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# Comparative Study on Architectural Contemporary Schools Based on Interaction of Form, Function and Structure

**Mohammadreza Ranjazmayazary*, Akbar Abdollahzadeh Taraf and Mohammadjavad Mahdavinejad**

*Tarbiat Modares University Faculty of Art and Architecture, Azarbayjane Sharghi IRAN, Islamic Republic*

## Abstract

The aim of current paper was to study the role of structure and structural thinking in the architectural design process in the three contemporary architectural schools. Paying attention to the structure along with other components of architecture (i.e. form and function) is of great importance in the architectural design process. Such attention in the past by the architects caused unity of the structure with other components. In the current era, development of the sciences and technology in different fields such as architecture and complexity in design and architecture has caused professionalization of different stages of design process. Hence, the professions such as structure engineering and architectural engineering have required static thinking and establishment of the structure, to loose structure unity with other architectural components, at some cases. In this paper, since structure influences and is influenced by the tow components of form and function it was tried to study their triple relationship in the form of three contemporary architectural schools (i.e. modern architecture, High-tech architecture and deconstruction architecture). To do so, a triple theoretical model was developed in order to explain the relationship among three components of structure, form and function. The research method of the study was descriptive-analytical. Hence, first the relationship among these components was described in each school with focus on the issue of structure. Then relying on the content analysis method and referring to written and visual resources of architectural example of each school, it can be concluded that modern architecture focuses on separation of form and function from structure, deconstruction architecture emphasizes on the issue of " structure follows form" and in the high-tech architecture structure is a determining factor in formation and construction.

**Key words**: Structure; Form; Function; Structural; Structural design; Contemporary architecture

## Introduction

Structure in architecture is the first important issue in establishment of the space. Paying attentions to structure along with the two other fundamental factors (i.e. form and function) is of great importance in design and construction process of a building, an attention which necessitates synchronization of structural building during design process. In the past, synchronization of design and construction of a building inspired by spatial and time condition of each area would resulted in a unique unity in tangible achievement of these architectural components.[1]

At the same time with industrial revolution (i.e. since 2nd half of 18th century) and development in different fields of sciences such as science of structure engineering, the architecture went away from the new structural applied science and such lag caused architecture to lose its dominance on the materials and structure of the new buildings such as grand hall of the exhibitions, stores and big roofed factories and other types of large scale engineering buildings and even it sit back from work space in favor of structure engineers [1]. In this regard and to eliminate the created gap the architecture and structure engineering, it seemed necessary to develop a new line of architectural education and to accompany it with curriculum which would increase perception and analysis power of the structure behavior by the architect. With continuation of such approach and with investigation of architectural examples such as Nervy, Fuller and Calatrava's works, sometimes such closeness reaches a place where bordering between architecture and structure engineering seemed void.[2]

In this paper, due to influence of three factors of structure, function and form on each other, it was tried to explain triple relationship among them in the form of contemporary architectural design schools and analyze degree of attention paid to each component in several index buildings of the contemporary architecture. Most of the architects follow the aim of architecture in determining form and function. The designers have all the time confronted the question that: which one of these two fundamental factors would start architectural design? It seems that in some cases of the contemporary history, some architects believe that structure and structural thinking is considered as the last stage of design process. This might be due to excessive reliability of architecture to the developed science of the structure which makes it possible to build every form of the building. The aim of current paper was to explain the role of structure in architectural design process in the contemporary architectural schools. In this regard and in order to achieve the research objective, finding answer to the following questions seems necessary:

1- Which one of the above mentioned factors (i.e. form, function and structure) does play important role in the contemporary architectural schools?

2- In which of the studied architectural schools the relationship among above mentioned three factors has much unison?

[1]The issue can be easily seen in the traditional architecture of Iran especially in Seljuk's period and in the world architecture especially in the Gothic period.

[2]This refers to works of architects such as Pier Luichi Troy and Buckminister Fuller.

***Corresponding author:** Mohammadreza Ranjazmayazary, Tarbiat Modares University Faculty of Art and Architecture, Azarbayjane Sharghi IRAN, Islamic Republic, Tel: 989123269123; E-mail: mr_azar83@yahoo.com

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3- What was the effect of structure and its developments in facilitating functional relations and designing various forms in the schools?

## Research Methodology

The research method of the current study was descriptive-analytical. This research, firstly tries to describe each of three contemporary architectural schools (i.e. deconstruction, high-tech and modern schools) with focus on the structure. Then based on content analysis approach, architectural photos and plans, it proceeds on the relationship among three factors of structure, form and function. Finally, the importance level of each component was explained in each of three contemporary schools. The study cases selected from modern architecture were Insurance Building of Chicago, Domino's Home and Villa savoye building. The selected cases for high-tech architecture are Hong Kong Bank, P.I Building, Milwaukee Museum and South Street Building and for deconstruction architecture Guggenheimmuseum building and OpenHouse for Malibu were selected. Hence, following diagram was drawn to explain the process (Figure 1).

## Description of the Terms

By the term "structure" in this article we mean its common sense, being defined as holding frame of the building. If it is eliminated, the architectural building will lose its stability and by the structural form we mean the main structural system of the building or structural system which is dominant visually.

By structuralism (i.e. designing based on structural approach) we mean building and holding sustainable factors of the structure in creating architectural form and facilitating functional relationships finds determining and intermediary role, as in structuralism approach where it is used to achieve form and function goal at the same time. In this kind of designing, creation of the architectural work starts with the structure concept. In this case:

1- Structural form estimates function'sobjective, not creating an obstacle to physical planning. Such structure design might involve buildings with designed columns network in line with functional walls to buildings with new structures which create wide spaces without obstacle.

2- Structure form determines architectural form goal. In this case architectural form indicates structure and its behavior in the building. The approach can be seen in tall buildings of Chicago school to tall buildings of high-tech architectural school.

## Review of Related Literature

The relationship between structure and architecture and their interaction does not require to be proved, however, attitude toward it and its effect on the form or building function is, undoubtedly, of great importance. Throughout history, structure has been undoubtedly an indispensable part of architectural art, in practice. Typically, in some points of history the structure was used to establish the architectural form. Vitruvius's book was among the first books in the field of theories of architecture which emphasized on the structure along with other elements such as beauty and efficiency [2].

Since historical considerations of architecture tend to introduce structure as an aesthetic element, they emphasize on medieval architecture, an era during which the structure shows itself both in interior and exterior form, trying to create optimal function and space occupation features inside the building through elimination of heavy and solid piers. Moreover, doing so, this develops structural symbolism in exterior façade of the building.

Such attitude toward the structure and its relationship with architecture shows again itself with changes occurred in the 18th century, an era when iron and glass, later, was considered as constructible materials on a large scale. When these materials of industrial era and aesthetic concepts of industry and higher strength of steel were recognized, they showed themselves more in the buildings, exhibition buildings and bridges. This can be seen more or less in the façade and structures of Crystal Palace building, car gallery of Eiffel and Sun bridge structure.

Following such changes and developments in the structure of building materials, construction technics and civil engineering, curtain walls were used in the façade of building architecture in Chicago school. Doing so, the architects were able to experience large sized windows in the buildings [1,3]. Later and in the modern architecture, with elimination of pillars from corners of the building and consequently placing windows at the corners of building, we could see development of more fluid forms of architecture, the actual formation of which can be seen in the Le Corbusier conceptual design for Domino's building. Later and after walls took distance form columns, architectural form found two main features: 1- creating free plan and 2- creating continuous glass surfaces on the building façade. "Concrete, steel, glass and timbers are the most common materials, being used in the field of modern construction" [4].

The effect of structure on the architecture developed so that the structure was seen as building form in the architecture at the beginning of first half of 20th century.

Such attitude can be seen in Nervi's works. Such changes later known as high-tech architecture caused advent of newer forms in the architecture. [5] and his architectural school advocates emphasize on the structure with aesthetic attitude in combination with technology to create an architectural work. Today organized studies have been carried out in the field of the interactive relationship among form, function and structure. Charlson in the book titled "structure as architecture" proceeds on the relationship among these three components at

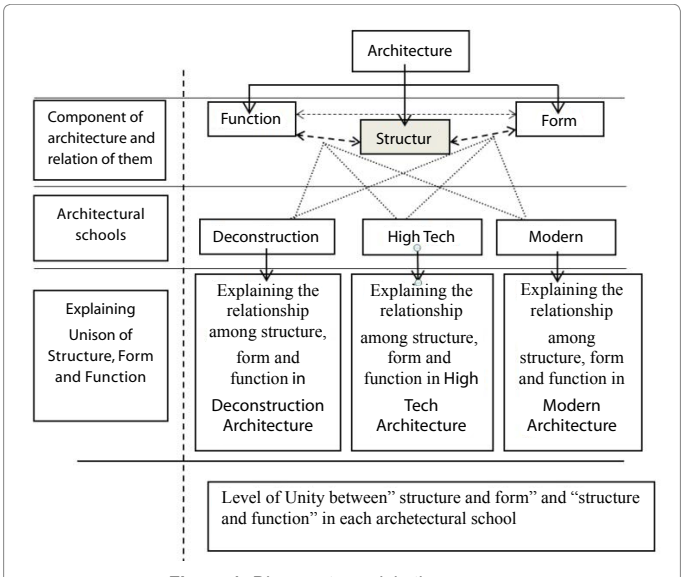



**Figure 1:** Diagram to explain the process.

different buildings, having, of course, an aesthetic attitude toward the structure in the architecture. MC Donald in his book of "structure and architecture" proceeds on importance of structure in the formation procedure of architectural work, proceeding on architectural-structural analysis through developing questions such as "what is architecture?" Holgate (1986-1996) sees structure as an aesthetic element of architecture, introducing whole architectural designing process such as creativity and whole effective factors such as political, economic, industrial considerations and functional needs of the building, showing themselves in philosophy of structure design [6-9].

## Functionalist approach, a basis for structural revolution (Modern architecture, initial modern)

At the same time with industrial revolution and especially with invention of independent steel structure the relationship among form, function and structure was changed and the traditional concept of the building changed, accordingly. On one hand, the issue of form and formalism was developed in the architecture, so that according to pierre von meiss "with the aid of 20th century's technical tools, architecture was considered as a vast freedom of form" [10]. On the other hand, functionalism and rationalism became largely interested in architecture; it was the matter that supported by trends of mathematic and logic [11]. In this period, form and function design was released form limitations of structural requirements to some extent. Such new facilities, was the result of a change in the structure which at last, such releases in the late 19th century" resulted in the new tendencies. Each tendency was showing structure unity with form and function, influence of each tendency on each other or lack of such influence.

**Form follows structure's function (Chicago School):** Chicago school can be considered as starter of such building construction. The most important buildings of the period which were mostly tall and official were implemented in 1888-1910 in Chicago. "The building had two main features: one is steel frame and the other is clear static transparency and structural performance of the building form and hence, they involved one type of innovation and transparency in the architectural words which was useful in progress of modernism [12]. The popular word of Louis Sullivan - the most famous architect of the school who considered form as follower of the function- shows authenticity of the structure in the architecture. This means that "building form should indicate the structure's function (i.e. the behavior of forces imposed to the structure) [13].

Before advent of tall buildings with steel frame, buildings with tall load-bearing walls were made where increase of the wall thickness with increase of number of floors was resulting in occupation of more area of the architectural building. This can be easily seen in the last sample of structures generation (i.e. northern angle of Monadnock 16-floor building). The wall thickness of the building reached 180 cm [14]. On the other hand such load-bearing walls had introvert state, depending on functional obligatory hierarchy. The steel frame could create a flexible and harmonious system with different functions through eliminating such thick walls. This was due to the reason that created open spaces would provide the conditions for designing spaces with different functions based on the project needs by mere functional panels in the spaces among the columns.

The 10-floor home insurance building of Chicago was among the first buildings designed with steel frame. The building was designed by William Lu Baron Jenny in Chicago (Figure 2).

**Independency of column from walls (Initial Modern in Europe):** Reinforced concrete was first used by Le Corbusier as a tool for architectural objectives, separating column (structural element) from wall. With his structural solution he created transparency and fluidity in the architecture, paying much attention to architectural performance through developing free plan; hence he could design interior parts of the houses with much variety. In these houses spiral stairs, direct or curved walls would help the plan variety. Moreover the wall found new elegance and penetration of interior space to exterior environment became possible which was unprecedented till that time [15].

Using independent column in architecture, Le Corbusier could separate form from architecture, proceeding on the form design independently. The columns are far from façade, inside the house and the roof continues in the consular form. The facades are only light weight parts made of protecting walls or windows. The façade is free and the windows can be placed from one side to another side of the façade without interruption[3] [16,17] (Figure 3).

On the other hand building design in the pilot method which would release the building land can be evaluated in line with helping functional and formic objectives.

Study of his works shows that reaching form and function objective

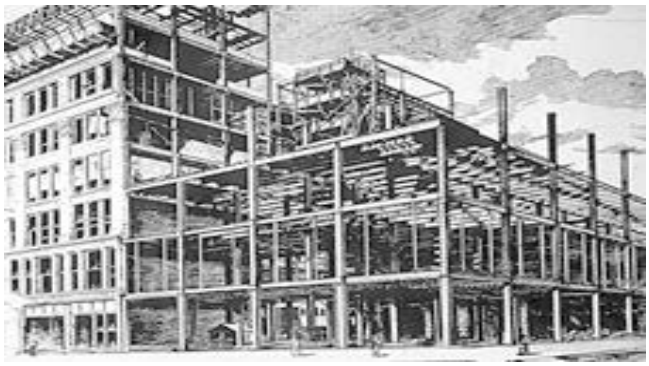


**Figure 2:** Home Insurance Building, William Lu Baron Jenny, Chicago, United States of America: the building had no load bearing wall and all weight of the building was imposed on its steels structure.

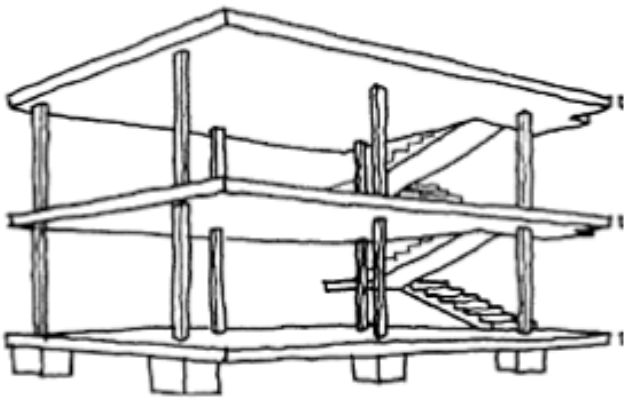


**Figure 3:** Domino's house, 1915, replacement of the column from wall to interior space.

[3]It should, of course, be noted that structure transfer before Le Corbusier, was carried out by Abraham Darbi III in the second half of 18th century at steel frame of a factory but its change to design method was developed by le corbusier.

is without structural limitations, which is accompanied with form without paying authentic attention to the structure and its combination, the goal which was achieved by Le Corbusier later in councils' palace. In this building, he reached one type of unity and parallelism between form and structurethorough combining them. The building load of the design is born by a large iron arc whichalso plays a basic role in the architectural combination. The roof of thebuilding's main hall is hold by stable and relatively thin wires hung from such big arc [18].

In spite of tendency of architectures of the period to use technology (though it was at its initial stages) unlike high-tech architecture, the architectural thinking process was separate from engineering.

## Structure is the usual expression of the form (High-tech)

High-tech architects started architectural design with structural concept. Such design method enabled them to proceed on the form and structural function at the same time. Hence, the designed structure in the high-tech buildings is not mere for stability and sustainability, rather with elimination of the structure, the form will also be incomplete, not providing appropriate function. In this type of architecture the structure (usually steel) is always visible, beinga symbol of technology. The visibility of the structure brings the issue of aesthetics, accordingly. Hence, the structure requires visual expression, undertaking usual expression of the form.

Separation of the structure from the walls causes free plan in the modern architecture, however this couldn't eliminate the voluminous columns from interior space of the building. With development of the technology, and increase of apertures accordingly and the movement started from late modern period, the conditions were provided to transfer the structure toout of the building. Hence, with the aid of technology high-tech architects could find a solution to eliminate space loss through putting the structure out of the mass (in most cases), preventing creation of inappropriate spaces beside the columns. As a result there was no separator and all functions were designed in a wide space without wall. In this type of architecture most of fixed elements such as external walls, roofs and structural frames could be transferred and picked.

Honk Kong Bank founded by Norman Faster is among the examples in which the structure can achieve form and function at the same time. In this building all six floors are hung from trusses with height of 1.5 floors on two rows of quaternary masts (external mass). The exclusive structural system of the bank provides completely open plans. In this building, the final form is the same designed structure and glass is the only non-structural element (Figure 4) [19].

Another example is P.I Heights Counseling Building made by Richard Rogers. In this building 9 A-shaped big steel masts with height of 18 m which have been placed in middle extension in a raw along with cables connected to big linings form the building frame. The 4000 square meter rectangular building has been designed in a way that people inside the building can see big and beautiful view of the building. Placing a glass skylight in the main axis extension the architect has provided a vision for the people inside the building to outside and the grand building. The use and practical advantage of such design is creating vast interior space without column [20]. Moreover the structural form of the building shows technical and structural development resulting in a strong visual presence of the technology. (Figure 5).

Calatrava cannot be considered as famous architects of high-tech style[4]. But his use of high-tech in the architecture caused his architecture to be discussed in this paper. For Calatrava "the structure is the factor which establishes balance among form innovation, practical rules and principles of efficiency [21] in his works, every structural element has some logical reasons and change of structural sections take place intelligently to structural requirements and aesthetic issues.[5] Hence, their form which is composed of structural elements and glass should be investigated in terms of structural appropriateness. On the other hand, structural technology provides the condition to create larger and more flexible spaces for the needed functions. The visible interior structures in Calatrava's works act like a tool in the architect's hand to create various functional space[6], so that wide tall spaces can be seen

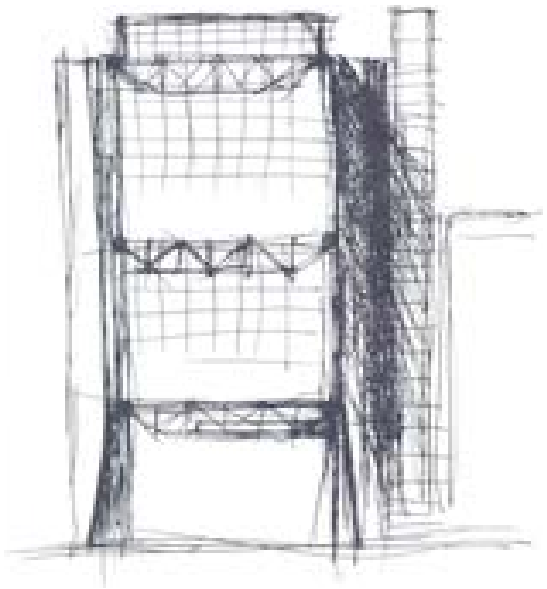


**Figure 4:** Hong Kong Bank: Scheme of façade with combination form and structure.

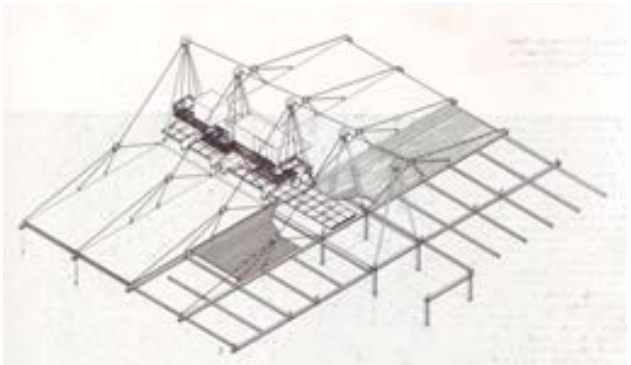


**Figure 5:** P.I building.

[4]High tech is referred to the buildings which were designed in the recent 20 years by designers such as Richard Rogers, Norman Foster, Nicolas Grimshaw or Michel Hopkins who mostly used steel technology in their buildings.

[5]Of course, in some of Calatrava's works there are some hesitations about structure form output. The example of such issue is StodelHofman urban train station (Golabchi, 2012, p:172)

[6]The origin of such architectural approach in Calatrava's works can be found in the works such as T.W.A airport. Statue-like approach and its effect of interior space can be easily seen in these works.

in the main and central saloons (Pavilion of Milwaukee Museum) and short structures in the designed galleries (exhibition space of the Milwaukee museum which has concrete and arc-shaped frame with lower height). With this approach the intervention between structure andfunction (circulation and space organizing) found in the previous works (including initial modern and earlier works) was avoided (Figure 5) [22].

Doing so the unison and unity can be seen among structure, form and function at the best condition which was result of three decades of his work in the field.

## Deconstruction

According to Bernard tschumi, deconstruction means anti-form, anti-hierarchy and anti-structure and the opposite point is all principles which establish architecture [23]. With this definition it can be claimed that like other architectural elements the structure has gone out of his former structure and a different approach is taken compared to the past. In some cases such approach results in avoiding static law. When studying the works designed with this style, we come across with the tow dominant approaches [24].

**Dominance of form to the structure (the structure is a path to reach form's goal):** These are the works which consider independent personality to the structure. The building structure cannot be seen in these monuments and the form is superior to the structure. Hence, in this case, it is only the form which involves architectural sense and concept and the structure is just a hidden bed for the form. Bilbao museum designed by Frank Gary is the prominent example of such architecture. In this building, eliminating the structural cover, we come across with a forest of irons which have been implemented in the modern buildings way ( i.e. in the frame way), having no correspondence with its deconstruction form and cover as if the structure and form have been linked with difficulty. In this building, The architect conceived the form of the building using three-dimensional models without any thought for the structural behaviourbehavior [25-28].

Another type of structure bedder can be seen in the buildings made without observing structure's functional issues and with the aid of high-technology. In these buildings higher power of concrete and steel is used in the smaller aperture." Strong power of the steel to tension, pressure and its ability to bear higher levels of concentrated loads make it possible to create networks with elements' free form in smaller apertures. In the Vitra museum of Swiss(1987-1989) designed by Frank Gary, presence of strong curved forms and continuous structural surfaces, complex consular mass and limited number of openings in the building are implemented using strong materials (i.e. concrete). Such form is not created by structural considerations and the structure is not of active form type[7]. In these cases, concrete continuously bears the building load and effective forces imposed to the building and the building mass has structural role. The building is deconstruction structural mass and the deconstruction appearance of the building iscreated by the form not by the structure [29]. In other words the form here dominates structural technology (Figures 6 and 7).

**Deconstruction:** Another approach to the structure among the deconstruction architects is like the behavior of form and function to the structure. In the works of such architects, unlike previous state, the structure is not bed to achieve form's goal rather, like architectural form, it participates in the ideation process, being deconstructed. In

[7]In the form-active designs only internal axial forces are imposed to the object and there is no internal bending force (Mack Donald, 2014, p:53).

**Figure 6:** structure of the picture is associating the movement path that shows Functional attitude in the form of structure.

**Figure 7:** in this building the structure follows form being hidden beneath form layers.

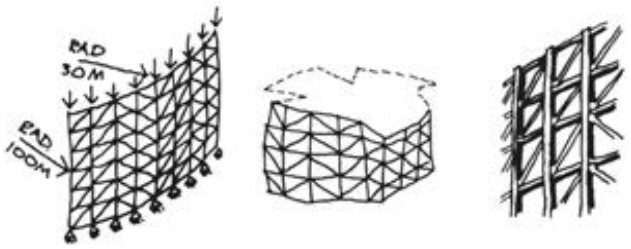



**Figure 8:** Guggenheim Museum-Structural concept and detail.

**Figure 9:** Initial Scheme of the design which has deconstructed the structure and the form.

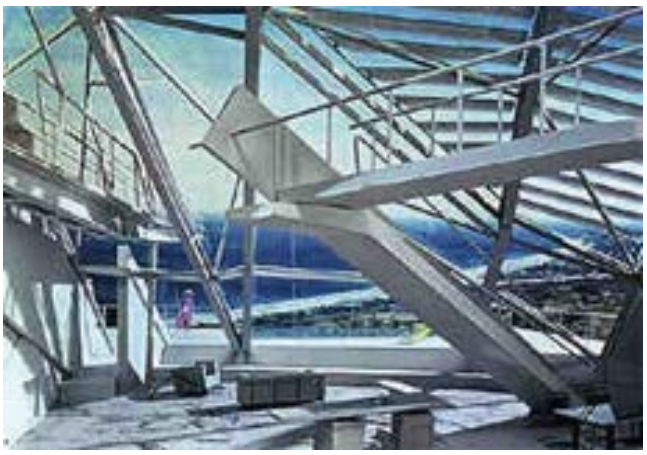


**Figure 10:** In this building, the structure is in line with architectural idea, promoting the main architectural idea (deconstructive architecture).

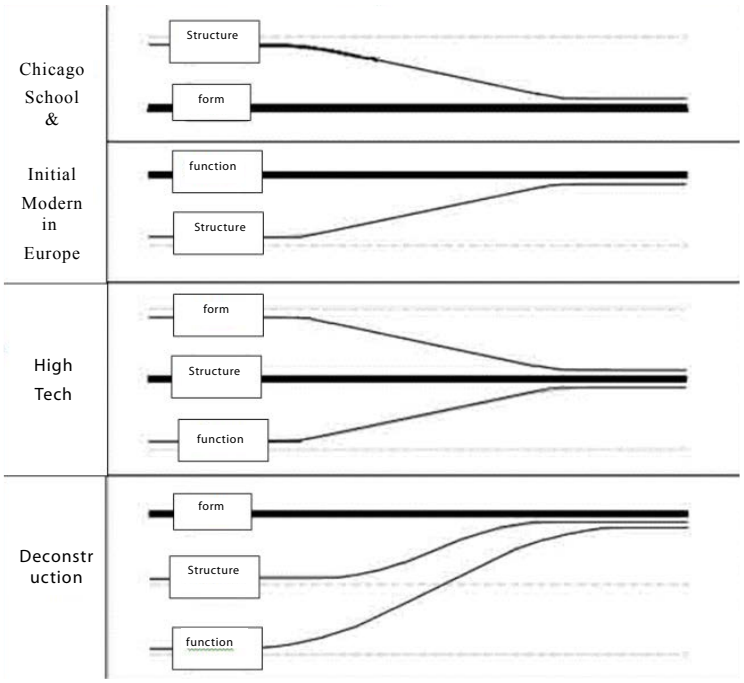



**Figure 11:** This figure shows tendency of each index in relation to other indexes with focus on the main parameter in each architectural school.

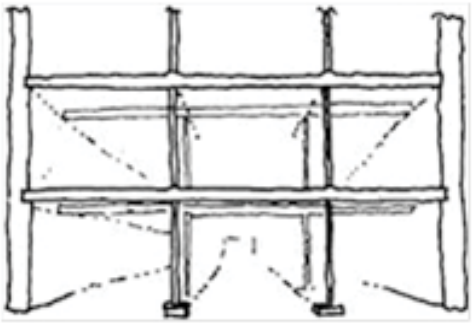


**Figure 12:** Factory with simple interior iron frame.

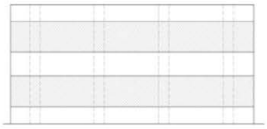
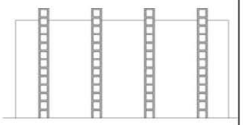
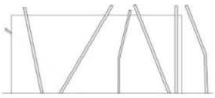
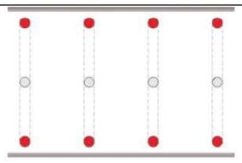
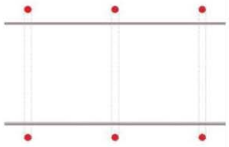
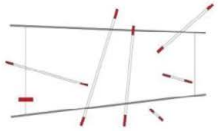
| Architectural school | | Initial Modern Architecture | | High Tech Architecture | Deconstruction Architecture | |
|---|---|---|---|---|---|---|
| | | Chicago School | Initial Modern in Europe | | | |
| Type of approach to the structure | | Seperation of form and function from structure limitation | | Structure is the usual expression of the form | Deconstructed structure | |
| Structure and form | | Visible static transparency and structural function of the building form ( the form shows structure's function) | Structure results in the form freedom (independency of the column form the walls) | 1.strcuture as the form<br>2.strcuture as the producer of the form | the structure participates in the design process, being deconstructed( hesitation in the structure and static rules) | The structure as the bed to reach form goals, being indifference to functional components |
| Structure and function | | Elimination of bearing walls(functionalism, free plan, transferring the structure to interior part of the plan) | | The structure helps complete functional flexibility( transferring the structure to external part of the plan) | Anti-function (contradiction) | |
| Graphical expression of structure in relation with | Form( Elevation) |  | |  |  | |
| | plan |  | |  |  | |
| Ordinary structure | | Concrete or steel frame | | Cable and masts frame structure, truss and spatial structure | Concrete and steel frame | |
| Index building | | Insurance building | Villa Savoye | Hong Kong Bank | Open house for Malibu | |

**Figure 13:** comparative study of structure place in the architectural design.

this type of architecture, the structure follows form. Hence, one type of following form and function's goal can be clearly seen in such architecture when treating with the structure. It is in fact questioning machine cut accuracy, its repetition and in fact machine's mechanical perfection. The roof space project of Coop Himmelblauis one example of such architecture. The structure of the project has been convoluted and unlike the common tradition it has gone out of rectangular cubic state (beam and column) (Figures 8 and 9).

But it should be taken into account that it is only aesthetic considerations of structural forms that is participated in the architectural design process, not functional considerations of the structure. This sense can be found in Wolf Prix's word who was designer of Coop Himmelblau Company. "... we want to keep the design moment free of all material constraints ...". 'In the initial stages structural planning is never an immediate priority ...'[8] [30-32].

The event can be interpreted in line with cooperation of function with deconstructive architecture goal, in other words moving toward some illogical functional decisions which are accompanied also with the structure (Figures 10 and 11).

## Conclusion

Studying three architectural contemporary schools it was tried to

[8]Whenever in creation of cut effects in a building we act in a way so that internal forces movement to be placed in an unusual path of structural components, its compensation will be possible only with spending much costs(Golabchi, 2012, p:173).

proceed on investigation of the role and place of structural technology in architectural design and its relationship with the two factors of form and function. The summary of the issue can be seen in Figures 12 and 13.

### Acknowledgment

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