PERFORMANCE STUDY OF CONCRETE STRUCTURES OF HOSPITALS IN KERMAN, IRAN

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Keywords: Concrete Structures of Hospitals, Seismic Rehabilitation, Performance Based Design, Pushover Analysis, Target Displacement

ABSTRACT

Studying the vulnerability of buildings such as hospitals for decreasing the damages and immediate occupancy of therapeutic centers as well as hospitals, after the average earthquakes, is of paramount importance. In this article, two concrete structures of hospitals in Kerman as the most important hospitals of this province are evaluated by the non– linear static analysis and the Instruction for Seismic Rehabilitation of Existing Buildings NO.360 (First Revision) The first three stories' structure (with 3000 m2 area) was designed and used in 1986 and 2002, respectively as well, the second,third and the fourth is one and two story's structure (with 3000, 1000, 500 m2 area) was designed in 2013 and it is now under the construction. The performance of these hospitals in the Basic Safety Earthquake 1 (BSE 1) and in the Basic Safety Earthquake 2 (BSE 2) must be associated with immediate occupancy and life safety level, respectively. Based on the related assessment, it is shown that the first structure is not able to stand the target displacement of BSE 1 and it becomes instable in a displacement less than the target displacement as its factors will be studied in– detail. One of the other aims of this article was to study the design of the very high important buildings such as hospitals considering the current codes of designing in Iran; means that whether these codes could provide the real needs of the aforementioned buildings as the immediate occupancy during the average earthquakes and life safety level during the severe earthquakes (or not). So, studying these hospitals showed that the codes of seismic design could provide the real performance of these structures in the events such as average earthquakes.

INTRODUCTION

Designing based on the performance of a philosophy is the comprehensive design in which the criterion of designing are based on the functional purposes. The functional purpose can be the desirable contour/balance of the seismic performance of a structure such as lateral deformations, lateral sways of floors, ductility of element and the index of element's damage in a face of a definite balance from the risk of earthquake; in other words, a functional aim will be formed by combining a performance balance of a building and the balance of an earthquake. Hospital is accounted as an organization which satisfies the needs of humans and also it is one of the main parts of the health system. Based on the necessity of using the hospitals during the earthquakes, studying the seismic behavior of concrete structures of Kerman hospitals considering the performance level which indicates the real performance and behavior of structures during earthquake and also determining the weakness points of the aforementioned structures based on the Instruction for Seismic Rehabilitation of Existing Buildings NO.360 (First Revision) seems essential as well, whether these kinds of structures that must provide the services to the patients during the event of earthquake possess their performance which is the immediate occupancy [Basic Safety Earthquake 1 (BSE 1)] and life safety level [Basic Safety Earthquake 2 (BSE 2)] or not. So, in this paper, these issues will be studied. The resulted applications from this article are the acceptability of codes of designing the most important structures such as hospitals which are based on the power/force and also comparing it with the Instruction of Rehabilitation as designing is based on the level of performance and deformation. In this article, four concrete structures of hospitals in Kerman which are the most important hospitals of this city were evaluated by the non-linear static analysis and Seismic Rehabilitation of Existing Buildings NO.360 (First Revision).

STRUCTURAL SYSTEMS OF CONSIDERED MODEL

The first hospital which was evaluated was Afzali Poor with an area of 40,000 m2 located in the highway of Imam Khomeini. This hospital which was designed by the design consultant in 1986 and its construction process was initiated in 1999 is accounted as the most hospital of Kerman. In 2002, this hospital was opened and initiated its activities. The aforementioned hospital consists of 33 blocks (1-33) in two and three stories [floors] and due to its width, block no: 10 was studied. This block with the infrastructure [area] of 3,000 m2 is in three stories. The above structure includes the concrete structure with a flexural frame along each direction as well; the two-way slab (thickness of 10 cm.) was used in order to carry the gravitational load of floors in the ceilings/roofs.

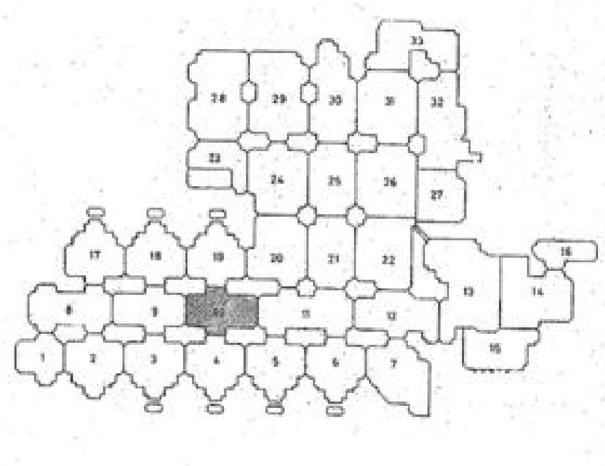
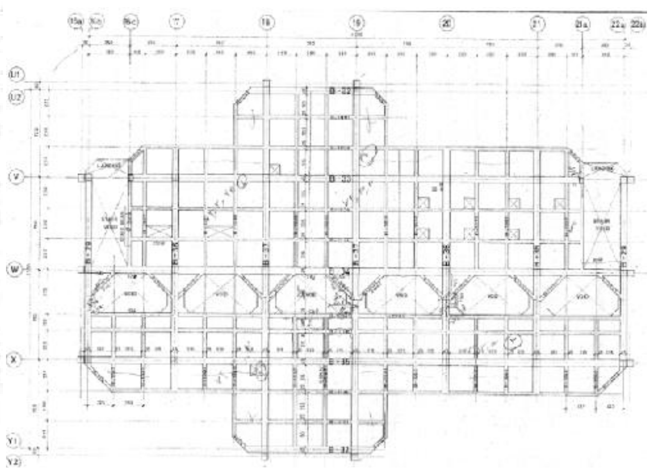

Figure 1.Site plan in Afzali Poor hospital of KermanFigure 2. Plane in Afzali poor hospital of Kerman

The second hospital which was studied is the psychiatric hospital with an area of 10,000 m2. This hospital was designed by the design consultant in 2013 and its construction process was initiated in 2014. Due to its width, only three blocks "A, G and F" were studied. Block F. with an infrastructure [area] of 3000 m2 is in two floors and also Block G. and Block A. with infrastructures of 1000 m2 and 382 m2 are in two and one floors, respectively. The above – mentioned structures consist of flexural concrete structure along two directions and the roof of a flat concrete slab has a thickness of 15 cm.

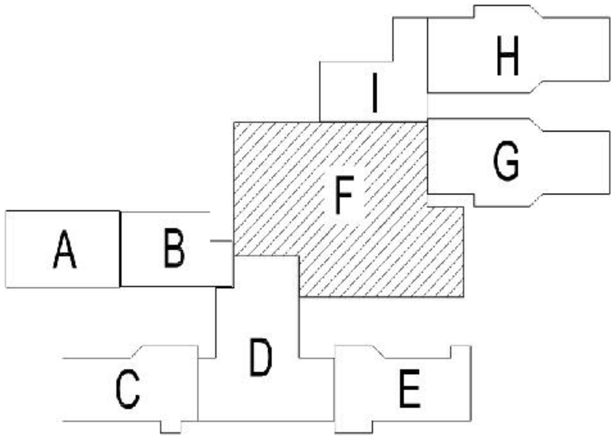

Figure 3.Block F Site plan in kerman psychiatric hospital

Figure 4. Block F Plane in Kerman psychiatric hospital

DETERMINING THE PURPOSE OF UPGRADING/RECLAMATION AND THE AWARENESS COEFFICIENT

According to Appendix A of publication 360 (first revision) Table (c–a), the aim of upgrading/reclamation of Emdadi building is specific which must be associated with the performance level of B-1 (continuance use) in terms of the structural and non-structural elements in the earthquake of risk level 1 (earthquake with a return period for each 475 year) and performance level of C-2 in terms of structural elements of limited failure and non-structural elements of life safety in the earthquake of risk level 2 (earthquake with a return period for each 2475 year). Since the purpose of upgrading/reclamation is specific and the level of information must be in the level of comprehensive information, so based on table 1-2 of upgrading/reclamation instruction 360 (revision), the awareness coefficient of K will be equal one.

PLASTIC JOINTS/HINGES AND THEIR

In order to do nonlinear analysis, the plastic joints must be defined and allocated to elements (means that the nonlinear characteristic of materials or the nonlinear behavior of elements must be defined). Based on the provisions of instruction, the parameters of modeling (a, b, c) and the criterions of acceptance for each section and elements will be defined. Due to the conditions of the considered structures in the concrete beams, the plastic joints will be defined at the beginning and the end of beams (Nonlinear joint M3 at the beginning and end of the beam) but for the columns, the plastic joints will be defined at the beginning and the end of columns (Nonlinear joint PM2M3 at the beginning and end of the columns).

DEFINE THE LOAD-DEFORMATION RELATIONSHIP

Based on the provisions of the instruction given the type of element, the cross-sectional sizes and the dimensions of the modeling parameters (a, b, c) were extracted from the tables of instructions and are defined for all elements (all beams and columns). According to the sixth chapter of this instruction, modeling parameters of a, b, c were defined for beams (flexion/bending) and columns (flexion/bending interaction and axial force) as the below figure. In the reinforced concrete materials with non-symmetrical reinforcement, there is not a curve to the basis of symmetry and for instance, in the beams with different reinforcement in the lower and upper side, the capacity values of positive and negative moments are different. In the point of B, the cross-sectional capacity is calculated by assuming the expected characteristics of materials (concrete and reinforcement) and the slope changes of BC section will be 0-10% of slope of AB section as well, in these structures, this slope is about 3%. The details of the load-deformation (bending) relationship of the elements as well as the assumptions about the range of slope changes of BC section are shown in the following figure.

Table 1. An example of the values of the load-deformation graph in July (B-04-23 and 26), Block A

Points	A	B	C	D	E
Rotation	0	0	0.025	0.025	0.05
moment	0	1	$1 + (0.03) \times 0.025 = 1.0007$	0.2	0.2

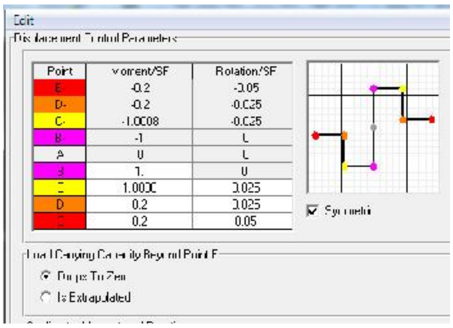

Figure 5.Force – curve – displacement.

FIRST NONLINEAR ANALYSIS AND CALCULATION OF THE INITIAL TARGET DISPLACEMENT

After defining the elements of the non-linear model using a combination of gravity and lateral loading (0.9QD, 1.1 (QD + QL) and the initial analysis, it is possible to calculate K_e and T_e by using the bilinear behavior curve of the structure and also, the initial target displacement will be determined.

Table 2. Values of displacement of first target based on the instruction of Seismic Rehabilitation

Displacement of final target, (cm) δ_t in BSE 2		Displacement of final target, (cm) δ_t in BSE 1			
Distribution of type 2	Distribution of type 1	Distribution of type 2	Distribution of type 1	Performance	Building
16.95	17.95	11.05	11.97	Shear	Block 10., Afzali Poor hospital
5.13	5.24	3.35	3.51	Shear	Block F., Psychiatric hospital
3.70	3.84	2.43	2.56	Shear	Block G., Psychiatric hospital
3.25	3.35	2.13	2.23	Shear	Block A., Psychiatric hospital

After the first analysis, the initial displacement is calculated and the displacement curve to the basic cut of the structure (binding curve) is obtained. Based on the above curve, the bilinear behavior of the structure will be specified and at the end, after trial and error, the displacement of the ultimate target will be calculated as its values were presented in the below table.

Table 3. Values of displacement of final target based on the instruction of Seismic Rehabilitation

Displacement of final target, (cm) δ_t in BSE 2		Displacement of final target, (cm) δ_t in BSE 1			
Distribution of type 2	Distribution of type 1	Distribution of type 2	Distribution of type 1	Performance	Building
37.55	37.75	25.01	25.17	Shear	Block 10., Afzali Poor hospital
12.95	13.11	8.60	8.74	Shear	Block F., Psychiatric hospital
10.96	11.14	7.21	7.43	Shear	Block G., Psychiatric hospital
10.34	10.51	6.9	7	Shear	Block A., Psychiatric hospital

GENERAL PUSH CURVE OF THE CONSIDERED MODELS

Based on the displacement of the final aim in Basic Safety Earthquake 1 (BSE 1) and life safety level [Basic Safety Earthquake 2 (BSE 2) of the modeled structures, it is observed that the structure of block 10 of Afzali Poor hospital does not reach its displacement means 25 cm. The general enveloping curve of structure continues to 22 cm. and it faces failure in this displacement and affects the whole structure or damages it.

But the enveloping curve of blocks A, F and G pass these target displacements and do not face failure. This means that the structure of models can carry the target displacement in Basic Safety Earthquake 1 (BSE 1) and life safety level [Basic Safety Earthquake 2 (BSE 2).

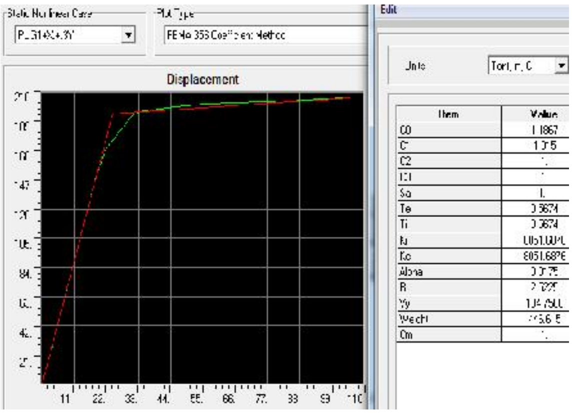

Figure 6. Force– curve– final displacement of block A in BSE 1

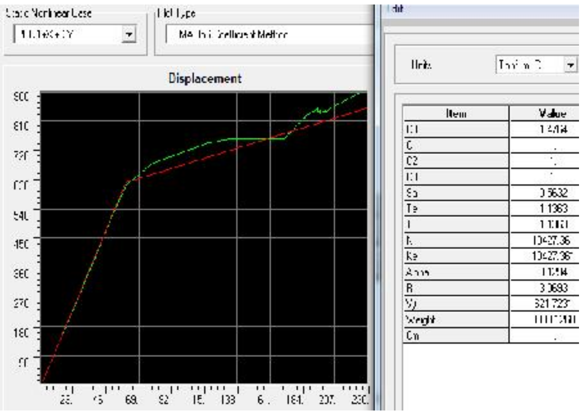

Figure 7. Force– curve– final displacement of block 10 in BSE 1

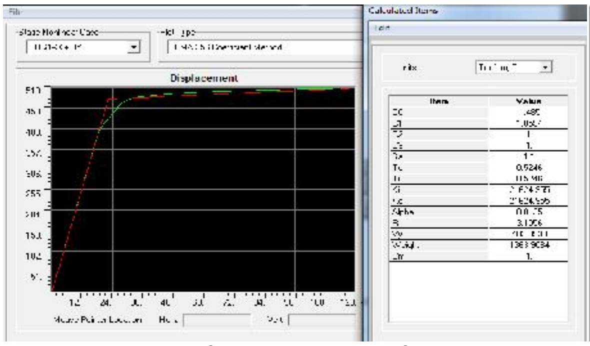

Figure 8.Force – curve – final displacement of block G in BSE 1

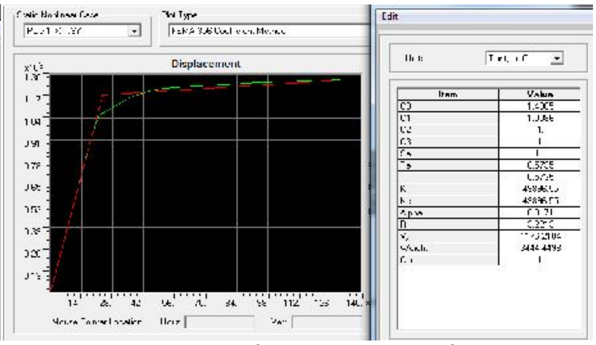

Figure 9. Force – curve – final displacement of block F in BSE 1

Non-Linear Evaluation of Beams Elements

In a concrete beam, bending and shear/cut were controlled by deformation and power, respectively. These controls must be done in the critical cross-sections of beams which are at two ends of beams and if 80% of bending strength of beams is used in the middle of opening under the gravity load, so a critical cross-section of bending must be assumed in the middle of opening.

NON-LINEAR EVALUATION OF COLUMN ELEMENTS

In a concrete beam, shear/cut and axial force were controlled by power in all situations; however, bending is mostly controlled by deformation in most cases and controlled by power in the especial situations.

Table 4. Shear control in some beams in one of the loadings, direction X in BSE 1 of block A

Baem	Load	Step	V_{max} (ton)	V_{cap}(ton)	A.C.
B-01-(A-B) (20)	$E_X + 0.3E_Y$	10	6.4	47	0.136
B-01-(B-C) (20)	$E_X + 0.3E_Y$	10	5.3	47	0.11
B-01-(C-E) (20)	$E_X + 0.3E_Y$	10	5.54	47	0.11

Table 5. Shear control in some columns in one of the loadings, direction X in BSE 2 of block A

Col	Load	Step	V_{max} (ton)	V_{cap}(ton)	A.C.
$C_1(A-20)$	$E_X + 0.3E_Y$	11	7.1	60	0.118
$C_1(B-20)$	$E_X + 0.3E_Y$	11	8.3	60	0.138
$C_1(C-20)$	$E_X + 0.3E_Y$	11	8.25	60	0.137

Table 6. Shear control in some beams in one of the loadings, direction Y in BSE 2 of block A

Baem	Load	Step	V_{max} (ton)	V_{cap}(ton)	A.C.
B-04-(20-22)(A)	$E_Y + 0.3E_X$	12	5.24	47	0.11
B-04-(22-23)(A)	$E_Y + 0.3E_X$	12	7.01	47	0.15
B-04-(20-22)(B)	$E_Y + 0.3E_X$	12	4.43	47	0.09

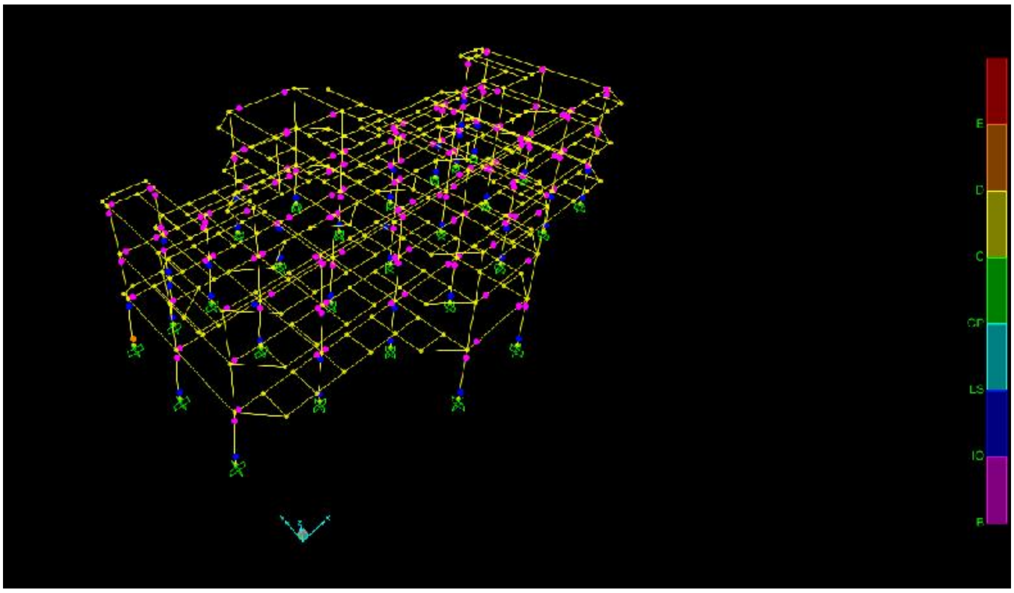

Figure 10. Formation area of flexural hinges of block 10 in Afzali Poor hospital of Kerman

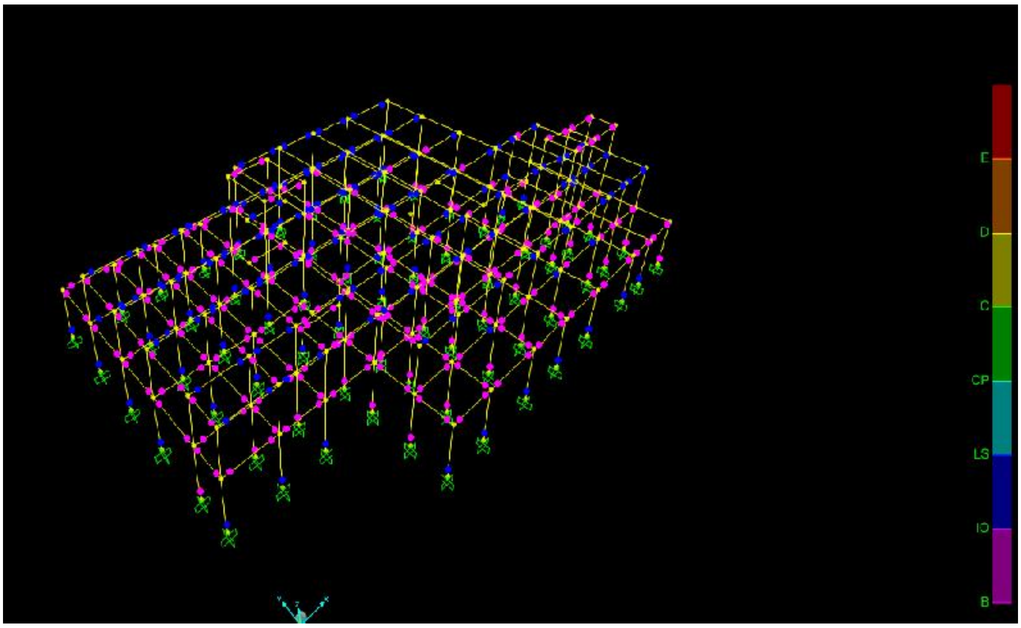

Figure 11. Formation area of flexural hinges of block F in Kerman psychiatric hospital

CONCLUSION

Moment in the beams of the structures of psychiatric hospital in Kerman is the control deformation as it was shown in the figures related to the plastic hinges of beams. Most of hinges which are formed in the beams maintain their needs which are the immediate occupancy [Basic Safety Earthquake 1 (BSE 1)] and life safety level [Basic Safety Earthquake 2 (BSE 2)]. Axial force and the moment of columns in these structures is the control deformation which is being defined by the plastic hinges related to the graph of the interaction of axial force and flexural moment as it was shown in the figures of formed plastic hinges in the columns based on BSE 1 and BSE 2. All hinges of columns will be in the immediate occupancy and life safety level as provide the performance of the above mentioned structure in BSE 1 and BSE 2. Shear in the beams and columns is accounted as the control force which was presented in table 4. So, all beams and columns satisfy the required shear in BSE 1 and 2. As well, moment in the beams of Afzali Poor hospital is the control deformation. So, most hinges which are being formed in the beams are in the domain of immediate occupancy. Axial force and beams' moment in this structure is the control deformation. Most hinges of the columns are in the field of complete failure and damages the whole structure. The main reason of the lack of general enveloping curve of the structure toward the target displacement is the weakness of columns and the formation of flexural mechanism in the columns. By studying the concrete hospitals of

Kerman (as mentioned in the results of hospitals), it seems that the hospitals which were investigated by the new edition of designing codes (such as Blocks A, F and G of psychiatric hospital) in BSE 1 and 2 are able to reach their target displacements which is the level of the considered performance of structure and also do not affect the task of health system that is providing the services to the patients. The hospitals which were used in the design (based on the previous edition of designing codes) such as Blocks 10 of Azali Poor are not able to reach the target displacement in BSE 1 and 2 and for this reason, these hospitals are so vulnerable in the earthquakes of BSE 1 and 2. So, reinforcement is required.

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