Investigation Of Seismic Performance Of Existing Building Strengthened With Cfrp

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Abstract

In this study, the seismic performance of the Merkez Efendi hospital building was determined with CFRP strengthening methods according to the Turkish Earthquake Code-2007. Firstly, the building was considered with the masonry walls and without masonry walls and the effect of the masonry walls to the performance of the building was investigated. Afterwards, the building was strengthened with CFRP plates to get the required seismic performance level. Consequently, the seismic performances of the hospital building were compared for these three cases.

Keywords: Strengthening, Masonry Wall, CFRP, Seismic Performance

1.INTRODUCTION

Buildings are subjected to earthquake, wind, fire etc. during their lifetimes. Sometimes, addition of a story and change in the purpose of using occur. For these reasons, the performances of the buildings should be investigated according to the present earthquake codes of the countries. If the performance of the building is insufficient, it must be rehabilitated. The Turkish Earthquake Code-2007 (TEC-2007) gives alternative rehabilitation methods. One should choose the most suitable method for buildings. Chapter 7 of TEC-2007 entitled "Assessment and Strengthening of Existing Buildings" and sets standards for

336

assessment and rehabilitation of existing buildings (Sucuoglu 2006). Recently, there have been some studies about linear and non-linear procedures in TEC-2007 and concluded that results of linear procedures are more conservative than non-linear ones (Sengoz 2007, Tuncer et al. 2007, Kalkan and Kunnath 2007).

In this study, the seismic performance level of the Merkez Efendi hospital building with and without masonry walls is determined according to TEC-2007. The some masonry walls are strengthened with CFRP plates for rehabilitation of building. The capacity curves and performance levels of the strengthened buildings are determined with incremental static pushover analysis and compared.

2.DESCRIPTION OF THE HOSPITAL BUILDING

The hospital building has ground floor and three stories. The height of the ground floor is 3.70 m and the heights of the other floors are 3.20 m. The building has dimensions 34.90 m by 14.70 m in plan. The building has two shear walls, columns and beams (Fig.1). The building is situated in the 1.seismic zone and Z3 local site class. The standard compressive strength of the concrete of the building is determined from the samples taken from the columns as 11 MPa (Fig.2.b). Material properties are 220 MPa for the yield strength of both longitudinal and transverse reinforcements.
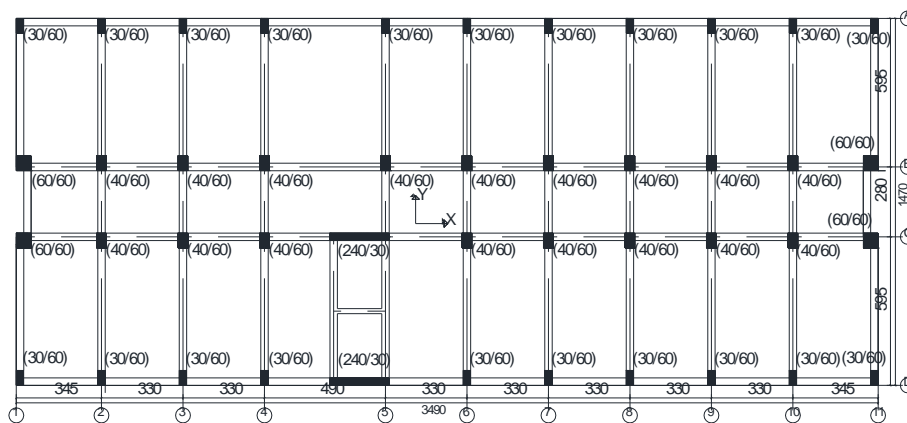

Figure 1: The plan of ground and first floor of the existing building

a) The hospital building   b) The coring

Figure 2: Existing Building

The existing hospital building was modeled with the present masonry walls and without the masonry walls and they were shown in Figure 4.a and 4.b. After the existing hospital building is rehabilitated with CFRP plates (Fig 4.c).

The masonry walls of the hospital building were compared to trusses according to FEMA and Mainstone who had recommend the formulas Equation 1, 2 and 3. According to TEC-2007 the elasticity modulus of the masonry walls and compression strength were determined as   1000   MPa,   1   MPa,   respectively.

d   : Diagonal length

t   : Width of masonry wall

Wef   : Effective wal width

Em   : Modulus of elasticity (Masonry)

Es   : Modulus of elasticity (Frame)

R   : Bearing capacity

H`   : Length of masonry wall

H   : Story height

L`   : Net span width

L   : Span width

θ   : Angle of diagonal compressive bar
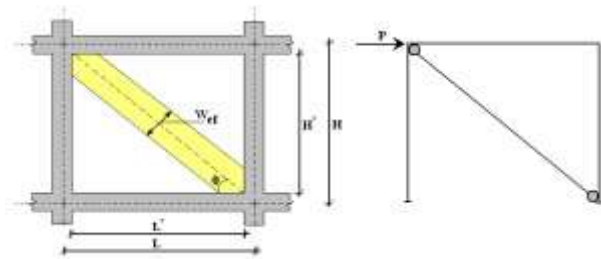
Ic   : Moment of inertia of columns

Figure 3: Diagonal compression region in masonry wall under lateral load and equivalent virtual diagonal compressive bar element that represents the masonry wall

$$d = \sqrt{H^2 + L^2} \qquad (1)$$

$$w = 0.175(\lambda_1 \times H)^{-0.4} \times \sqrt{H^2 + L^2} \qquad (2)$$

$$\lambda_1 = \left[\frac{E_m \times t \times \sin 2\theta}{4 \times E_s \times I_c \times h} \right]^{\frac{1}{4}} \qquad (3)$$

The strengthening with CFRP plates is seen in Fig.4.c. The width of the CFRP plates is 100 mm and the thickness is 1.4 mm, the modulus of elasticity of CFRP is 210000 MPa. The three CFRP plates are bonded to the masonry walls side by side. The performance levels of this rehabilitation are compared with the existing building performance. The connection details of CFRP are shown in Fig.5.

H-EB   = Existing Hospital Building

H-EBMW   = Existing Hospital Building with Masonry Walls

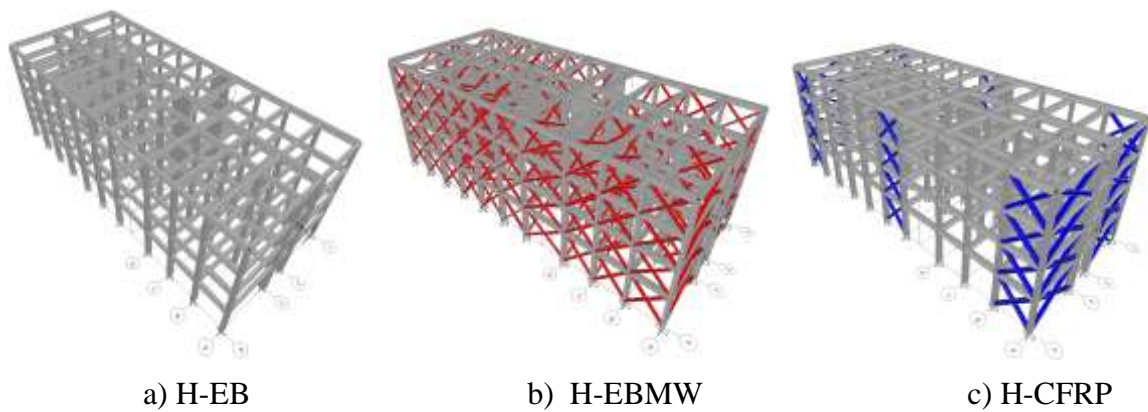H-CFRP   = Strengthened Hospital Building with CFRP

a) H-EB   b) H-EBMW   c) H-CFRP

Figure 4: The existing and strengthened hospital buildings with CFRP method
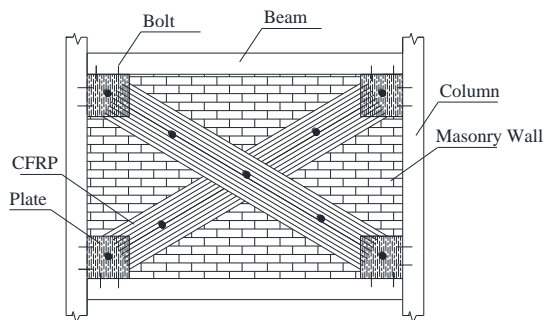

Figure 5: The connection details of CFRPs

3.METHODS

340

The incremental static pushover analysis was employed for the performance assessments. The incremental equivalent static lateral force analysis is limited to 8 story buildings with total height not exceeding 25 m, and not possessing torsion irregularity. Nonlinear flexural behaviour in frame members are confined to plastic hinges, where the plastic hinge length Lp is assumed as half of the section depth (Lp= h/2). Pre-yield linear behaviour of concrete sections is represented by cracked sections, which is 0.40EIo for beams and varies between (0.40-0.80)EIo with the axial stress for columns. Strain hardening in the plastic range may be ignored, provided that the plastic deformation vector remains normal to the yield surface.

The objective is to carry out nonlinear static analysis under incrementally increasing lateral forces distributed in accordance with the dominant mode shape in the earthquake excitation direction. Lateral forces are increased until the earthquake displacement demand is reached. Internal member forces and plastic deformations are calculated at the demand level. A capacity diagram is obtained from the incremental analysis which is expressed in the "base shear force - roof displacement" plane.

The reference design spectrum in the Code has 10% probability of exceeding in 50 years. Based on Turkish strong motion data, it is estimated that the spectral ordinates for 50% probability of exceeding in 50 years are half of the reference spectrum whereas the ordinates for 2% probability of exceeding in 50 years are 1.5 times that of the reference spectrum.

Building earthquake performance level is determined after determining the member damage states Evaluation of the investigated buildings is performed using the recently published TEC-2007. Three performance levels, immediate occupancy (IO), life safety (LS), and collapse prevention (CP) are considered as specified in this code and several other international guidelines such as ATC-40, FEMA-273, FEMA-307, FEMA-356(ASCE 2000), FEMA-440, EC-8 and NZS-2003. The rules for determining building performance in TEC-2007 are given for each performance level.
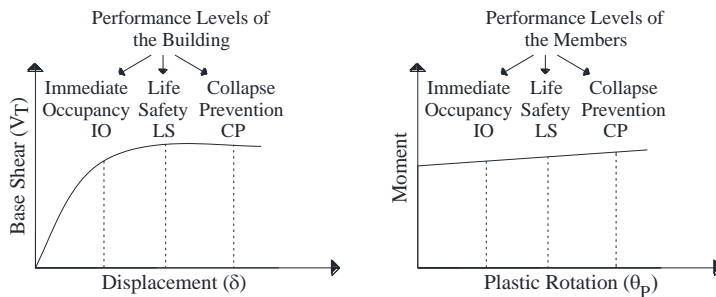

Figure 6: Performance levels for members and buildings

4.RESULTS

Modal properties of the first mode of the building are given in Table 1. The effect of the rehabilitation method with CFRP plates on the dynamic properties of the building are shown in Table 1.

Table 1: Period values of the hospital building

Type of Building	H-EB	H-EBMW	H-CFRP
X direction	0.566	0.517	0.528
Y direction	0.555	0.511	0.520

The capacity curves (base shear-displacement) of the buildings are obtained for x and y directions with incremental static pushover analysis and shown in Figure 7.
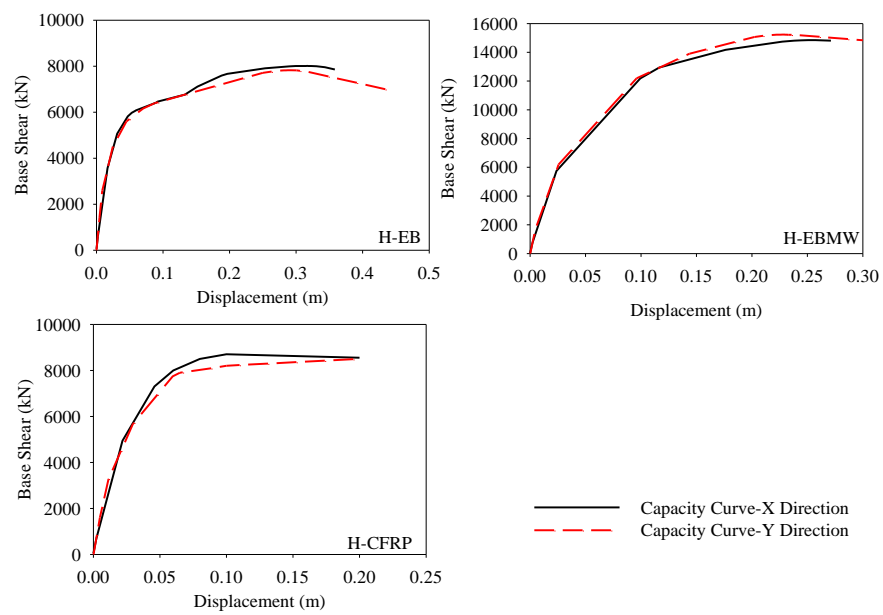

Figure 7: The capacity curves of the building

According to TEC-2007, the seismic performance points of the hospital building are obtained with incremental static pushover analysis and shown in Table 2. While the base shears of the strengthened building and having masonry walls increase according to the existing building without masonry walls, it is observed that displacements are same levels.

Table 2: Performance points for incremental static pushover analysis

	H-EB		H-EBMW		H-CFRP	
	X	**Y**	**X**	**Y**	**X**	**Y**
Base Shear (kN)	6233	5703	9809	8537	8182	7470
Displacement (m)	0.073	0.050	0.071	0.053	0.070	0.050

According to TEC-2007, the member damage states are determined and shown in Table 3, 4 and 5. Since the existing building does not provide life safety level, it is strengthened with CFRP plates. The seismic evaluations of the building are calculated for each state with the TEC-2007.

Table 3: Performance level of H-EB for incremental static pushover analysis

Story	<IO		IO		LS		CP	
	Beams	**Columns**	**Beams**	**Columns**	**Beams**	**Columns**	**Beams**	**Columns**
1	0(%0)	0(%0)	10(%29)	19(%43)	18(%53)	12(%27)	6(%18)	13(%30)
2	0(%0)	44(%100)	1(%3)	0(%0)	14(%41)	0(%0)	19(%56)	0(%0)
3	0(%0)	44(%100)	3(%9)	0(%0)	20(%59)	0(%0)	11(%32)	0(%0)
4	0(%0)	44(%100)	20(%59)	0(%0)	14(%41)	0(%0)	0(%0)	0(%0)
Evaluation	**Life Safety Level X**							

Global performance level of the building is given for incremental static pushover analysis in Table 3. In first story, in the direction of the applied earthquake loads, 29% of the beams
343

and 43% of the columns are in the immediate occupancy states. 53% of the beams and 27% the columns are life safety states in this story. 18% of the beams and 30% the columns are collapse prevention states in this story. In this situation, the building performance does not satisfy life safety (LS) level.

Table 4: Performance level of H-EBMW for incremental static pushover analysis

Story	<IO		IO		LS		CP	
	Beams	Columns	Beams	Columns	Beams	Columns	Beams	Columns
1	0(%0)	0(%0)	10(%29)	19(%43)	18(%53)	12(%27)	6(%18)	13(%30)
2	0(%0)	44(%100)	1(%3)	0(%0)	14(%41)	0(%0)	19(%56)	0(%0)
3	0(%0)	44(%100)	3(%9)	0(%0)	20(%59)	0(%0)	11(%32)	0(%0)
4	0(%0)	44(%100)	20(%59)	0(%0)	14(%41)	0(%0)	0(%0)	0(%0)
Evaluation	Life Safety Level X							

Table 5: Performance level of H-CFRP for incremental static pushover analysis

Story	<IO		IO		LS		CP	
	Beams	Columns	Beams	Columns	Beams	Columns	Beams	Columns
1	27(%79)	39(%89)	5(%15)	3(%7)	2(%6)	2(%4)	0(%0)	0(%0)
2	29(%85)	44(%100)	3(%9)	0(%0)	2(%6)	0(%0)	0(%0)	0(%0)
3	34(%100)	44(%100)	0(%0)	0(%0)	0(%0)	0(%0)	0(%0)	0(%0)
4	34(%100)	44(%100)	0(%0)	0(%0)	0(%0)	0(%0)	0(%0)	0(%0)
Evaluation	Life Safety Level √							

344

5.CONCLUSIONS

In this study, the seismic performances of the Merkez Efendi Hospital building are determined according to the conditions of TEC-2007. Since the seismic performance of the existing building is insufficient, CFRP method is used for the rehabilitation and the results are compared.

As a result of the performance analyses:

- The existing hospital building does not satisfy the life safety level for the earthquake that may be 2% probability of exceeding in 50 years.
- The performance analyses of the building were considered with the masonry walls and without the masonry walls. The lateral load capacity of the building with the consideration of the masonry walls was 57% more than that of the without masonry walls. However, the displacements were the same for two cases.
- The strengthening members (CFRP) are designed according to the minimum standards of the TEC-2007.
- Although lateral load carrying capacity of strengthened building increase, horizontal displacement at the roof for the building is same with existing building.
- As the member damage conditions are investigated, the performance of the strengthening method according to the conditions of TEC-2007 is satisfactory.
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As a result of this work:

Once the effect of the masonry walls is taken into account in structural analyses, the buildings are designed more economic. The application of CFRP plates should be detailed very good and applied very well. As a result, it can be said that the CFRP method recommended in the TEC-2007 can be applied with confidence.

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