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The Role of the Ceilings with Folding Smart Shell in Creating Thermal Comfort (A Case Study of Redesigning an Educational Building in Mashhad)

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Abstract

It is necessary to design structures with fabrics indicating the culture and identity, in such metropolises as Mashhad, in buildings like educational buildings, which are regarded as public, crowded buildings with high effects on society and could form a great number of buildings over the city. In this regard, attentions are mostly directed at creating designs which more adapt to the climatic features and increase the level of comfort. In the current study the focus is on folding surfaces with some kind of pantographic shell used in educational places. The study is mainly concerned with presenting a way for improving the efficacy of the smart models in designing the ceilings with folding shells. The studied pantographic structures were structures with elliptical arch, extensive folding structures with elliptical arch and domal folding structures with elliptical arch, which most of the time require a cover to protect them from the rain, sunlight or wind and could be connected to the main structure itself. In the current study, it is attempted to present a strategy for increasing and improving the efficacy of smart models for designing ceilings with folding shell, considering the climatic situation, tempreture and the residents' density in the educational building. From the objectives viewpoint, the research method is practical, and it is attempted to define a new design in a practical way and achieve some palpable results to implement the results of the study, using two software programs of Designbuilder and Matlab. Accordingly, the situation was considered in the schools from the scale of 10, based on the the smart models for designing ceilings with folding shells and the distributed thermal comfort level based on the simulated models. The results show that there is a relationship between the matter mentioned and the optimization of energy consumption. With regards to the instruction of double-skin folding shell used in summer and winter, it was indicated that the best plan of smart double-skin folding shell for obtaining the best situation for air conditioning is the instruction of double-skin folding (opening) shell used for 6 hours in summer and 2 hours in winter, the instruction of double-skin folding shell (opening) used for 6.5 hours in summer and 2.5 hours in winter and the instruction of double-skin folding shell (opening) used for 5.5 hours in summer and 2 hours in winter.

Keyword: *Folding smart ceilings, the optimization of energy consumption, thermal comfort, educational building*

Introduction

Today, one of the great challenges that big cities face while constructing public and relatively big centers is the high cost of construction resulted from the type of single-pivot application, designing based on the minimum use of the space, ignoring to use the features of designing flexible surfaces with smart shell which could be effective in response to the limitations and the diversity of demands (Hosseinian, 2014:17). Today, the architecture of flexible smart surfaces like ceilings with folding smart shells is the issue of disscussion in scientific meetings, and they are used in different structures in the world successfully, in practice (Sababi, 2014:4). Considering the importance of this kind of flexible surfaces with smart shell for obtimizing the use of the structure's space, in the current research it is attempted to use the features of flexible surfaces with smart shell for designing an educatinal building which could serve as a place for the individuals' gatheirng and lesuire time in addition to artistic and relegious applications. Flexibility is an approach based on which the designer changes the functional pattern of the project in order to respond to the needs of the user. In the current study, considering the high range in flexible surfaces with smart shell, the objective is creating flexibility in the educational structure's skin (Jafarvand, 2013:5). The structure's surfaces might be in different forms based on their application, climate type and weather condition: folding, cut, integrated, domal, parabolic cylinder, conical and other geometric shapes. In the current study, the researcher attempts to design the educational structure, taking into account the type of the structure's

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surfaces, with an emphasis on folding surfaces. Folding surfaces could be open or close, and in the closed form, they form a compressed set of relatively parallel rods; umberella is a common example. Such structures are used greatly, from temporaty structures to the aircrafts (Shahi, 2014:26). The design pattern of such an architecture with folding shell is the nomadic tents and/or Roman villas. The skin of the folding structure should have the capability of getting open and close based on the environmental conditions, in different seasons. The benefits of such structures are mainly the ability to be expanded once or more, possibility of being used in all parts of the structure or part of it, feasibility of movement, immidiate use, the possibility of being used at the time of crisis and being economic (which depends also on the scale and type of project (Kaveh, 2004:7). The point worthy of note is that while analyzing the case studies of the contemporary architecture, the interaction between two principles of physic and content becomes important. This method is very important in the process of context-based design and criticisms based on which. What is regarded as the concern of the current study is selecting a scientitifc method to approach this field. Analyzing the contemporary architecture of Iran requires drawing an inclusive theoretical framework and defining a precise analytical structure by which one may reach acceptable results in addition to analyzing the built samples and structures. The type of folding skin that the current research investigates on it coherently is the pantographic shell. In this structure, the basic folding unit is made of two parts which are connected to each other from the middle or near middle along their length, and have created the sissors mechanism. The expansion of the mentioned parts may form an expanded truss. Being lightweight and modular are of characteristics of such a structure. If these patterns are connected to each other in a way that make each part able to move, a mixed system is created which could move in one, two or three spatial directions. The structural elements refer to the rods connecting to each other by their end, and are connected in a middle node like hinges, so whenever the hight of the shape increases, its length decreases and vice versa.

1.1 Research Variables

1.1.1 Independent Variables

a) Reducing the costs of constructing the educational building

b) Incresing the usable space of the educatinal building

c) Increasing the adaptation of the educational building to the climate

1. Research Objectives

1.1 Main Objectives

Investigating the role of the ceilings with folding smart shell in order to create thermal comfort with an emphasis on energy consumption reduction in the buildings, a case study of redesigning an educational building in Mashhad.

1.2 Sub-objectives

1.3 Creating changeable surfaces with a smart shell and folding skin in the educational building in order for decreasing the construction costs of the educational building.

1.4 Creating changeable surfaces with a smart shell and folding skin in the educational building in order for increasing the application space of the educational building.

1.5 Creating changeable surfaces with a smart shell and folding skin in the educational building in order for the educational building to adapt more to the climate.

2.Methodology

The current study is practical, from the viewpoint of its objectives, and descriptive, from the methodology viewpoint. In this type of study, the goal is discovering and determining the cause and effect relationship between two or more variables. Moreover, it is a descriptive study because data are gathered through field-based and liberary methods.The current research attempts to conduct a comprehensive novel investigation, by focusing on the issues of cost and the speed of executing the project with the application of folding surfaces in a structure (educational building), given the presentation of productivity ways including the pre-fabrication of some parts of the structure and its effect on the speed of execution, omitting parts of the fixed ceilings, the ridge and insulating coating and its role in the cost and speed of execution, and developing roofed spaces and open spaces, ommiting the blind enclosures and less-accessed areas and its effect on the productivity of the project, because in the field of developing folding surfaces, few studies paid attention to the issues of cost and time. Folding structures are grid workspace systems which have the capabiliy of being moved in terms of location and geometry. The basic unit of the folding structure studied in the current research is the pantographic units. Folding structures have different geometrical models including flat, drum, dome structures, towers, etc. The behaviour of the folding structures, from pantographic type, is alo investigated. The study may come to some results which are both important for the future studies and creating an approach for the execution of the projects on the changeable surfaces with a smart shell and folding skin.

1.Instrument and Type of Data Analysis and Statistical Population

The study is quantitative in terms of nature, and the goal of such studies is fundamentally generalizing the results to other similar populations and samples. Therefore, to make this goal possible, the selected samples should represent the population under study, and since in qualitative studies, the sampling process is biased and the participants' opinions affect the research, it is believed that each participant has unique features in terms of opinions, so such samples could not be selected by random sampling (Chavoshian, cited by Baliki, 2005:310). In quantitative studies, the random selection is quite emphasized, while in qualitative studies random selection doea not work and does not lead to an appropriate statistical population. In the current study, in which the samples are selected from schools, the theoretical sampling method is used, because contrary to the quantitative methods, the samples are selected with the goal of clarifying the details and the type of relationship between the pivot concepts and categories, which is achieved by considering the initial data and their analysis by two advanced software programs, namely, Designbuilder and MATLAB.

1.1 Simulation and Logical Reasoning

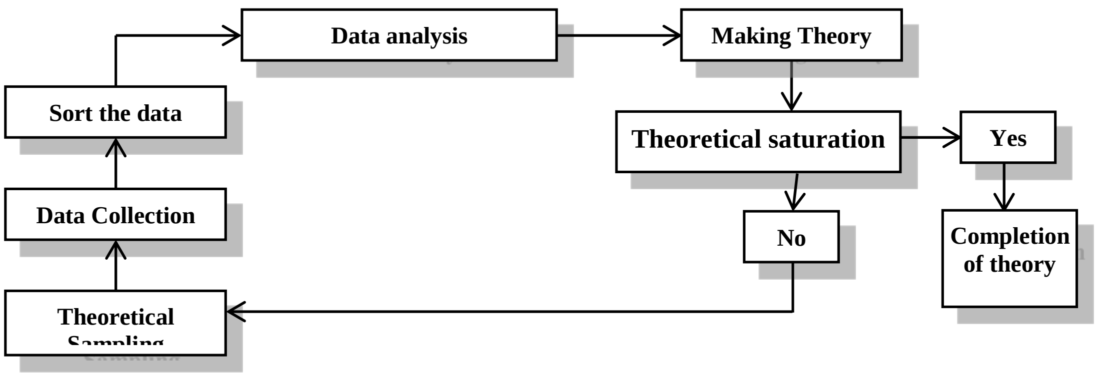
After selection, the sample shall be analyzed by the specialized software programs of Designbuilder and MATLAB. After comparing the results, they shall be discussed, and finally the results shall be explained.

3. Research Methodology

After determining the research method and collecting the required data for testing the questions using approriate instruments, the collected data are categorized and analyzed by using suitable statistical techniques which are compatable with the research method and the type of variables. Then the questions are tested and the relevant scientific results are extracted.

6.The Process and Simulation of the Research

After considering the output of the famous smart models in designing the ceilings with folding shell, the type of folding of ceilings based on the climatic situation and density shall be simuated and modelled using MATLAB software (source: authors, 2018). Study the balcony of smart well-known models in designing calling with folding partition. Fir better comparising the aperation of these smart models, we have chosen sin different enamples which is mentioned below: (Table 1) The results of the analysis showed that the best folding smart plan for gaining the best condition as for the folding (opening) instruction regrading the air conditioning is 6 hours in summers and 2 hours in winters, and the folding (opening) instruction of 6.5 hours in summers and 2.5 hours in winters, and the folding (opening) instruction of 5.5 hours in summers and 2 hours in winters. Results of the analysis indicated that regarding the folding instruction based on the climatic and tempreture conditions and density of the residents of the educational building, the best smart plan for the folding (opening) instruction based on the cloudiness state is open-closed, the folding instruction based on the density of people is opening in the density peak, opening-closed in the low density, and the folding instruction based on the tempreture is: high tempreture of more than 32 degrees (closed), 25-31 degrees (opening-closed), 15-25 degrees (opening), 10-15 (open, closed), lower than 10 degrees (closed) . Along with the following studyings in relation with folding instruction based on folding ceiling’s sort situation due to the condition of transparent crust in relation with light in traning building, we have shown that the best smart folding ceiling instruction, from middle with gloomy crust in relation with light and folding ceiling from rolling with transparent crust in relation with light. The analysis showed that regarding the type of folding of the ceilings based on the transparency of the skin against light in the educational building, the best smart plan for the folding ceiling instruction is folding from the middle with a blurred skin against light, and the ceilings folded from the roller, with a skin transparent against light. The analyses showed that the simultaneous application of two MORE and EX OR routing protocols for imprving the efficacy of oportunistic routing, using the Framework method, indicated the optimized reults of finding the level of thermal comfort routed by MORE and EX OR routing protocols, in a 300*50 area, at six different times, which showed the best and the most optimized level of energy consumption.



Daigram 1. Methods and Instrument of Data Analysis (Source: Glaser and Strauss)

Table 1. *Type of Folding Instruction of the Ceilings in Summers and Winters*

Example	**Conelitions based on well-knoen smart models in designing cellings with folding partition**	**Spreaded thermal tranquility level busued on model scaling from 10**
1	Folding instruction (opening) of 8 hours in summer and 3 hours in winter	9
2	Folding instruction (opening) of 7 hours in summer and 2.5 hours in winter	8
3	Folding instruction (opening) of 6.5 hours in summer and 2.5 hours in winter	10
4	Folding instruction (opening) of 6 hours in summer and 2 hours in winter	10
5	Folding instruction (opening) of 5.5 hours in summer and 2 hours in winter	10
6	Folding instruction (opening) of 5 hours in summer and 1.5 hours in winter	8

Table 2. *Type of Folding in Ceilings based on the Climatic and Density Conditions (Source: Authors, 2018)*

Example	**Conditions based on well-known smart models in designing ceillings with folding partions**	**Spreaded thermal tranquility level based on model scaling from 10**
1	Folding instruction (opening) based on the cloudiness state (open-closed)	9
2	Folding instruction based on the state of radiation, radiation peak (closed), the average and low radiation (opening)	10
3	Folding instruction based on the state of day and night, nights in summers (open), nights in winters (closed), days in summers until 11:00 a.m (open), 11:00 a.m to 4:00 p.m (closed), 4:00 to 9:00 p.m (open); in winters, except for 11:00 a.m to 3:00 p.m (open), the rest of the day is closed	10
4	Folding instruction based on the state of density of people, density peak (opening), low density of people (opening-closed)	10
5	Folding instruction based on the state of tempreture, high tempreture of more than 32 degrees (closed), 25-31 degrees (opening-closed), 15-25 degrees (opening), 10-15 (open, closed), lower than 10 degrees (closed)	8
6	Folding instruction based on the state of tempreture, high tempreture of more than 33 degrees (closed), 28-32 degrees (opening), 17-27 degrees (opening), 10-16 (open, closed), lower than 10 degrees (closed)	9

Table 3. *Type of the Folding of the Ceilings based on the Status of Skin Transparency against Light*

Example	**Conditions based on well-known smart models in desighings with folding partition**	**Spreaded thermal tranquility based on model scalling from 10**
1	The ceiling folded from the middle, with a transparent skin against light	9
2	The ceiling folded from the edges, with a transparent skin against light	8
3	The ceiling folded from the middle, with a blurred skin against light	10
4	The ceiling folded from the middle, with a blurred skin against light	10
5	The ceiling folded from the roller, with a transparent skin against light	10
6	The ceiling folded from the roller, with a blurred skin against light	8

Table 4. *Investigating the Level of Optimization of Searching for a Shorter Route in the Research Results (Source: Authors, 2018)*

Optimization level, optimization competence, energy consumption	**Thermal tranquility. level tracked by more protocol and en op tracking protocol in a 330*500base in different times**	**Time Persecond**
18.55	The folding (opening) instruction of 8 hours in summers and 3 hours in winters	1
18.77	The folding (opening) instruction of 7 hours in summers and 2.5 hours in winters	**3**
20.01	The folding (opening) instruction of 6.5 hours in summers and 2.5 hours in winters	**5**
20.25	The folding (opening) instruction of 6 hours in summers and 2 hours in winters	**7**
20.89	The folding (opening) instruction of 5.5 hours in summers and 2 hours in winters	**10**
21.96	The folding (opening) instruction of 5 hours in summers and 1.5 hours in winters	15
21.40	The folding (opening) instruction based on the cloudiness state (open-closed)	1
22.48	The folding (opening) instruction based on the radiation status; radiation peak (closed), the average and low radiation (opening)	**3**
23.00	Folding instruction based on the state of day and night, nights in summers (open), nights in winters (closed), days in summers until 11:00 a.m (open), 11:00 a.m to 4:00 p.m (closed), 4:00 to 9:00 p.m (open); in winters, except for 11:00 a.m to 3:00 p.m (open), the rest of the day is closed.	**5**
16.89	Folding instruction based on the state of density of people, density peak (opening), low density of people (opening-closed)	**7**
17.22	Folding instruction based on the state of tempreture, high tempreture of more than 32 degrees (closed), 25-31 degrees (opening-closed), 15-25 degrees (opening), 10-15 (open, closed), lower than 10	**10**
17.98	Folding instruction based on the state of tempreture, high tempreture of more than 33 degrees (closed), 28-32 degrees (opening), 17-27 degrees (opening), 10-16 (open, closed), lower than 10 degrees (closed)	15
18.38	The ceiling folded from the middle, with a transparent skin against light	1
19.95	The ceiling folded from the edges, with a transparent skin against light	**3**
19.59	The ceiling folded from the middle, with a blurred skin against light	**5**
20.32	The ceiling folded from the middle, with a blurred skin against light	**7**
20.00	The ceiling folded from the roller, with a transparent skin against light	**10**
21.48	The ceiling folded from the roller, with a blurred skin against light	15

Table 5. *Factors of Indigenous Climatic Architecture with the Saving of Energy on which the Definitions Presented by the Experts Have Focused (Madahi, 2011)*

Formation of design and architectural activity in the context of indigenous tradition and knowledge	Refuge and housing as a major part of indigenous architecture	Native architecture without an academic theoretical background	Diversity in models and finite species	Native forms and forms as accepted by the people	Spatial forms and organization that respond to the values, economics and lifestyle of a particular culture (people)	Ecology and climate as the culture of most people	Forms that respond to specific human needs	Regional forms, forms, materials and technologies	Pundits
									Paul Oliver
									Amos Rapoport
									Baker
									Porter
									Allsopp
									Brunskill
									Rudofsky
									Marcer
									Pietro Belluschi
									Holm
									Alpagano
									Hassan Fathi
									Flamkei
									Haeri Mazandarani
									Emir Bani Masoud
									Memariyani

8.Conclusion

Mashhad is one of the metropolises of Iran that due to its high population needs structures to be designed and constructed for public application, so that different people at any age might spend their leisure time there. Considering this necessity, designing some structures indicating the cultural and identity of the country including educational centers might be worthy of note. Given the importance of modern architecture in designing the structures compatable with the environmental conditions, creating some designs more compatable with the climatic conditions and increasing the level of comfort are issues under focus. The current study focuses on the folding surfaces for designing an educational center. The concern of the theory is creating some spaces different from the past and bringing the architecture near to a field in the form of a pure science with the patterns of mathematics and physics in order for being able to help the human civilization at the same pace as various scientific phenomena, more than ever. Actually, such an architecture is inspired by the folding style based on very complicated mathematical equations, which is founded by a French mathematician. Opening structures with elliptical arch, expansive folding structures with elliptical arch, and the domal folding structures with elliptical arch are among this category, and most of the time a surface cover is required for the protection against rain, wind or sunlight, which might be conncted to the structure itself. The covers are usually in the form of fabrics. As said earlier, the current study attempts to present a route for improving the efficacy of famous smart models in designing ceilings with folding shell. The manner of organizing the green space in the outer layer of the skin, inspired by the rural farms, has emerged from the combination of leeks and oats, and the folding surfaces of the skin is like an abstract purification of the earth's topography and are modelled on the same basis and were analyzed by the software. The results show that underneath termal distribution was in a 3.80-meter distance from the floor, and in this section, the average tempreture of the structure was about 24 centigrade degrees. The results showed that the underneath thermal distribution was in a 0.9-meter distance from the floor, and in this section, the average tempreture of the structure was about 24.5 centigrade degrees. The results also showed that the underneath thermal distribution was in a 1.2-meter distance from the floor, and in this section, the average tempreture of the structure was about 25 centigrade degrees. With regards to the instruction of double-skin folding shell used in summer and winter, it was indicated that the best plan of smart double-skin folding shell for obtaining the best situation for air conditioning is the instruction of double-skin folding (opening) shell used for 6 hours in summer and 2 hours in winter, the instruction of double-skin folding shell (opening) used for 6.5 hours in summer and 2.5 hours in winter and the instruction of double-skin folding shell (opening) used for 5.5 hours in summer and 2 hours in winter.

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