A Comparative Feasibility Case Study on Hybrid RCS Moment Frames with Concrete and Steel Frames in Construction and Project Management Point of View

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Abstract: RCS structures are new developed hybrid frames made of reinforced concrete columns connected to steel beams. These frames can provide practical and economical merits by combining longer steel beams with high compression resistant reinforced concrete columns. RCS structures by use a system of reinforced concrete supports and steel frame beams have been recognized to possess several advantages in terms of structural performance and economy compared to pure reinforced concrete, steel and concrete frames. This study aims to investigate a detail compared feasibility study between RCS, steel and concrete structures. The applied procedure is validated through the testing of a real case study in Tehran. Experimental results indicate that the proposed design procedure is effective in controlling deformations and damage, leading to economic and feasible criteria. Obtained results indicate that in equal conditions, RCS frames are shown better circumstance cost, required human resource, physical and financial progress, management and economical condition than steel and concrete structures.

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INTRODUCTION

Construction management or construction project management (CPM) is the overall planning, coordination, and control of a project from inception to completion aimed at meeting a client's requirements in order to produce a functionally and financially viable project. Construction managers plan, direct and coordinate a wide variety of construction projects, including the building of all types of residential, commercial and industrial structures, roads, bridges, wastewater treatment plants, schools and hospitals. Construction managers may oversee an entire project or just part of one. They schedule and coordinate all design and construction processes, including the selection, hiring and oversight of specialty trade contractors, but they usually do not do any actual construction of the structure.

Typically the construction industry includes three parties.

1. An owner
2. A designer (architect or engineer) which should execute work inspection, change orders, review payments, materials and samples, shop drawings and 3D image.
3. The builder (usually called the general contractor).

Traditionally, there are two contracts between these parties as they work together to plan, design, and construct the project (Halpin, 2006). The first contract is the owner-designer contract, which involves planning, design and construction administration. The second contract is the owner-contractor contract, which involves construction. An indirect, third-party relationship exists between the designer and the contractor due to these two contracts. For planning and scheduling, project management methodology includes the following sub procedures.

- ✓ Work breakdown structure
- ✓ Project network of activities
  - ☐ Critical path method (CPM)
  - ☐ Resource management
  - ☐ Resource leveling

As shown in figure2, a traditional phased approach identifies a sequence of steps to be completed. In the "traditional approach", five developmental completion components comprising initiation, planning and design, execution and construction, monitoring and controlling systems of a project can be distinguished. Not all projects will have every stage, as projects can be terminated before they reach completion. Some projects do not follow a structured planning and/or monitoring process. Projects need to be controlled to meet their objectives and deliver benefits. Objectives are defined in terms of expectations of time, cost and quality as shown in figure2.

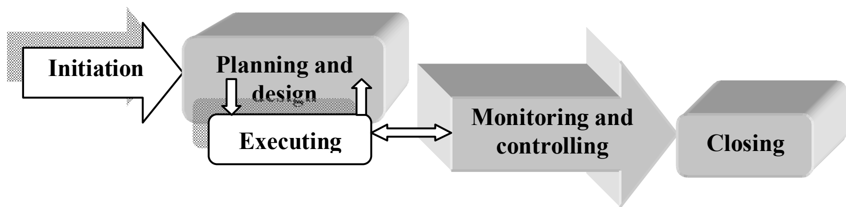

Figure1. Typical development phases of an engineering project

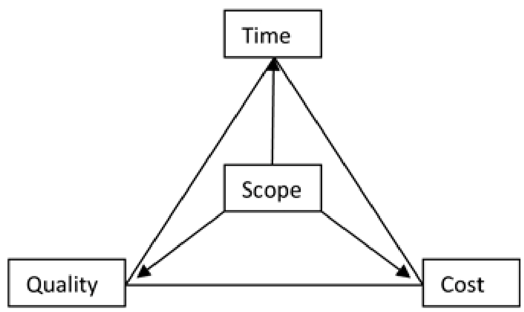

Figure2. Project objectives

The case study of this paper is a hybrid combined structure that called as RCS. RCS frames are one of the most recent practical bending frames in cases of large spans and moderate height as shown in figure3. This type of structure has been used as a cost-effective alternative to traditional structural steel or RC construction (Griffis, 1992).

All of the materials are of the highest quality in order to achieve rational structures, withstand great force and at the same time allow wide spaces between supports. As shown in figure4, this type of construction allows for large open structures like warehouses for heavy loads and shopping centers. To further develop such hybrid structures, it is necessary to determine the strength and ductility of the connection. In this case a program named as DYNAMIX for the dynamic analysis of mixed of 3D steel and RCS frames with capabilities to perform inelastic static and dynamic analyses of has been developed (El-Tawil et al. 1996).

Reinforced concrete frames, due to increasing in depth of beam and loss of architectural space, are not suitable; therefore RCS frames were proposed to improve these systems (Chopra, 1995).



Figure3. RCS frames performance (Tehran-Case study of this paper)

From the construction viewpoint, these systems are usually built by first erecting a steel skeleton, which allows the performance of different construction tasks along the height of the building (Griffis, 1986). Structurally, the connections between steel beams and RC columns have been reported to possess a good strength and stiffness retention capacity when subjected to large load reversals (Kanno, 1993; Parra-Montesinos and Wight, 2000a). Utilizing compressive strength of concrete in columns and stiffness and strength of steel beams which makes them suitable for long spans, results in a cost effective hybrid system, which behave well under both gravity and lateral loads (ASCE ,1994).
In seismic design, reduced forces due to different causes like, damping, ductility, excess resistance and etc are calculated from dividing linear seismic spectra to a factor named is behavior coefficient (ATC, 1996; C.M.Uang, 1991). Several researchers such as Deierlein et al. (1988), Kanno (1993), Kim and Noguchi (1997), Parra-Montesinos and Wight (2000b) were compared the accuracy of design equations to predict the shear strength of RCS joints between ultimate experimental and predicted strength. However, their use has been limited to low or moderate seismic regions due to lack of appropriate design guidelines for RCS frames in high seismic risk zones.

ANALYSIS FRAME WORK

For this study the selected building in Tehran, was modeled for three various kinds of structures (steel, concrete and RCS) for similar conditions. By this consideration that structural steel members, have high second moments of area concrete is a material with relatively low tensile strength and ductility and will reinforced by bars usually embedded in concrete before sets. It means that characteristics of steel structures allow them to be very stiff in respect to their cross-sectional area.

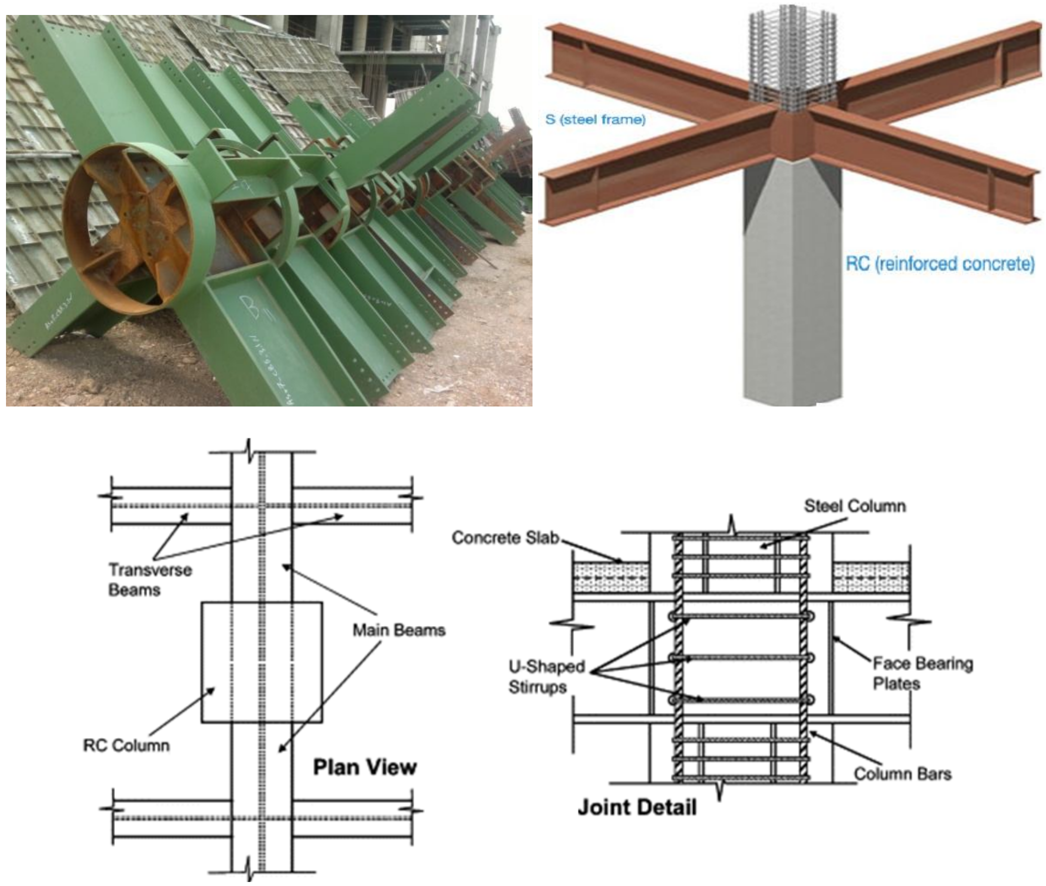

Figure4. Real RCS joints and schematic one with detail

By refer to modular analysis frame work which is given in figure5, and application of ETABS software package the modeling for three kinds of structures by above mentioned assumption was executed and the required data were extracted which is indicated in figures 6, 7, 8 and tables (1), (2) and (3) respectively. By obtained results of the constructed models, the authors would be forced to use MATLAB programming environment to analyze the results of the models and MSP software outputs. The written code is capable to draw the requested diagrams and can analyze the applied loads on the structure. Obtained results of the mentioned code and comparative plotted diagrams are indicated in figures 9 to 11.

By consideration of the performed analysis and to show better resolution of obtained results a detailed separately comparison was executed and the results are given in figure 12 respectively.

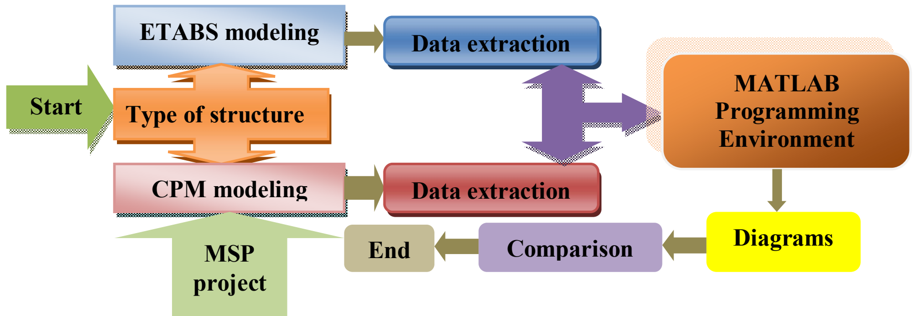

Figure5. Modular analysis frame work of this study

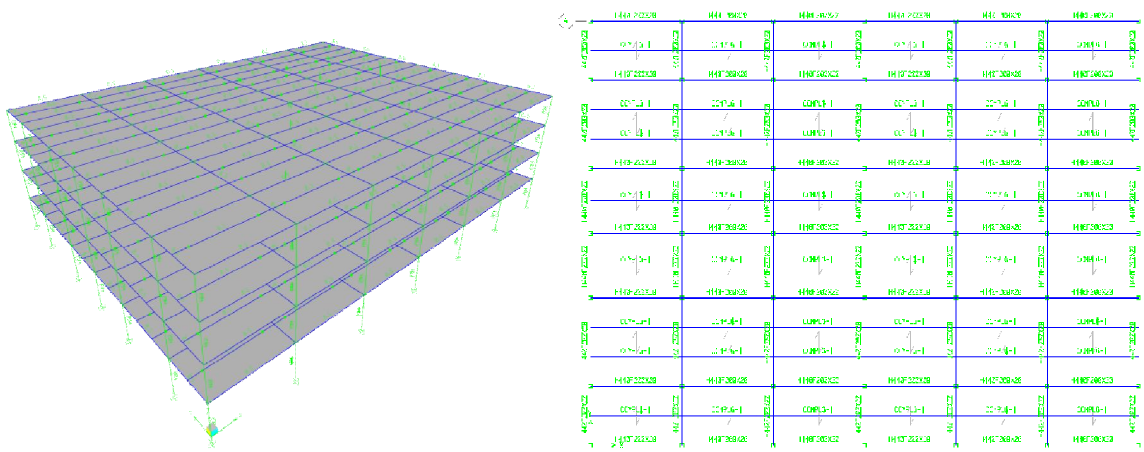

Figure6. ETABS model of steel structure for the case study

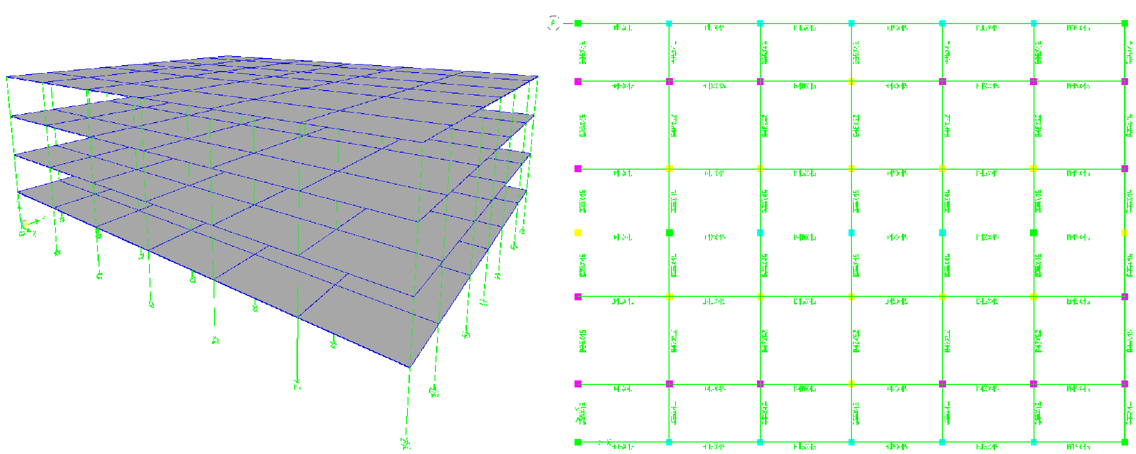

Figure7. ETABS model of concrete structure for the case study

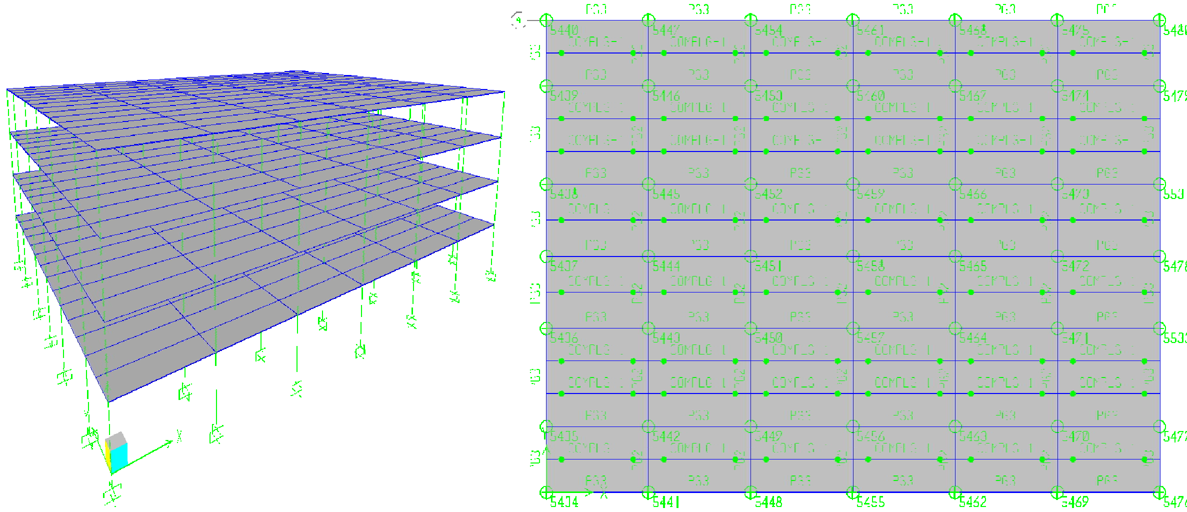

Figure8. ETABS model of RCS structure for the case study

Table (1). Steel structure characteristics extracted by ETABS

			Column	
		Column section	All the frames	stories
			B_{ox} 350x20	1, 2
			B_{ox} 300x20	3, 4
	beam			
	frames			stories
	(B-C) 30 (B-C) 31 (B-C) 32 (B-C) 33 (B-C) 34	(E-F) 30 (E-F) 31 (E-F) 32 33(E-F) (E-F) 34	others	
Beam section	250x20 F 440H	250x20 F 440H		1, 2
	440 H F 200x20	440 H F 200x20		3, 4
			200x20	1, 2, 3, 4

Table (2). Concreter structure characteristics extracted by ETABS

	Beam				
	frames				stories
	31, 32, 33, 35, 29	30, 34	A,C,E,G	B,D,F	1, 2
Beam section	40x45	40x50	40x45	45x45	
	35x45	40x50	35x45	45x45	3, 4

	Column							
	frames							stories
	29, 32, 35	30, 34	(31-F)(31-G) (31-A)(31-B)	-F)(33-G) -B) (33 (33-A)(33	29, 35	31, 32, 33, 35, 40	30, 31, 32, 29, 33, 34, 35	
Column section	50x50	55x55	55x55	55x55				2
					45x45	50x50		3, 4
							60x60	1

Table (3). RCS structure characteristics extracted by ETABS

	Beam		
	frames		stories
	A, B, C, D, E, F, 29, 35	30, 31, 32, 33, 34	
Beam section	PG_3	PG_2	1, 2, 3, 4
	Column		
	frames		stories
	A, B	C, D, E, F, G	
Column section	C_5	C_6	1, 2, 3, 4

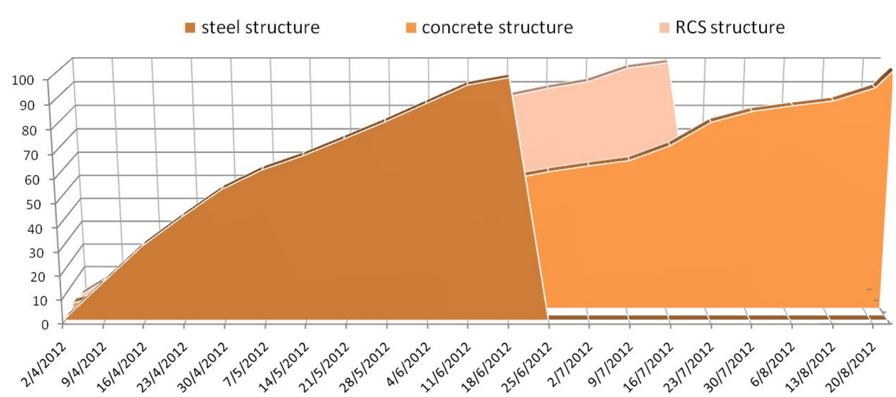

Figure9. Comparison of physical progress for three kinds of structure

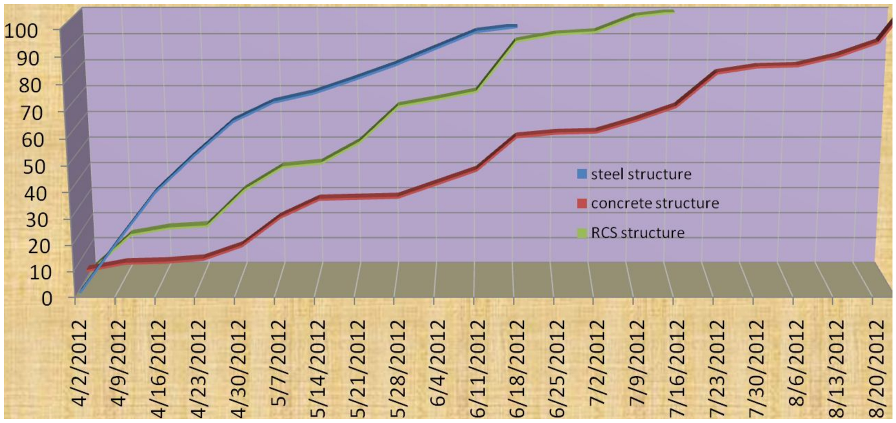

Figure10. Comparison of financial progress for three kinds of structure

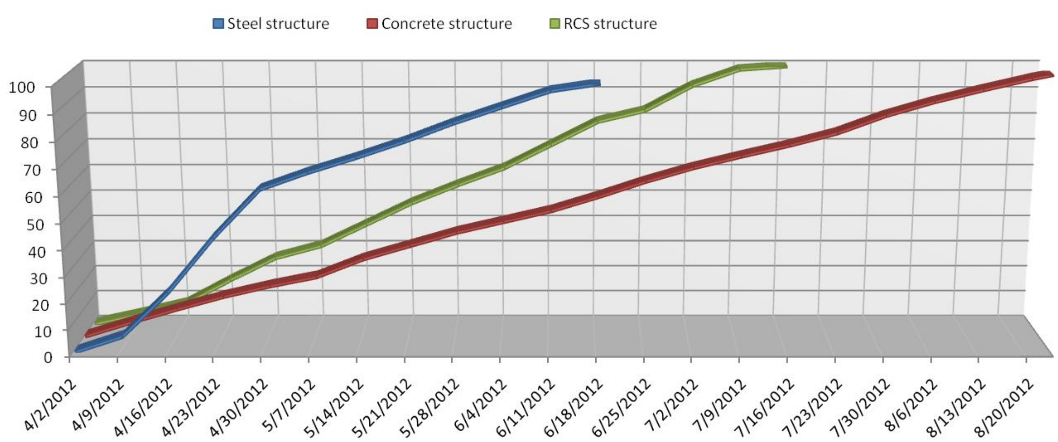

Figure11. Comparison of development of human resources for three kinds of structure

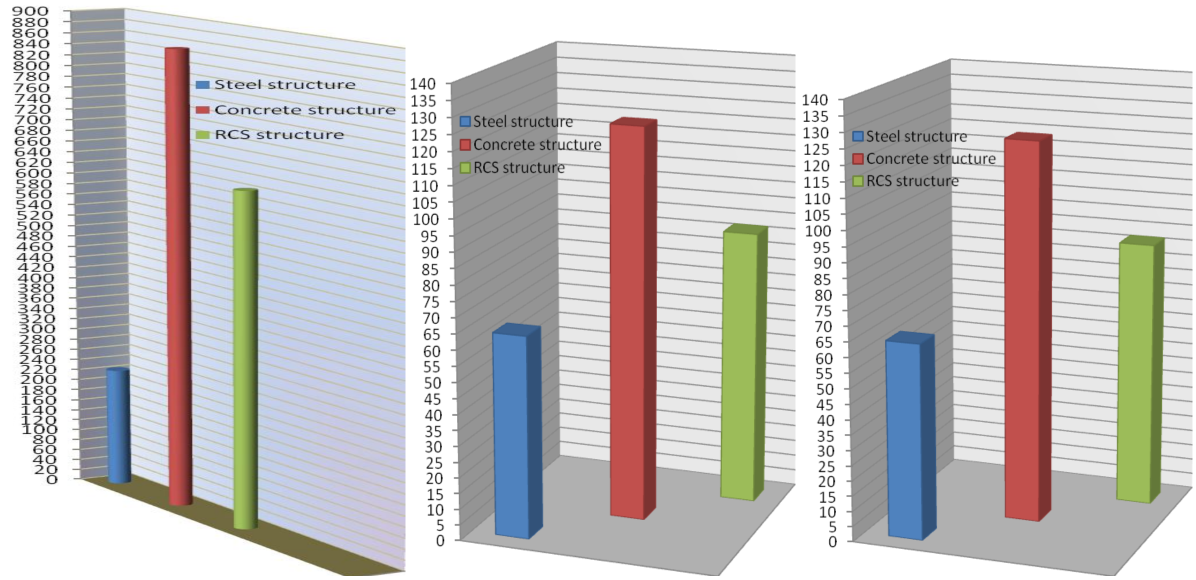

Figure12. Comparative diagrams of the number of required personnel (left), required performance time (middle) and required cost (right) for three kinds of constructed model

CONCLUSION AND DISSCUSION

It can be concluded from the observed general performance that the presented hybrid beam-column connection provides an adequate strength and ductility. The hybrid connection method can be an alternative design in building frame type structures. All of the materials are of the highest quality in order to achieve rational structures, withstand great force and at the same time allow wide spaces between supports. This type of construction allows for large open structures like warehouses for heavy loads and shopping centers.

In this study a practical model to predict the advantages of RCS structures versus steel and concrete ones by regarding a real case study RCS structure in Tehran was presented. The proposed methodology was based on the state of generated computer code, which was defined through the development of a detailed analysis of a case study. A good agreement was found between experimental results and the calculated and predicted by the proposed model. More than the results and resolution of outputs of the generated code in comparison with other available software packages shows good agreement with practical and indicated that this code can employed as a good, strong and reliable tool for this type of analysis.

1. A detailed comparison feasibility study on technical, economical and management conditions between usual structures (steel and concrete) with RCS were performed. At the first by ETABS three mentioned kind of structures with similar basic characteristics were constructed. Then by MSP the performance timing of each of them with total required costs, time and personnel were extracted. At the end to clear the obtained results, by use of MATLAB programming environment a computer code was generated to design the structures and project timing performance. The obtained results showed that the generated code can detect and process of civil operation data and capable to provide higher quality output diagrams with an upper resolution and accuracy.
2. Experimental results indicate that the proposed procedure is effective in controlling joint deformations and damage, leading to economic condition. The obtained number of required personnel for three kinds of model shows that the third place with 224 personnel belongs to steel structure and concrete structure with 852 personnel was the first. In this case the RCS structure with 624 personnel takes the second place. In required performance time (day), the number of 64 (steel structure), 124 (concrete structure) and 87 (RCS structure) was obtained in this study. For required cost (Rials, Iranian unit money), 8660000000 for steel structure, 5160000000 for concrete structure and 7600000000 was computed on base of case condition.

3. Results from the testing of physical progress, required costs and development of human resources in RCS versus steel and concrete structures show that hybrid structures consisting of RC columns and steel beams are suitable for use with lower risk in upper level of construction management.

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