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POST OCCUPANCY EVALUATION OF *BUILDING SYSTEM # 5* AS SUSTAINABLE STRUCTURAL SYSTEM IN JORDAN

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Summary

The reported study was conducted to analyze, compare and evaluate building system #5 as sustainable structural system produced by Building research center at Royal Scientific Society (RSS) and built in different locations in Jordan. This system was invented as low-cost building system that depends meanly on local construction materials, as well as, on local labor and appropriate technology. The purpose of the research paper was to examine the efficiency of this system to match the housing demand in Jordan. The criteria for evaluation are based on the relationship between spatial characteristics, building performance, and economic systems in one side with resident's satisfaction and preference on the other side. Building quality assessment technique was used to estimate the level of satisfaction of the tenants and the efficiency of the building. The following parameters were included in evaluation: economic, functional, aesthetic, and durability of the structure. Moreover, the study determined the applicability of sustainable concepts into this structural and construction system.

To achieve the goals of the research, several techniques were utilized: first, in depth interviews with designers, engineers and decision makers to come up with indicators of the design and the possible improvement for future application. Second, structured questionnaire with tenants was conducted to test the level of satisfaction and preference of the users. Moreover, Physical analysis, that include checklist and evaluating indoor environmental quality were conducted.

The findings indicated that level of satisfaction of this system is highly associated with income and family size. As the income is high and family size is low the satisfaction level is acceptable, and vice versa. Several tactics and consideration should be taken into account in the early phase of design for newly projects; such as areas of the dwelling, number of bedrooms, insulation level, orientation, flexibility of design, and implementing green architecture measures- rating system.

1. Introduction

Environmental evaluation (or assessment) represents "an appraised of the degree to which a designed setting satisfies and supports explicit and implicit human need and values" (Friedman 1978). People knowledge of their environment affects their use and evaluation of the particular environment (Kaplan 1983). Consequently, the designed housing project should be understood in the context of users' experience.

"Post Occupancy Evaluation (POE) is recognized and valued as a process that can improve, and help explain, the performance of the built environment" (Rabinowitz 1988). It has been defined as "the examination of the effectiveness of designed environments for human users" (Zimring and Reinstein 1980, as cited in Bechtel et. al. 1987). It considered as inclusive examination and evaluation of building. It evolves systematic evaluation of opinion about buildings in use, from the viewpoint of the users. The outcome of evaluation is beneficial not only to occupants but also to owners, architects and decision makers.

Jordan has limited natural resources. It is considered among the low-income countries of the region. The average GDP per capita in 1999 was 1.4 *103 US$ compared with an average of 104US$ for neighboring Arab countries, with the exception of Egypt, Syria and Yemen. Recently, it is estimated that in Jordan, there are about 7.5*105 houses are built annually to accommodate the increase of population which is expected to be2.8%. This considered one of the highest in the world.

Searching for sustainable architectural design, which attain the needs and ambitions of the residents, is one of the main concerns of architects, engineers, and housing policy makers in Jordan. Building research center at Royal Scientific Society (RSS) came up with a sustainable structural solution (Building System #5) that could be described as economic, and efficient. This systems based on designing and producing building's components (usually 11 prefabricated concrete units), that are used all through the building. This system is a modification of traditional building approaches, which depends usually on local construction materials. Building system #5 was wildly used in residential practice. It is assumed to be economic, durable, and accomplishing the aesthetic needs.

The purpose of this research is to analyze and evaluate this structural system in residential buildings in different locations in Jordan. The criteria for evaluation are based on the relationship between spatial characteristics, building performance, and economic systems in one side with resident's satisfaction and preference on the other side. Building quality assessment technique will be used to estimate the level of satisfaction of the tenants and the efficiency of the building. The following parameters were included in evaluation: economic, functional, aesthetic, and durability of the structure. Moreover, the study determined the applicability of sustainable concepts into this structural and construction system.

2. Description of building system #5

Building System #5 is a semi prefabricated building system; it is a trying to develop the traditional system to minimize the overall cost of housing unit for low income families in Jordan, using (11) main structural components (blocks, bricks) produced by special machine either on the site or in the factory.

At this time there are many buildings were realized using this system, either it is administrative buildings or houses for low income people such as Prince Talal housing complex in Amman city.

The main aims of this system are to:

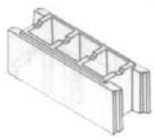
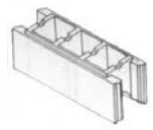
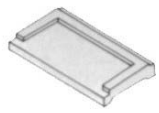
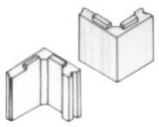
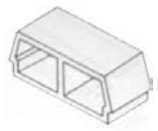
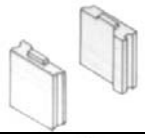
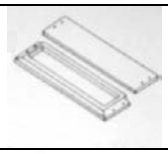
- Used repeatedly some certain prefabricated units
- Minimize the efforts, cost and excess (waste) of materials.
- Reduce (saving) the time of construction.
- No need for using scaffolding and framing in the site.
- Support a good thermal isolation.
- No need for using cranes and other machines in the site.
- No need to qualified manpower (labors).
- Building (structure) committed to Arabic and British concrete code standards

Technical characteristics of the system #5:

- Using standard measurement system (60*60 cm) or (60*20 cm) for horizontal planes and (20 cm) for vertical planes (elevations).
- The "tail & groove "method is applied in wall Installation without using cement mortar.
- Saddle brick (Assarj): it is a multiuse precast concrete unit, used as:
    - A lentil of doors and windows openings
    - A support for stairs units.
    - A support for roofing hollow bricks.
- Electrical and sanitary pipes are inserted in the walls and roofs without digging (excavation)
- The system has three structural sub-systems:
- Foundation and wall system.
- Stairs system.
- Roofing system.

The system contains (11) standard components with different shapes (forms) of blocks dependent at its location (position) in the structure (building).
Building materials used in this system are:
Cement, soft and rough sand in specific proportions, water, steel
Manufacturing of the building units (blocks) are utilized exiting special machines but forms of dies redesigned for this purpose. The main building units are:

Table1: The structural elements of Building system #5

Main cement brick unit, (60*20*20) cm, its hollow brick with four internal (hollows) barriers with a use of special die, mainly using for walls.		Saddle unit (Assarj)	
The same shape with tow different heights lay on the top of openings of doors and windows.		Window sill	
Corner block		Roof hollow brick	
Closing brick		Stairs unit (tread and riser)	
Door & thresholds		concrete beams	

3. Methodology

Based on research questions and specific research context, building quality assessment technique (BQA) was adopted. That could be described as a tool for scoring the performance of a building relating actual performance to requirements for user groups in that type of building (Baird,G,etl 1996).

Method of inquiry included both empirical and subjective techniques. Physical analysis of the sampled building was conducted. Checklist was prepared to record and investigate all attributes and characters of the building. Performance analysis using computer simulation programs to define the environmental responsive of the building were done. Moreover, a structured questionnaire and in-depth interview with tenants were conducted to test the level of satisfaction and preference of the users

The population under consideration is the residents of king Talal housing project. This specific project was selected because it was constructed using *Building system #5* as the main structural system. Moreover, it represents one of the largest low income housing projects in Jordan. King Talal project include both owner and renter households. The length of residence ranges from decade to less than a year.

A simple random sampling strategy was used. The initial sample of the study consisted of 25 household. The response rate for this study was 65 percent. Consequently, the sample used in the study consisted of 17 household. The unit of analysis included the adults living in the dwelling unit and welling to participate in the study.

3.1 Physical Analysis

Physical analysis will include the attribute for selected buildings. A check list was provided to record the conditions of the building after it has been occupied for 10 years. Construction conditions, which include all those items which make up the physical building, and supports its shape, spaces and materials. These

include the skeleton system, fabric, internal walls, finishing systems, and building services. These construction factors provided a clear vision of the quality of building.

Economic analysis was conducted to evaluate the physical qualities and performance of selected sample of buildings, in order to suit the operation of the organization. As physical resource, condition, and expected life of building and services were assed. Resident satisfaction and functional suitability were considered. Moreover, a comparative evaluation between building system # 5 and the conventional approach were conducted to determine the suitability of such system for low income people.

3.2 Subjective Measurement

Two procedures were utilized to measure resident satisfaction and preference: first: in-depth interview with the architect and decision makers, second: questionnaire with tenants. The open ended interview helped in determining the major variables to be considered in the questionnaire design, As well as, defining the conceptual framework of evaluation strategy of building system #5. Designers who initiated this idea defined the strength and weakness of the conventional approach and they highlighted the possible applicability of the suggested system. Besides, they predicted any possible saving in initial and operation cost of the system.

Structured questionnaire was used as the basic tool for post occupancy evaluation of the system. A 5-point likert scale was developed to measure resident satisfaction and preference, where number (1) represented the lowest degree of satisfaction and number (5) represented the highest level. The scale consisted of six sections each contains several questions. The first section represent the confounding factors, other sections represent : site attribute factors, space and structure attributes, internal environment attributes, building services attribute, and socio-economic attribute factors. The scale consisted of (53) statements some of which is repeated to enhance the reliability of the measurement. The statements were written in Arabic describing how residents understand and feel the factors affect their satisfaction with this type of structural system. The initial scale was given to group of people to test the sensitivity, reliability and validity. There after the scale was modified before distribution to the tenants.

Descriptive and factor analyses techniques were used to analyze the data. Mean, medium, standard deviation, and some other descriptive numerical and graphical methods were implemented. Factor analysis (Orthogonal Transformation Solution -Varimax), as analytical method to reduce the number of variables, were used, where in each factor, only items with loading above 0.5 were identified.

4. Results and Analysis

4.1 Economic Analysis

The cost of the skeleton structure as shown in table 2 is relatively high comparing with the traditional system. The reason is that the initial cost of fabrication the basic units is high, as it is newly system and required a special molds to be casted . However, this system reduces the quantity of finishing works such as plastering, stucco, electricity, and plumbing systems. The plastering is limited in the ceiling not in the walls, because the smooth surfaces of the walls don't need extra treatments.

Roof construction in system #5 is different in assembly and fabrication. All the components are pre fabricated and just need less number of labors to do the job. Moreover, no formwork is required by using this system and this will produce quick, efficient and low cost system. This system required also less amount of concrete comparing with the traditional system. It requires 5 cm of concrete, while the traditional system required 7 cm.

The cost of foundation system is lower than that in the other system. Because the dead load of the system is relatively low, the size of foundation is small that required less amount of excavation.

On the whole, this system was considered as a new experience in the Jordanian housing practices that was designed to be economical, durable, sustainable structural system. As it was the first experiment, the cost was run high in some items because of the high cost of casting machines and training of people who were in practice.

Table 2 Analysis of construction cost of Building System #5 compared with Traditional Construction System (Bakir 1986)

Construction Item	Building system #5 construction cost %	Traditional system construction cost %
Excavations	5	2
Foundation	4	5
Wall Construction	20	12
Roof Construction	15.5	19
Total Skeleton Construction	44.5	38
Internal Plastering	1	5
External Painting	2.5	2
Tiles and Flooring	4.5	4
Internal Wood Work	2	6
Windows (Aluminum Work)	3	6
Internal Painting	3	2
Steel Work	2	0
Total Finishing Works	18	25
Internal Electric Works	5.5	2
Plumbing Works	7	6
External Water Network	2	2
External Sewage System	6	6
paths and Pavements	6	6
Administration and Others	11	15
Total Services Works	37.5	37

4.2 Interviews and Questionnaires

The findings of the in depth interview with the designers and the decision makers at Royal Scientific Society (RSS) / Building research center, indicated that this system was created to fulfill the great demand of low cost housing in Jordan. The major indicators of this system could be characterized as follows:

. It was designed to minimize the cost of the building by reducing the amount of the form work used in traditional building system. It was based on semi fabricated building system that used eleven pieces of structural elements that could be assembled with effortlessly.
. Durability: this system was designed to be strong enough and durable during the operation of the building. Several lab experiments were conducted to test the durability and strength of the system.
. Time efficient during construction: the time was reduced by 30% of the traditional system by using system #5.
. Efficiency in building materials
. Flexibility in future expansion in both vertical and horizontal directions

The questionnaire considered six parameters to measure and evaluates the satisfaction level of the residents of prince Talal housing project that was built using building system #5, and could be considered as a sample project of this type of building system. The structure of questionnaire consisted of six parameters to be tested. These attributes and factors included: site attribute, space attribute, construction and structure attribute, internal environment attribute, building service attribute, and satisfaction with socio economic factors.

Table 3 shows the responses of the residents. Mean scores and standard deviation indicated that there is a trend of dissatisfaction of this system. The area size of all housing units is 75 squared meter. And the average family size is 6.52 persons. Around 47% of the housing units are rented, the rest were owned by the residents. The unit consists of two bed room with two storey building.
The majority of the residents are low income. Sixty four percent of them earn between 100-250 JD a month, while the others earn around 250-500 JD a month.

Table 3: Mean scores and standard deviations of residents responses of Prince Talal housing project

Factors	Mean scores	Standard deviation
Satisfaction with site attributes	3.764	1.0914
Satisfaction space attributes	3.0588	1.2976
Satisfaction with construction and structure attributes	3.745	1.2760
Satisfaction with internal environment attributes	3.176471	1.074436
Satisfaction with building services attributes	2.529	0.9430
Satisfaction with socio economic factors	3.235294	1.09141

Table 4 shows the correlation level of all factors that were taken into consideration; it indicated that there are no significant trends in level of satisfaction. There is a negative level of association between family size and satisfaction with the space and indoor environmental quality. This is logical because families with large size required a good quality of space attributes and indoor environment. In short, the designer of building system # 5 did not take the family size as major factor in design. In addition, there is a negative relationship between income and satisfaction with structural and construction factors, this is also logical because people with high income would prefer other building systems that could match up their needs and aspirations.

There is a strong positive relationship between space attribute and indoor environmental quality. The spacious halls will have good quality of air, thermal properties, lighting properties and moisture control. The area size of the living rooms is enough and fulfills the needs and requirements of the residents. Moreover, there is a negative relationship between space properties and structural attributes. This could be a result of having high weight structural components with large size rooms that brings the feeling of doubt of the durability of the system and consequently feeling of dissatisfaction.

Table 4. Correlation matrix showing the relationship among the selected variables

	Correlations (Spreadsheet1) Marked correlations are significant at p < .05000 N=17 (Case wise deletion of missing data)							
	Family size	**Income**	**Site**	**Space**	**Structure**	**IEQ**	**Services**	**Sci Eco**
Family size	1.0	-0.31	-0.67	-0.52	0.20	-0.31	-0.25	-0.45
Income	-0.31	1.0	0.47	0.56	-0.28	0.32	-0.05	0.35
Site	-.067	0.47	1.0	0.28	-0.42	0.04	0.01	0.31
Space	-0.52	0.56	0.28	1.0	-0.30	0.66	0.23	0.65
Structure	0.20	-0.28	-0.42	-0.30	1.0	0.20	-0.17	-0.32
IEQ	-0.31	0.32	0.04	0.66	0.20	1.0	0.09	0.60
Services	-0.25	-0.05	0.01	0.23	-0.17	0.09	1.0	0.48
Sci Eco	-0.45	0.35	0.31	0.65	-0.32	0.60	0.48	1.0

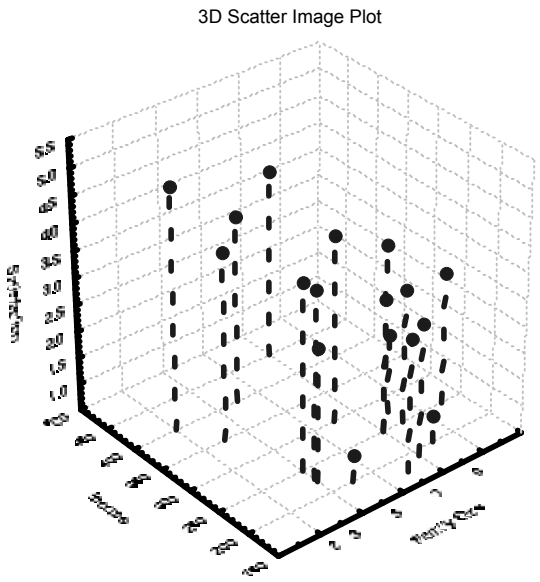


Figure 1 satisfaction level as correlated with family size and income

5. Conclusions

Jordan, as developing country with limited resources and high level of growth rate, requires a building system that could be described as low cost, sustainable and effective. There is a need for new developed building system to fulfill the demand for low income residents. Building system #5, as sustainable building system, was presented, analyzed and compared with traditional system in this paper. It was a new experiment in Jordanian housing experience. Therefore, the need to evaluate this system was the target of this paper.

The purpose of a building is not only to provide shelter for its occupants, but also to provide an environment conducive to high performance of all intended occupant activities. As it has shown, the designer of this system did not take into consideration the environmental, social and aesthetic factors from the early phases of design. Most residents believe that this system would not satisfy their needs and aspiration. It could be describes as affordable housing system, rather sustainable one. However, the need for integrated design is very important to be taken into consideration from the early phases of design.

Integrated design and construction can develop a building's functional and operational design to meet environmental and financial goals. It is the cornerstone for developing sustainable buildings, which are efficiently combined systems of coordinated and environmentally sound products, systems, and design elements. Designers can obtain the most effective results by designing various building systems and components as interdependent parts of the entire structure (Bernheim, A & Reed, A. 1996). Sustainable design, through an integrated design approach, takes into consideration the effect these factors have on one another. This conceptual framework starts at the pre-design stage and is carried throughout design and construction to building

In sum, sustainable development concepts, applied to the design, construction, and operation of buildings, can enhance both the economic well-being and environmental health of communities. Recent studies have shown that sustainable building measures taken during design and construction can result in significant building savings, as well as increases in residents comfort and satisfaction. To achieve our main goals, Building-rating systems can be applied that evaluate new and existing buildings based on their environmental performance. Building reviewers issue credits in each performance class and assign an overall environmental performance rating to the structure (Gottfried, 1996). With public acceptance, rating systems can change the way designers, building owners, and tenants evaluate buildings.

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