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## **THE INVOLVEMENT OF STRUCTURAL SYSTEMS IN AIRPORT TERMINALS FORMING AND ARCHITECTURE**

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### **ABSTRACT**

This article involves with airport terminal building structure systems and its influence on the architectural form of the building. Airport terminal's architecture reflects the identity and the human values of the country and nation. The importance of the research can be formed in the necessity of integration of terminal buildings architectural formation and its structural systems to deliver the building as a symbolic expressive icon. The problem of the research is the lack of researches and studies about the structural systems role in achieving the expressional symbolic function as an architectural goal of terminal buildings. The aim of the research is unveiling the role of structural systems in introducing the expressional function of these buildings and its architecture, as a result, this function will show the development, special identity of country architecture and play a deep impact factor in the architecture of terminal building.

Key words: Terminal structure, Airport architecture, Structural systems, Expressive function.

## 1. INTRODUCTION

Airports are considered one of the most advanced facilities of transport across the world, its reflect the development of human civilization and show the unique identity of nations and countries. By the beginning of the 21<sup>st</sup> century, architecture of the airports entered a new era and many new technologies had been applied in airports design and construction using new forms and structural systems. Passengers terminal building is the main element and the biggest building of airport complex, it has many advanced facilities and technologies which are being developed continuously depending on the increased number of passengers every year and the new applied technology systems in airports.

Many airports terminals are designed to be architectural monuments expressing the development of the country and its prosperity, in addition, terminal building has two main functions: Being a transport node to change the mean of transport from land to air and providing spaces and areas to complete passengers processing inside airport. Complication of terminal systems and the high flexibility which demanded in it, the urgent needs for expansion in short time and the specialty of airports architecture are the main considerations which make the using of structural systems with long spans inside airport terminals one of the most essential demands in terminal design. Many international and domestic airports had been followed this direction and used a long span steel and concrete structural systems. In the same time, the modern architectural movement deals with complicated structural systems and new building materials to create an architectural form that respects the local and traditional privacy, trying to simulate the prevailing architecture in the region, and introducing this architectural form as an icon of the country which has an expressional function expresses the specialty of the local architecture.

The airport terminal is very complicated functional building because of the number and the quality of the functional processes inside it, it has to contain passengers, visitors and staff movement, luggage processing etc. In addition, technology and flexibility are playing a major role in making terminals as hi-tech modern buildings, can contain and process the increasing numbers of passengers.

**Problem of the research** involves with lack of researches and studies about the structural systems role in achieving the expressional symbolic function as an architectural goal of terminal buildings. The previous researches which deal with airport terminal design and architecture, didn't clearly show the expressional function of structural systems in terminal buildings especially the theoretical expressional level in forming these buildings, it's also didn't deal with the relationship between structural systems as an impact factor and terminal architecture as a creational result. In addition, the disappearance of deep view on this impact in the most of previews researches and focus only on the planning and operational side in terminal design.

**The aim of the research:** Unveiling the role of structural systems in introducing the expressional function of these buildings and its architecture, as a result, this function will show the development, special identity of country architecture and play a deep impact factor in the architecture of terminal building, create a theoretical form to explain the concept of expressional function of terminal building and the capacity of structural systems.

**Methodology of the research:** The used methods in the research divided to: **Theoretical method** by presenting the features of structural systems in terminal building as tools to build a theoretical form to explain the expressional symbolic function of terminal buildings, capability of these structures and showing the expressional characteristic values. **Applied method** by applying the theoretical form of the research in four international airports projects and make a deep analysis on the structural systems and used construction materials in these projects and give the final conclusions.

**The importance of the research:** Considering the integration between architectural form and function by using the ultimate structural system, a main principle in airport terminals

design and architecture. This integration will be used to achieve the expressive symbolism and iconography to the airport terminal buildings.

## **2. CONCEPT OF STRUCTURAL SYSTEMS IN TERMINAL BUILDING**

Structure design of the building is depending on a complicated structural system which creates the shape of the building and plays a big role in the construction process, this structural system developed during the planning of functions and design of the architectural form of terminal building in the design phase, each structural system has historical roots and unique features. All systems depend on the technology in that period of history and the location where its take place, constructional materials, building function, the level of complication and the possible methods to apply this system. [10]. We see logical transformation operations on the traditional structural systems and create new systems satisfying the complicated architectural demands of terminal buildings, achieving the shape volume, scale of architectural spaces and Zeitgeist demands, in maximum efficiency, accuracy and developed methods.

New developed methods are created to apply a new structural system of a certain design requirement which may will not be used in other projects and buildings, there are many examples of new creative structural systems or transformed updated old systems. Some of these systems divided according the way of forming to (Form active), (Vector active), (Bulk active) and (surface active). These structural systems are different in shape, structural elements, its methods to transfer the live and the dead loads of the building, completing the functions and dealing with constructional materials.[24]

The majority of terminal buildings construction depends on mega structural systems, because of the complicated functions and operational systems inside these buildings and the high flexibility which is necessary in the most of areas and spaces of the terminal building.

All these considerations make using of long-span mega structural systems is one of the most important demands in terminal building design and planning. The structural method of terminal building related to many factors for example the used structural system, constructional materials and the economic factor. All these factors are related to other factors too, the choose of structural system is depends on the loads which applied, the quality of functional activates and the costs of construction, so the choose will be done by following methods lead to achieve the aims of project construction decreasing costs and saving the time, in the same time create effective new ways and maximum use of constructional sources serving the expressional architectural goals. Because the Architecture is a creative phenomenon doesn't stand on absolute principles, produced according to creative views, control in it to present different architectural styles. [24]

## **3. INTEGRATION OF STRUCTURAL, FUNCTIONAL AND OPERATIONAL SYSTEMS INSIDE AIRPORT TERMINAL BUILDING**

Integration of structural and functional systems as a technological concept can be achieved by the balance and harmony between building's functions and the mechanical systems inside it. The functional integrated building is a result of correct decisions made by authorities which are in charge but the successful expressional building is a result of harmony between the architectural concept and structural system integrated with the functions of the building.

When the constructional idea becomes to reality, special expressional shape can be found be the integrated relationship between structural systems and operational functional systems in terminal building. The integration between architectural and structural design is high value in modern terminals architecture, in many cases the used structural

system merges to the architectural form to create an optimized shape. Structural system is a core of final architectural shape because it reflects the development of latest construction technologies, in addition, technical necessity demands a certain kind of construction and detail which can add a many expressional dimensions to the building. As a result, the integration of structural solutions and functional operational systems is a base of successful architecture in terminal buildings.

#### 4. THE EXPRESSIVE PRIVACY OF MODERN TERMINAL BUILDINGS

Airports are considered one of the most important and complicated buildings in the last 100 years, its don't have any competitive in function, scale and shape. In spite of its similarity to the rail stations, airports have its own volume and a huge scale makes other structures too small in front of it. Airports start as planned projects and end as integrated urban units, have many functions, continuous expansions and changing.

It's not easy integrating the new airports with the other urban and suburban unites, some airports are considered small cities, as example: Heathrow Airport which serves 63 million passengers every year which considered an integrated independent urban identity in the concept of 'airport city', with its roads, buildings and functions.

Terminal building architecture reflects the universal qualities of modern air transport, it has a technological felling balanced with regional pride of local architecture. Countries and cities prefer in airport architecture to have a common universal qualities and local specialization. [8] There activities and functions are taking place by the same time in terminal building, as a result, to design this kind of buildings, there must be a respect to cultural expression of modern life and functional expression.

The new generation of airports is different from the first generations, airports now are landmarks in the cities (such as LAX International Airport) and it do the expressional functional tasks commensurate with internal and external changes according to ordered basics and functions. *The expressional shape of the building is a result of interaction different values with the designer's view depending on many factors (structure, shape, function, technology, material, etc.).* [21]

#### 5. INTELLECTUAL LEVELS OF ARCHITECTURAL EXPRESSION IN TERMINAL BUILDINGS

The Intellectual level is following many factors effect on it, these factors can be (social, political, economic, cultural, etc.). The basic aspects in the intellectual levels of architectural expression can be defined by the following:

- 1) Zeitgeist and its influence on terminal buildings architecture, considering it a main source of inspiration. Terminal buildings architecture depends on several factors express its specialty and respect history and traditions, deal with the cultural heritage of its period in history.
- 2) Continuation of architecture shows the importance of symbols, the architectural values which achieved by using the past to create the present and the future, it can be a brief of society activity during a period of history and represented by new concepts, shown as the relationship between past and present, these symbols can be created by using a path has two directions: The designer's vision and his understanding to the present, and the vision of society and their understanding to the past. *The expression of terminal buildings is a mental activity, created by the human mind, realized by science, formed in a physical shape, its role is introducing new ideas and representing a cultural heritage in society and its identity.*

## 6. PHYSICAL LEVELS ARCHITECTURAL EXPRESSIONS IN TERMINAL BUILDINGS

To achieve an idea in reality, we must use systems and elements from reality and employ it in a similar way with values and adjectives of knowledge and human thought, these systems are in main two concepts:

### 1. Expression of constructional materials in terminal building

This includes all physical characters and features of natural and artificial materials, there is no building can stand without construction materials, it has its own systems of formation, these systems divided to:

- All these materials and technics connected in one place and a geographical area, used in different periods of history
- The new materials which created by human and its technics, these materials and technics are a challenge to be integrated with the local identity and privacy.

### 2. Expression of structural systems in terminal building

The architectural shape in terminal building can be created by different structural systems and different technics and using different constructional units and materials, but the architectural expression which been found as a result of process and integration of structural system and function, the constructional units and the feeling of human have a big role in the process of creating the architectural shape, the relationship between the shape of structural geometric systems and organic shapes in a continuous development since the building of ancient pyramids.

## 7. ACHIEVING OF SYMBOLIC EXPRESSIVE FUNCTION OF TERMINAL BUILDING

The expressional symbolic side can't only be found in monumental buildings, every human activity can express the environment, shapes, spaces and the quality or features of operational functions inside terminal buildings. Architect choose (If he can) and mix between materials and constructional systems to express the idea behind his design. Difference between symbolic and expressive function are:

**Symbolic function**, a need of human, in the same time an important element of human identity, symbolic in this concept element unites with other elements and creates his identity and the human can pronounce his identity by it.

**Expressive function**, a presentation of buildings functions by its physical shape, it can do it clearly where facades can express the building functions in words, and this mix between function and shape can be defined as expression.

So we can find each of symbolic and expressive functions in terminal buildings to be a mean of expression and delivering a clear important message, Architecture is logical art and the shapes of terminal buildings depend on its structural systems. Using the different structural systems and finishing methods for building elements leads to solutions and technics achieving the aesthetical values of the building even if we use a one constructional material, and replacing some of structural technical solutions by scientific solutions to create a new expression shapes where the technical factor is a main factor in its formation. The main aim of architecture is a social, so the conformation the role which played by structural systems in terminal buildings, is the core of architectural design process and leads to enrichment the aesthetical heritage of the society where founded, and concedes a success of expressing using specific materials and modern constructional methods to present the aesthetical values of the architectural period.

*As a result of human capability to understand the relationship between the thought and the physical shape, the structural system claims an expressional function added to its main function (Improving the building stability). When the structural idea transforms to*

*reality, it will affect in us as a result of expression which got from the relationship between the shape and power, this can be found in some of modern terminals buildings.*

This can lead us to the main research hypothesis which is ” **the structural system is a symbolic expressive tool of terminal buildings by its integration with the complicated functional and operational systems in these buildings** ”. That can be achieved by the success of expression in the terminal building using construction materials and construction methods to show the development of nations architecture and its identity in general.

The form and space of terminal building depend on its structural system so it is important to focus on these systems to see its levels of expression using its physical construction materials and the technology which applied in the terminal building construction. Finally, the terminal building architecture shows the inside building functional and operational systems and reflects the cultural values of the nation compatible with the climate of the region and the international standards and ideologies of International Air Transport Association.

## 8. THE FIELD OF STUDY AND THE APPLIED PROJECTS

The research applied projects have been chosen according to several factors (popularity, importance, modernity, the used structural system and diversity of structural and architectural solutions in these projects).

### Beijing International Airport-China

The terminal 3 building is located between the eastern runway and the third planned runway and occupied more than 3.1 million square meters. The section plans of terminal buildings show the special form of the roof and dominance of the structure system on the expression of the building to form the terminal as a real gate of the country simulates the local identity and to welcome the visitors of the country with the full energy terminal building which has dragon form and the roof is painted by red in the center and gold in the edges and has southeast-facing skylights enable the sun to warm the building on winter mornings and make the most of natural daylight , the red and gold colors are the traditional colors of the Chinese empire. The physical form of the building contains structural idea that the structural system of the building can be discovered and unveiled by experience and instinct of the human because of the clearance of structural system and its integration with the expressional function.



Fig. 1. The red columns on the facades. Source:[4]



Fig. 2. Skylights on the roof. Source:[5]

### Kansai International Airport – Japan

The airport is built on an artificial island in the Japanese Osaka city, the building length is 1700 m. has a central building contains the main activates of the airport like departures and arrivals halls, luggage processing, migration and customs control, airlines offices and airport administration, on the sides of the main building there are two wings have 41 gates connected by bridges to the airplanes. The structural system unique by its expression by using modern design elements and reaching an engineering formula allows to minimize the volume of the roof and use plates from one size and shape to cover the 90000 square meter roof, the designer has chosen a light structural form and used waved roof to eliminate the visual impact of the long roof.



Fig. 3. Kansai International Airport. Source:[11]

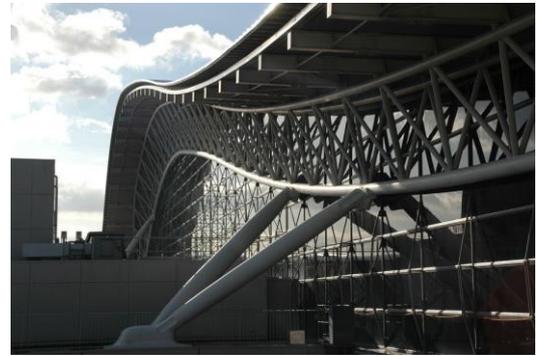


Fig. 4. The structure of the waved roof. Source:[12]

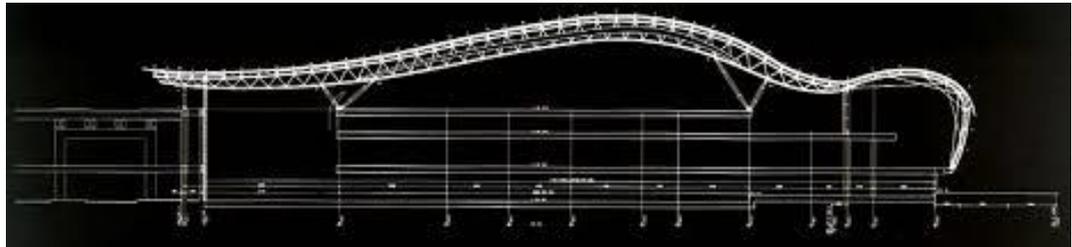


Fig. 5. Section across the main terminal building. Source:[13]

### Jakarta International Airport – Indonesia

The airport has two terminals (northern and southern terminal), each terminal surrounded by trees, green areas, pedestrian walkways so the passenger can feel the external environment and this is rarely seen in modern international airports. The design idea of the terminal building is the hybrid architectural style of terminals design, each terminal formed in a shape of curved line which has 3 secondary fingers contain the departure halls. The structure system is simple and integrated with the all operational systems, the building is isolated to the south east direction to get the maximum natural light from the diagonal roof which has windows located toward the south east direction. The building has two main layers where the procedures of departures are done in the ground floor and the arrivals in the first floor. The design concept depends on simplicity and respecting the human scale and inspired from the local traditional houses, the designer used a minimum number of layers to apply his design idea and used local construction materials to express the local culture and to present the terminal building as a gate to the country.



Fig. 6. Jakarta International Airport. Source:[15]



Fig. 7. Landscaping inside the airport. Source:[15]

### Madrid – Barajas International Airport – Spain

The airport has four main terminals. The roof of the terminals is formed by 9-meter span curved bridges supported by columns to form like a flying wing, the roof consists of 3 separated metal sections. The main terminal building has 6 layers with different operations and functions, three layers above the ground where the passengers and luggage processes are taking place, the other three underground layers are for the ground transport and maintenance. The underground layers constructed by reinforced concrete unlike the first three layers which have a high transparency. The concrete columns which formed like tree trunks are support points fixed the steel structural system and that can be seen on the facades and in the interior of the building.



Fig. 8. Madrid-Barajas International Airport Source: [23]



Fig. 9. The Y shape columns inside the airport. Source:[18]

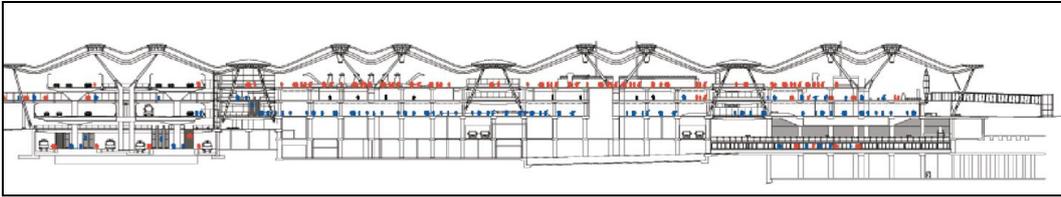


Fig. 10. Section across the terminal building in Madrid-Barajas International Airport. Source: [17]

### Conclusions on analysis of the applied projects

- 1) The results of applied project analysis which related to the level of design integration in passenger building, show high concentration on using the straight-line style in terminal building design, that style can be seen mainly in Madrid-Barajas Airport and Kansai International Airport and as minor style in other projects.
- 2) The results which related to the efficiency of space organization on the plan level and section in terminal building, show high concentration on using the multi-levels buildings as in Kansai International Airport and Beijing International Airport.
- 3) The results of applied projects analysis which related to the used structural system in the design, show high concentration on using active structural systems in a unique way and showing it clearly inside and outside the building to deliver a high level of expression.
- 4) The results of applied project analysis which related to the used construction material a high demand on the efficiency and capacity of used material to give a high level of expression specially in the building interior, as example Madrid-Barajas Airport where the bamboo is used as construction material in the long span ceiling to provide the natural lighting beside its special expression of the regional identity.
- 4) The capability of the material can be clearly seen in Jakarta International airport where the red roof tile used to express the identity of the place and region in a high constructional efficiency.
- 5) The results of applied projects analysis which related to the privacy of structural systems show a special invention and use of unusual hybrid structural systems give a special expression of modern technology and the prosperity of the country. The results also show the integration of the structural systems with the external form of the building.
- 6) The results of applied projects analysis which related to the physical level of architectural expression, show a high harmony between the structural system and material and the aesthetic aspect of the building form depending on the geometrical relations. The chosen projects are having a high level of expression and can deliver meanings, ideas and an important message includes the design ideas and concepts. The achievement of the symbolic-expressional function of the terminal buildings depends on the success of using the suitable structural systems and construction materials in the first place, this achievement can be considered as scale of architectural excellence.

### 9. FINAL CONCLUSIONS

- 1) Structural system in terminal building has two main functions: Structural and expressional.
- 2) The structural solution in terminal building related to many factors such as: Used structural system, constructional materials, economic factor, construction technology.

- 3) Terminal buildings are characterized by achievement of integration concepts, whether this integration a result of pervious intend or not.
- 4) Majority of terminal buildings depend on mega structural systems, because of operational and movement systems complication and the high flexibility which demanded by these systems inside the terminal building. In addition, the need to a free space without obstacles for reaching a dynamic passenger flow traffic and accommodating the increased numbers of passengers and expansion plans in a short period of time, all these considerations make using of long-span structural systems is one of the most planning and designing demands in modern terminals.
- 5) The structural systems of terminal building are complicated mega structures have a long-spans system, it creates a dynamic architectural form and simulate the aerodynamic shapes of aircrafts and sometimes providing a flexible integrated long-span space.
- 6) The expressional symbolic function presented the specialty of terminal building and can be realized to be a mean of expression and delivering meanings and ideas created by the architect or designer.
- 7) By introducing the theoretical functional concepts in terminal building forms. The structural system played a major role in creating the architectural form which is carrying its own expression as a result of cultural background mixed with special values and meanings have local specialty and compatible with zeitgeist.
- 8) As a result of human capability in understanding the relationship between theory and physical form, the structural system had an expressional symbolic function, as well as, its main function (supporting the building structure and form).
- 9) Expressional symbolic function can be achieved in terminal building by the success in expression using a chosen constructional materials and construction methods and systems which used in terminal building construction.

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