural stability circumstances, he/she may by error use an unstable and non-optimum structure in his/her designing. In other hand, knowing about stability brings the opportunity of designing various structural

Fig. 1: Neutralize the thrust cables by weight of the mast

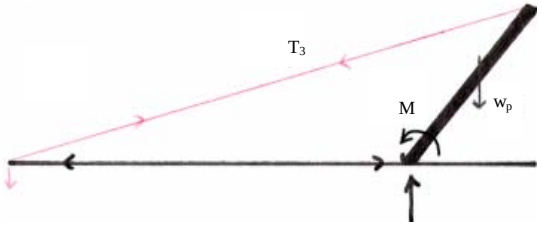

Fig. 2: Free-body diagram of forces

Fig. 3: Increase the bending strength of beam

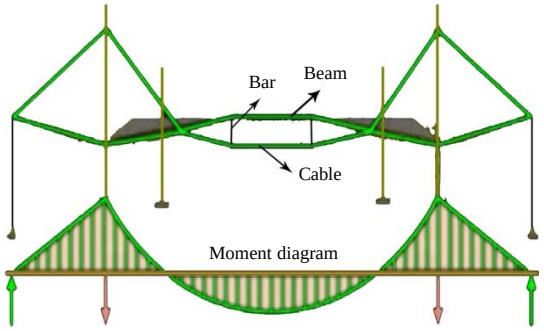

Fig. 4: By using bar and cable, foster has reinforced bending strength of beam from the middle of span

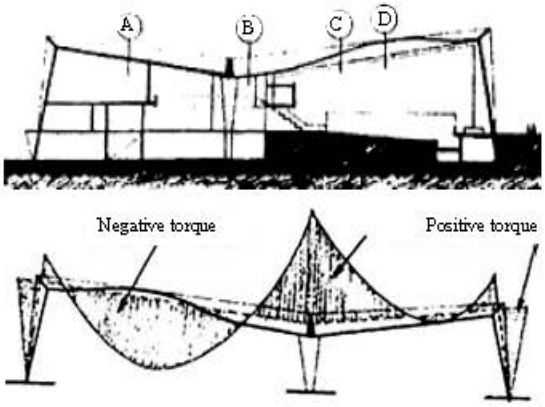

Fig. 5: Ceiling of UNESCO building designing based on bending diagram

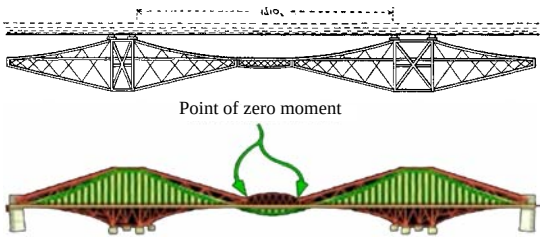

Fig. 6: Design of structure based on bending diagram

forms which are well-proportioned and elegant. For instance if we know that a frame is stable minimally with one hinge, we can use different states of frame for architectural designing (Charleson, 2008). One of the most important samples reached properly to an elegant and creative form by frame's stability is Lyon's metro station in France. Based on bending diagram, Calatrava who is himself a structural engineer has designed concrete frames which are elegant architecturally and optimum structurally (Fig. 5-7).

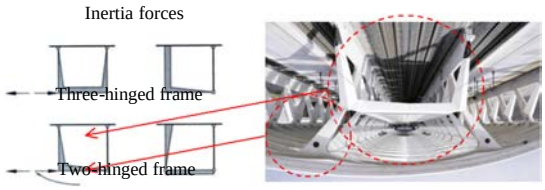

Fig. 7: Various forms of frame designed based on stability; concrete frames which are elegant architecturally and optimum structurally

CONCLUSION

To design a structural instruction model, purposes, method, tools and educational contents. One of the most important problems which causes discouragement and unwillingness for learning structural concepts by architectural students is structural lessons which have more computational topics than graphical and designing aspects and the student is always struggling in his/her mind that how will these concepts be applied in architectural designing. This study showed that to reach practical theoretical concepts of structure, structural analysis of prominent samples in architecture and structure can reveal which concepts are more practical for designing and which can succeed from theoretical level to practical level.

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