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INVESTIGATION OF REHABILITATION PROCESS OF A REINFORCED CONCRETE BUILDING IN TURKEY UNDER THE RISK OF EARTHQUAKE

ABSTRACT

Urgent measures, concerning reinforced concrete buildings which completed or about to complete their life cycle, need to be taken in regions with earthquake risks. It is important to be sensitive in the case of buildings with unique architectural characteristics during rehabilitation applications. This study presents the rehabilitation process of the Grand Tarabya Hotel as a case study. The selection of this particular case was based on various reasons such as: the building was an example of modern architecture, located in a city with great earthquake risk, the construction technique of it is reinforced concrete and that modern techniques were used for its rehabilitation. The rehabilitation process of the hotel, which includes seismic interventions, has been investigated in respect of project, application and organizational. General suggestions for the rehabilitation process of other similar reinforced concrete buildings have been developed by considering the problems encountered during the rehabilitation process of the case study.

Keywords: Reinforced Concrete Building, Rehabilitation, Grand Tarabya Hotel, Earthquake Risk, Seismic Intervention

TÜRKİYE'DE DEPREM RİSKİ ALTINDAKİ BETONARME BİR YAPININ REHABİLİTASYON SÜRECİNİN İNCELENMESİ

ÖZET

Deprem riski taşıyan bölgelerde, ömrünü tamamlamış/tamamlamak üzere olan betonarme binalarla ilgili acil önlemler alınması gerekmektedir. Özellikle özgün mimari özellikleri olan yapıların kapsamlı rehabilitasyon uygulamalarıyla gelecek kuşaklara aktarılması konusunda duyarlı olunması gerekmektedir. Bu çalışmada, Türkiye'de betonarme yapıların rehabilitasyon sorunları Büyük Tarabya Oteli'nin rehabilitasyon süreci örneğinde irdelenmiştir. Örnek seçiminde yapının modern mimarlık ürünü olması, deprem riski yüksek bir kentte yer alması, yapım tekniğinin betonarme olması ve rehabilitasyonunda modern tekniklerin uygulanması etken olmuştur. Sismik müdahale gören otelin rehabilitasyon süreci projelendirme, uygulama ve örgütsel yapı açısından incelenmiştir. Çalışma kapsamında benzer nitelikteki betonarme binaların rehabilitasyon sürecinde alınabilecek önlemler tartışılmaktadır.

Anahtar Kelimeler: Betonarme Yapı, Rehabilitasyon, Büyük Tarabya Oteli, Deprem Riski, Sismik İzolasyon

1. INTRODUCTION (GİRİŞ)

Turkey has been exposed to the large earthquakes during its history because its location on one of the most active seismic belts. Especially the 1999 Great Marmara Earthquake resulted in a big loss of life and building damage. Because the reinforced construction system is so widespread in Turkey, the majority of the buildings collapsed or damaged in the earthquake were reinforced concrete buildings (Erdik, 2006).

It is a widely acknowledged fact that the city of Istanbul, is under a serious earthquake risk. Until the Great Marmara Earthquake in 1999 reinforced concrete buildings were designed and built with inadequate seismic detailing in Turkey. Due to the new legislation (The Official Gazette, 2007) drawn for this purpose following the earthquake a lot of reinforced concrete buildings/monuments in Istanbul have become non-standard and therefore their rehabilitation is now on the agenda. Grand Tarabya Hotel, the case of this paper, is one of these buildings.

The architectural significance of the building, its age, and whether it is located in an earthquake risk area, are priority factors in taking the decision for rehabilitation. In this context, evaluation studies of the current condition of reinforced concrete building are completed. After the preliminary examination consists of reviewing the current situation and building’s documents the analysis study is carried out. This study includes, soil surveys, determining the quality of the reinforced concrete, statically evaluation of the building, and re-functioning studies. If the dimension of the building elements and the quality of the reinforced concrete is adequate, then it may be enough to do only repairs and conservation. However if the study shows the reinforced concrete not to be of adequate quality, then a comprehensive rehabilitation may be required. According to the determined strategy, the project and planning goes ahead using one or more of the available methods.

In the conservation of reinforced concrete, the key issue is whether the existing material can be repaired and conserved or whether it must be replaced. The concrete and the structure must be investigated to develop repair options and strategies. Laboratory analysis of the concrete to be repaired is an important part of the investigation. All repairs of existing concrete require proper preparations to provide a clean, sound surface to which the repair can adequately bond. During the repair existing reinforcement may be also required cleaning, priming, and painting with a rust-inhibitive coating. The repair area should be reinforced and mechanically attached to the existing concrete. Reinforcement materials can include regular steel, epoxy-coated steel, or stainless steel, depending on the conditions. Preparing trial repairs and mock-ups permit evaluation of the design’s of the aesthetic acceptability (Gaudette, Hime, Conolly, 1995).

Various repair methods available today reduce the rate of corrosion of embedded reinforcing and associated concrete deterioration. One method is cathodic protection. Cathodic protection is intended to reduce the rate of corrosion of embedded steel in concrete, which in turn reduces overall deterioration. Another technique to protect concrete is realkalization. Other methods include flooding with a corrosion inhibitor or, more aggressive, removing the concrete cleaning the exposed steel coating with a epoxy and covering the new concrete, and then sealing. Concrete deterioration is heavily influenced by moisture penetration; rehabilitation may also entail application of a decorative surface coating or a clear penetrating sealer, if appropriate. These water-resistant coatings and sealers should be breathable and alkali resistant. If specific components in reinforced concrete structures are beyond repair, replacement components can be cast in place to match historic ones. As with surface repairs, placement and finishing will dictate how well replacement concrete matches the historic concrete (Gaudette, Hime, Conolly, 1995).

In areas of high earthquake risk, comprehensive rehabilitation works are required for reinforced concrete buildings. Many rehabilitation techniques were investigated recent 20 or more years to apply to both pre-earthquake and post-earthquake rehabilitation. The expected performance level of the building following the earthquake (operational, immediate occupancy, life safety, collapse prevention) and the earthquake hazard levels impact the selection of the techniques (FEMA, 2000);

- Operational level: Backup utility services maintain functions; very little damage.
- Immediate occupancy level: The building remains safe to occupy; any repairs are minor.
- Life safety level: Structure remains stable and has significant reserve capacity; hazardous non-structural damage is controlled.
- Collapse prevention level: The building remains standing, but only barely; any other damage or loss is acceptable.

Retrofitting methods and elements used in the comprehensive rehabilitation of existing reinforced concrete buildings are as follows (Fukuyama, Sugano, 2000):

- Infill existing frames,
- Brace existing frames,
- Place side walls,
- Jacket existing members,
- Provide back-up structure,
- Wrapping existing members.

Another concept to reduce seismic response is to use base isolation systems. For base isolation (Fukuyama, Sugano, 2000):

- Elastromeric systems,
- Friction pendulum systems are presently available.

The locations for establishing isolation are, under the foundation girders, on the foundations, middle of columns or top of columns in a middle story of building. The rehabilitation of buildings with seismic isolation system means developing a new structural system. Then careful considerations of design criteria, structural planning and verification of performance are required. Although a seismic retrofit is more complicated than construction of new buildings, seismic isolation is particularly an effective technique for important buildings which should be functioned after an earthquake or which should be preserved with its original and valuable contents (Fukuyama, Sugano, 2000).

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

This study explicates the rehabilitation process of the Grand Tarabya Hotel. The building constructed with reinforced concrete frame system was designed at the end of 1950s, and seismic isolation and retrofitting applications were used during its rehabilitation. The rehabilitation process of the Hotel was observed on site and investigated in respect of project, application and organizational structure. General suggestions for the rehabilitation of reinforced concrete buildings under the risk of earthquake have been developed by considering the problems encountered during the rehabilitation process of the case study.

3. THE GRAND TARABYA HOTEL (BÜYÜK TARABYA OTELİ)

3.1. Location and History (Konum ve Tarihçe)

The Grand Tarabya Hotel is located on the coast line at the end of the Tarabya bay (Figure 1, 2). The Tarabya bay is located on the north of the Bosporus in Istanbul.

Tarabya Tokatliyan Hotel established by the Tokatliyan family used to be located at the present location of the hotel (Belge, 2003). Grand Tarabya Hotel was constructed between 1957 – 1965 to replace Tarabya Tokatliyan Hotel which burnt down in 1954 (Aysu, 1994). Grand Tarabya hotel started to operate in 1966. After the 1999 earthquake, hotel was evaluated to determine whether it needs rehabilitation. According to this evaluation rehabilitation decision was taken. Because of this reason the hotel was closed down in 2002.

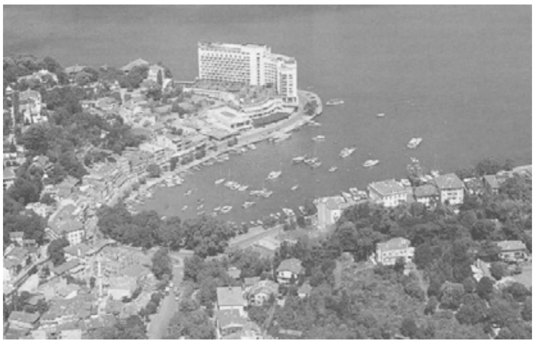


Figure 1. Tarabya Bay,1990's
(Resim 1.Tarabya Koyu, 1990'lar)
(Aysu, 1994)

Figure 2. Grand Tarabya Hotel,
(Resim 2. Büyük TArabya Oteli)
(Sami Yılmazturk, 1996)

3.2. General Architectural Characteristics and Structural Analysis (Genel Mimari Özellikler ve Strüktürel Analiz)

Grand Tarabya Hotel is one of the first large-scaled international hotels of Istanbul. Its massive curved shape following the shoreline illustrates the 1950s approach to the Bosporus shoreline (Batur, 2006). The hotel, which is sitting on a base area of approximately 6,000 m^2 and a total area of 40,960 m^2, is bordering the road (Tarabya Street) which is shaped in parallel to the natural shape of the coast line.

The four storey mass, were designed as service units (Figure 2). Bedroom floors rise on this mass. On the ten storey part of the bedroom floors, bedrooms are located on both the front and back side across from each other. The other eight storey part of the building has the roof bar at the top and the bedrooms are only located at the side of the coast line. On the bedroom blocks which end with a flat roof, there are lift houses which are a storey high and also the part of the building where the roof bar is located have reinforced concrete vaulted roof.

The hotel's facade formation is rhythmically formed. On the first four floors, reinforced concrete elements emphasize the lateral impact, which is achieved with open terraces. On the sea fronts of these floors, there are large spanning windows. The seafront bedroom floors have balconies which have been built in axial format. Although the front facade is outward looking, the back facade has a more of a blind effect.

The Hotel structure consists of 9 blocks separated by expansion joints. Blocks C1, C2, B2 & B3 form the high-rise portion of the

Hotel. Remaining blocks B1, D1, D2, D3 & D4 are low-rise structures (Figure 3). Reinforced concrete slabs are formed as one-way or two-way reinforced concrete slabs (10 cm) and as ribbed slabs in large spanning. When the Hotel was built there was no seismic code in Turkey. Thus, the existing lateral structural system is weak, consisting of only non-ductile beam/column frames. Thus, significant damage can be expected in a major earthquake. Comprehensive rehabilitation decision has been taken for these reasons.

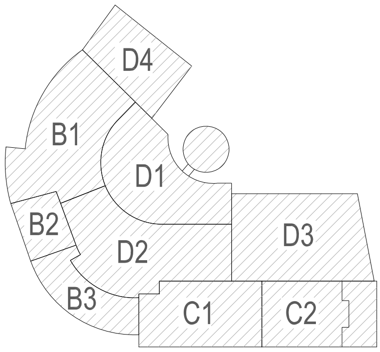


Figure 3. Original expansion joints scheme of Grand Tarabya Hotel
(Şekil 3. Büyük Tarabya Otelinin özgün dilatasyon derz şeması)
(DO-KA/Tuncel/EPS, 2003).

4. FINDINGS (BULGULAR)

The rehabilitation process of Grand Tarabya Hotel has begun in 2003. The retrofitting applications and seismic interventions have been completed towards to the end of 2004. But the re-use application has not completed yet. The main stages and sub-stages which form the rehabilitation process of reinforced concrete buildings, methods and tools used in the process and the results achieved by the various stages, still now, are presented in developed table format. In the table, the procedures used in the rehabilitation process of Grand Tarabya Hotel are shown in bold fonts (Table 1).

The preliminary examination stage at the hotel's rehabilitation process was implemented fully as shown by Table 1. Because it was established from the original documentation of the building that the reinforced concrete did not comply with the present standards, there was no need to further determine to quality of the reinforced concrete in the sub-stages of the analysis part. As a result of the preliminary examination and analysis work, no structural damage to the building was identified. During the re-functioning study, building survey and aboriginal cost analysis were prepared.

In order to determine the safety of the building under the impacts of an earthquake, calculations have been made in accordance with the current earthquake regulations and it was established that the building was not safe enough. With the analysis reports attained through these stages, it was decided that the rehabilitation should be conducted with retrofitting and seismic isolation techniques. Before starting the application, repair license and approval for the applications were obtained from the local authorities.

Because there was no regulation about the subject on the date the project started, the project continued with a lack of application auditing. The project management contractor formed his own audit system with the aid of academics in various stages.

Table 1. Rehabilitation process
(Tablo 1. Rehabilitasyon süreci)

Main Stages	Sub-stages	Methods/Tools	Results
Preliminary examination	Pre-observation of existing condition	**Determination of visual damages**	
	Investigation of existing construction and repair documentations	**Archive research**	
Analysis	Soil surveys (Inspection Hole)	**Soil Profile**, **Ultimate strength**, **Allowable soil pressure**, **Settlement analysis**, **Unit weight of soil**, Modulus of shear, Modulus of bulk, Poisson ratio, **Modulus of elasticity**, Soil fundamental period, Wave velocity P and S, **Site Seismic Hazard**	1 **Determination of structural damages** (Determination of cracking and deflection causes, determination of building components that lost bearing capacity) 2 **Determination of non-structural damages** (Determination of cracking caused by corrosion, Determination of shrinkage cracking, Determination of the segregated zone, concrete deteriorations) 3 **Determination of re-use alternatives (continuity of original function**, new function possibilities)
	Determination of reinforced concrete quality	Core sample, Ultrasonics and rebound hammer readings, Determination of rebars diameter and location with pachometer and cover meter, Petrographic evaluation, Chemical analysis	
	Evaluation of building structure	**Preparation of building survey, Comparison of survey with new project, Determination of new requirements of structural system and conformation to regulations**	
	Re-use study	**Preparation of building survey,** Determination of new functioning potential, Determination of conformation of new function to the project, **Aboriginal cost analysis**	
Determination of strategy decision		**Analysis Result Report** **Determination of expected performance level of the building**	Demolition decision: 1 Deconstruction 2 Classification of building elements/ materials Re-use decision with appropriate function: 1 Repair & Conservation 2 Rehabilitation with seismic resistant techniques 3 Rehabilitation with seismic isolation techniques 4 **Rehabilitation with mix (seismic resistant & seismic isolation) techniques**
Planning and preparation of project	Selection of material & technique Preparation of necessary detailed drawings Preparation of work plan Cost analysis	**Organization of specialists and technical team** **Equipment and hardware**	1 **The Re-Use (Architectural) project** 2 **Retrofitting (Static) project** 3 Mechanical project 4 Electrical project
Control of project	Determination of conformation to the regulations and specifications	Professional organs **Local** and state **organs**	**Approval for the application**
Application	Taking measures for technical safety	**Organization of technical team** **Equipment and hardware**	**Retrofitted reinforced concrete building**
	Preparation of the building Technical operations	Conservation methods **Addition of new footing** **Strengthening of existing footing** Infill existing frames **Brace existing frames** **Place side walls** **Jacket existing members** Provide back-up structure Wrapping existing members Elastometric system **Friction pendulum system**	
	Control	**Organization of team** **Equipment and hardware**	
Control	Control of material Observation on site	Professional organs Local and state organs	Approval for the use of building

4.1. Project and Application (Proje ve Uygulama)

During rehabilitation design no major changes have been made to the functional distribution of the hotel which is to continue to serve its original function. In project the usage capacity of some service unit has been increased, the original formation of the hotel's front facade has been kept to a large extent (Table 2).

Table 2. The functional distribution of original and re-use projects of Grand Tarabya Hotel
(Tablo 2. Büyük Tarabya Otelinin özgün ve yeni projelerine gore fonksiyon dağılımı) (DO-KA/Tuncel/EPS, 2003)

	Pre-Rehabilitation Layout		Post-Rehabilitation Layout	
Hotel Site		11,389 m^2		11,389 m^2
Use site	Superstructure	40,960 m^2	Superstructure	40,960 m^2
	Infrastructure	---	Infrastructure	---
	Total	40,960 m^2	Total	40,960 m^2
Height	With elevator shaft	47.80 m	With elevator shaft	47,80 m
Number of flat	Superstructure	14	Superstructure	14
	Basement	0	Basement	0
Vertical circulation	Client	2 Elevator	Client	2 Elevator
	Service	6 Elevator	Service	4 Elevator
Service units	Bedrooms	268	Bedrooms	245
	Standard (twin bed)	180	Typical room (twin bed)	119
	Large room	51	Typical room (twin bed)	77
	Suite	27	Small suite	26
	Small suite	10	Suite	18
			Royal suit	1
			Disabled room	4
	5 Conference/Meeting Hall	525 person	1 Conference hall	600 person
			12 Meeting hall	770 person
	2 Ball room	800 person	3 Ball room	600 person
	2 Kitchen		1 Main kitchen	
	2 Service kitchen		7 Service kitchen	
	4 Restaurant (closed)	400 person	1 Personal kitchen	
			Lobby saloon restaurant	90 person
			Patisserie	50 person
			"Noodles" restaurant	120 person
			Main restaurant	120 person
			Jazz bar	100 person
Parking Place	Open	40 car	Open	100 car

With the retrofitting project designed in such a way to meet requirements for the lateral loads affecting the building, the D4 block was left out of the project and blocks B2, B3, C1, C2 and D2 are joined up and made into one block (Figure 3).

For this joined up block consisting of bedroom blocks and common spaces, retrofitting methods such as jacketing of the reinforced concrete elements, addition of reinforced concrete walls and "Friction Pendulum" system which isolates seismic movements were applied in order to provide for the "immediate occupancy level" in the aftermath of an earthquake (Figure 4, 5). The other three blocks (B1, D1, D3) were retrofitted with reinforced concrete column jacketing and the addition of reinforced concrete walls in order to provide for the "life safety level" expectations.

The requirements arose for the retrofitting of whole building to be provided by strengthening of footings, expanding the sizes of spread footings, placing new footings under the additional reinforced concrete walls and joining up spread footings to build continuous footings. Additionally when deemed necessary footing elements were supported with lean concrete filling underneath. The part of the building consisting of joined blocks was equipped with an isolator system, which ensures that the earthquake loads have minimum effect on the building. These equipments were placed on the upper parts of the ground floor columns (110 cm down from the ceiling). In the joined up block in line with the locations of the placements of isolators, columns on the ground and first floors were strengthened with the reinforced-concrete jacketing system and hence there were losses of space on these floors. On the other floors, mainly additional reinforced concrete walls were used and the reinforced concrete jacketing applications were used locally. By means of this retrofitting design the loss of space at these flats was minimized. Additionally, as the floor height was rather high on the entrance hall, steel braces were used to achieve stability between the columns of lobby (Figure 5). The expansion joints separating this part from the other parts were increased to 40 cm because of the 32 cm movement capacity of the isolator system. In the area where the expansion joints had been increased, the reinforced concrete columns and beams which were cut off, were replaced locally by additional reinforced concrete walls and steel frame structure systems.

Figure 4. Jacketing existing columns
(Resim 4. Kolonların mantolanması)(DO-KA/Tuncel/EPS, 2003)

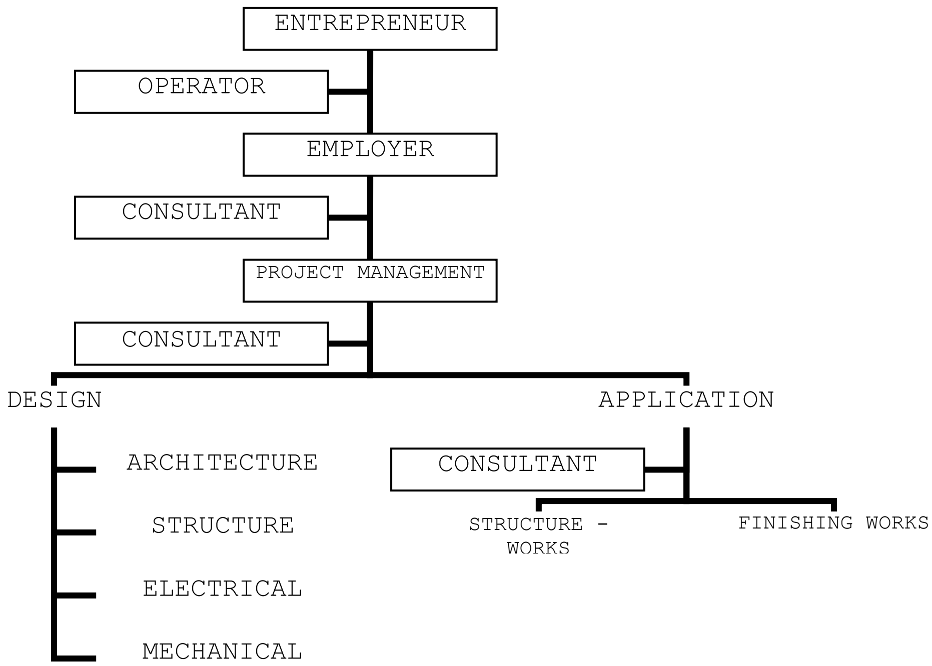
Figure 5. Isolator system and steel braces
(Resim 5. İsolatör sitemi ve çelik kuşaklar)(DO-KA/Tuncel/EPS, 2003)

4.2. Organizational Structure (Örgütsel Yapı)

The owner of the hotel decided to rehabilitate the hotel before it became operational again. A construction company which belonged to the owner was tasked with identifying the rehabilitation strategy. The rehabilitation work of the hotel was then given to another company which specialized in project management. The rehabilitation work is conducted by two different teams one responsible for design and the other for application.

Before the transfer of the project management and the start of the application, academic consultant were brought in for preliminary examination at the architectural and static project development stages. The control of the retrofitting of the structural system and the seismic isolation application conducted at the application stage was done by the static project developer (Table 3).

Table 3. The organizational chart of rehabilitation process of Grand Tarabya Hotel
(Tablo 3. Büyük Tarbya Otelinin rehabilitasyon süreci örgütlenme şeması)



5. CONCLUSION (SONUÇ)

Since the lack of legislation and organization model during the rehabilitation of reinforced concrete buildings in Turkey, the rehabilitation process of the Grand Tarabya Hotel has been taken long term. The regulations do not include new rehabilitation techniques used in the hotel. Considering the rehabilitation process of the Hotel, it is understood that the rehabilitation of reinforced concrete buildings needs organization in governmental policy and project management. It is also understood that the rehabilitation techniques used in the rehabilitation work determine the re-functioning task of the building. Since it is very important to balance the rehabilitation strategy with re-use possibilities of the reinforced concrete buildings.

In the aftermath of the earthquakes, a country wide disaster management policy needs to be developed and in line with this policy all the regulations concerning the issue ought to be made compatible. Additionally, in order to identify the seismic capacities and rehabilitation strategies of existent reinforced concrete buildings "seismic evaluation standards" and "rehabilitation guidelines" should be developed. These standards and guidelines should be developed in such a way so that they can also be applied to buildings which can be classified as architectural heritage.

The new regulations should define the organizational structure to be formed for rehabilitation applications, identify what its responsibilities and authority will be and ensure coordination between the various branches involved. The responsibilities and authorities of professional organizations and local governments should also be defined and an effective audit model should be developed for these applications. The rehabilitation process which is presented at Table 1 could play a supplementary role during the planning, application, assigning tasks to professions during planning and application and auditing of reinforced concrete buildings' rehabilitation. The lack of expertise about the issue should be overcome by the relevant academic institutions through the development of training programmes.

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