Surveying earth quake evaluation and rehabilitation methods of water storage

(Case study: Mashhad Water System)

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Abstract

Urban water storages are one of the most important components of water systems after earth quake. Continuing function and efficiency of storage make less casualties and crisis management after catastrophic. Mashhad is one of the biggest cities in Iran and because of their religious conditions, it receive many people and pilgrims every year which it shows importance of studying in these area. Mashhad Water System is included about 32 water semi buried storages which 20 of them are aged and under operation more than 35 years. These storages are different in capacity, shape and structural system that are caused complexity in the study process. In this study, after review of evaluation method, according to the performance based methods, types of earthquake rehabilitee methods for Mashhad water storages were studied and compared with technical and economic viewpoints beside operation conditions of them. Then, practical and proper methods for each type of reservoir were determined. In this paper summery of this process will be presented.

Keywords: management, Water system, Sami Buried storages, Earth quake Evaluation, Rehabilitation

1.Introduction

Iran is located on active earthquake band and according to the scientific documents and last events is one of the high risk countries in this subject. Therefore, preserving operational condition of water system will be important and directly and indirectly effects on casualty and damages after earthquake. On the other hand, most of these structures because of age and lack of earthquake codes or design standards are recognized vulnerable. Furthermore, cost of construction for new sections is higher than rehabilitation of existing reservoirs.

In general the purpose of these studies are increasing operation life and preserving foundation of reservoirs after earthquake. This study is aimed at the seismic evaluation and rehabilitation. In the current study, water storage necessity of quality and quantities evaluation of Mashhad water storages is reviewed and according to the performance levels and acceptance criterion, each of storage due to shape and strength of members and other characteristics is invalid.

2. Quantity and analytical evaluation

The first stage of evaluation study is quality evaluation. In this stage, is based on visual inspection and exterior condition of storages beside collected or available data. Collected information is included. General and specific specifications of the material and components, reports of related geotechnical investigation, as built drawing and the other operational order or requests of clients often data collection, all of them were categorized based on importance of structure and characteristics[1]. Regarding to the results, program for completing of shortage data was performed. Complementary studies are included geotechnical investigation and exploration activities, for geotechnical hazard studies like faults, slopes stability land sliding, liquefaction and etc,…, because of ages, strength of material and structural detail of storages were not enough for rehabilitation process and it should be determined in these stage in the analyzing evaluation with modeling and structural methods and based on the whole of gathering data was performed. In this stage, regarding to the performance levels and acceptance criterions, condition of storage for competence of studies and continuing up to rehabilitation and improvement were performed[2].

3. Performance level and acceptance criteria

In buried and semi-buried water storages related to the expected functions and operation conditions of them, the following performance levels were considered. These levels are the same specialized levels for seismic evaluation and rehabilitation of existing buildings (FEMA documents: 273, 310, and 356,547) [3].

PL3: Immediately operation (little damage) - In this level, global strength and stiffness remained as initial condition, but small and partial cracking are acceptable.

PL2: usable after short time (limited damage) – in this level, operation after event with water storage in short time and limit leakage is possible.

PL1: global damage without collapse- in this level, long term operation is not possible and repairing time is on long term. But collapse of storage is unacceptable.

PL10: inadequacy none of seismic performance levels

Earthquake levels are OBE, DBE, and MCE.[5].

3.1. Functional Objectives

Minimum performance level related to the rehabilitation objectives and ages of water storages are shown in table 1. load condition including Hydrostatic and Hydrodynamic water and soil pressure and the other sustainable loads, distribution and load combination have been applied based on ACI code and 123 (Iranian code for water storages). In process of modeling, effects of supports and walls beside simultaneity of loading as real condition were applied too. Structural analysis is linear elastic [4]. In this process at first, reliability of linear elastic analysis with controlling of DCR ration were considered. In this case, maximum DCR for main members is 2 and for others are 4. Furthermore, ratio of maximum displacement to the average displacement of water storage should be less than 1.75. Therefore, for satisfying these requirements, sometimes increasing of stiffness and strength of members and the whole of structure before controlling of acceptance criteria is necessary.

Table1-Minimum Performance levels for storages

Earth quack level	Objective of Rehabilitation								
	Basic			Desirable			Exceptional		
	0~15	**16~50**	**>50**	**0~15**	**16~50**	**>50**	**0~15**	**16~50**	**>50**
OBE	PL0	PL2	PL3	PL0	PL3	PL3	–	–	–
DBE	PL0	PL1	PL1	PL0	PL2	PL2	PL2	PL3	PL3
MCE	–	–	–	–	–	–	PL1	PL2	PL2

3.2. Acceptance criteria and limit conditions

Acceptance criteria in each earthquake level should be controlled by equation no. 1

$$\frac{C}{DR} = \frac{M_S}{\left(M_D \times \frac{C}{\eta} \right)} \qquad (1)$$

Ms: strength of members, MD: forces in members, C: increasing ratio andη: strength reduction factor according to the table 2. If C/DR patron will be bigger than 1.5, performance of members is credible and less than 1.25 it shows that the member should be rehabilitate. [6].

Table 2- reduction factor η

Force Control	Disp Control	Performance Level
1.0	2.5	PL1
0.8	2.0	PL2
0.8	1.0	PL3

Expected limit condition for members in performance levels as follows:

- Control of cracking in main members of water storage.

- Controlling compression failure of none confined member

- Controlling compression failure of confined concrete members.

- Controlling compression failure of related to the buckling of unbraced length of longitudinal bars

- Controlling compression failure on length of lap splice of longitudinal bars.

- Controlling shear failure of members (FEMA 356).

- Controlling joints or connections failure (FEMA 356).

4. Categorizing of storages

Water storages based on structural system and geometrical features have been classified. Next, seismic defects were reviewed and then rehabilitation methods were defined. All 18 selected storage of Mashhad, related to their shape classified in two rectangular and cylindrical categories which are including:

CU1: this type of storage is rectangular and foundation is continues under the walls and columns and beams are well connected to them. But roof slabs are precast concrete and laid on the beams.

CU2: in this storages, foundation continually extend only under walls and are single footing for columns. All beams and slabs are precast concrete and were simply laid on the top rake of columns. The thickness of exterior walls is 30 cm which are connected to the buttressed exterior columns.

CU3: this type is similar to CU2 type in foundation, but flat slab floor have been connected to columns and walls.

CU4: foundation in this type of storages continues under wall and columns and flat slab floor have been connected to columns too. But slab was simply laid on top of wall with slip joint connection.

CL1: shape of this storage is cylindrical and foundation, walls and roof slabs are continual. Arrangement of columns is linear. In CL1A type these arrangement are radial but the other features are similar.

CL2: this type is unique and used for one of small cylindrical storage. It had only one column at the center of storage and walls foundation and flat slab floor are continues.

All types of storages in Mashhad are shown in figure 1.

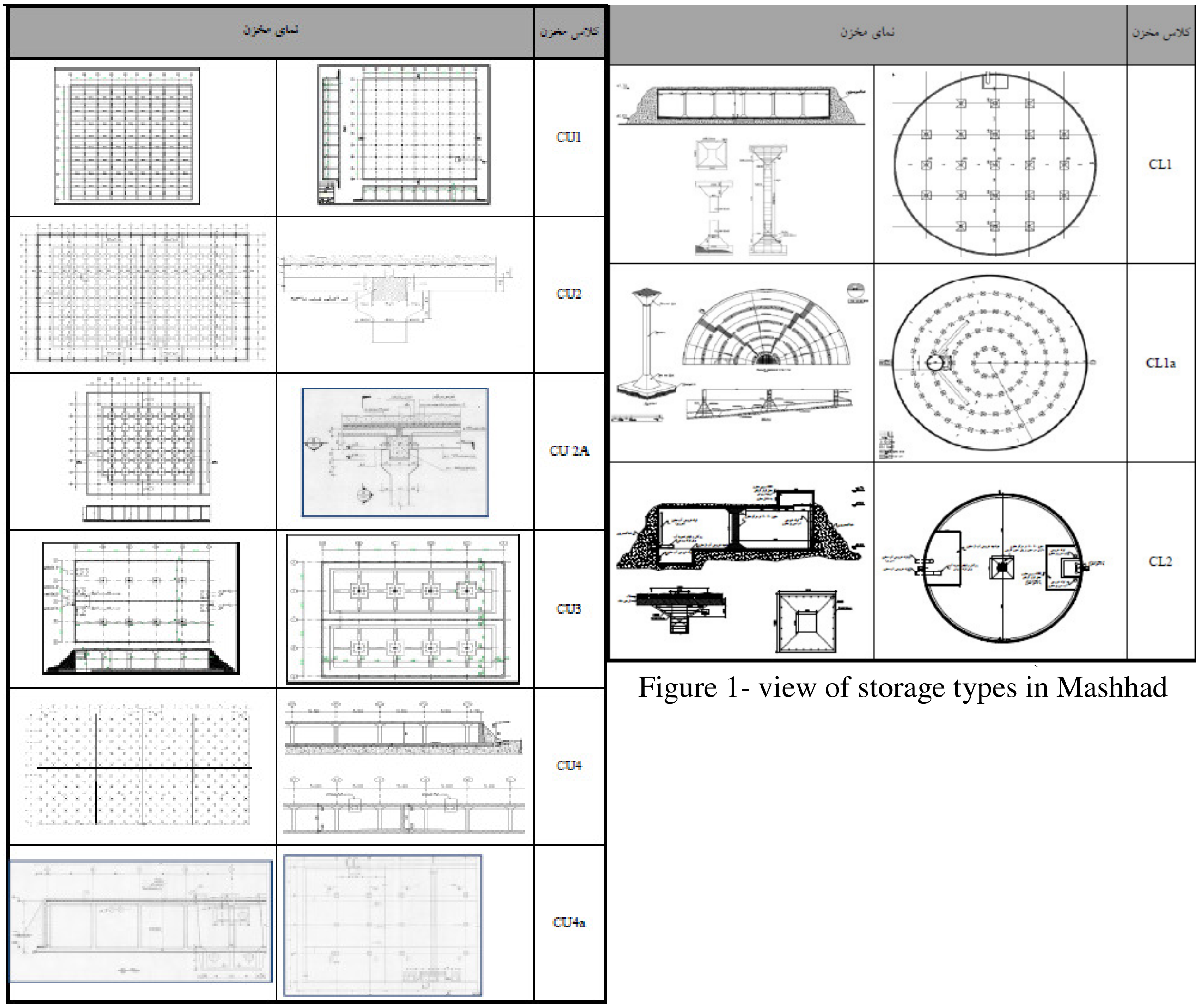

Figure 1- view of storage types in Mashhad

5. Seismic deficiency of storage

All of structural deficits for earthquake have been determined according to the results of evaluation process in the last steps and unconformity of acceptance criteria. Important seismic deficiency of storage classified as follows:

5.1. General strength deficiency

The most important reason of this deficiency is using of inappropriate codes for designing. These deficits often observed beside the other seismic deficiencies.

5.2. General stiffness deficiency

This deficiency is shown as a large displacement demands and the main reason is lack of lateral force resisting system on storages. This deficiency will be reduced by extra stiffening. Effect of this way is more effective than added strength.

5.3. Load path deficiency

Although general strength and stiffness deficiency have considerable effects on seismic performance of storages, any disconnection on load path cause damage or collapse. This deficiency reduces efficiency of seismic resistant system. Members of Load path are including roof slabs, beams, column, walls and footing with their connections.

5.4. Local deficiency of members

Response to the member demand is independent from global Strength and stiffness deficiencies in water storages. Cracking on wall and compression failure of members are located in this category.

5.5. Foundation deficiency

The main reasons of this deficiency are incomplete local path between footing and soil foundation besides losing of bearing capacity of foundation due to geotechnical hazard.

6. Classifying of seismic rehabilitation of storages

After recognition of deficiencies and other features of storage, regarding to the strength and stiffness demand seismic rehabilitation of storages were defined as follows:

6.1. Added new members

In general, this method will be one of more public and sensible ways to rehabilitate of water storage, if you have not operational limitation. Related to the last steps of study, added members are including interior or exterior shear walls beside increasing number of columns. In this process load pass of new members and effect on load bearing of other members are very important. New shear walls inside or outside of storage is shown in figure 2.

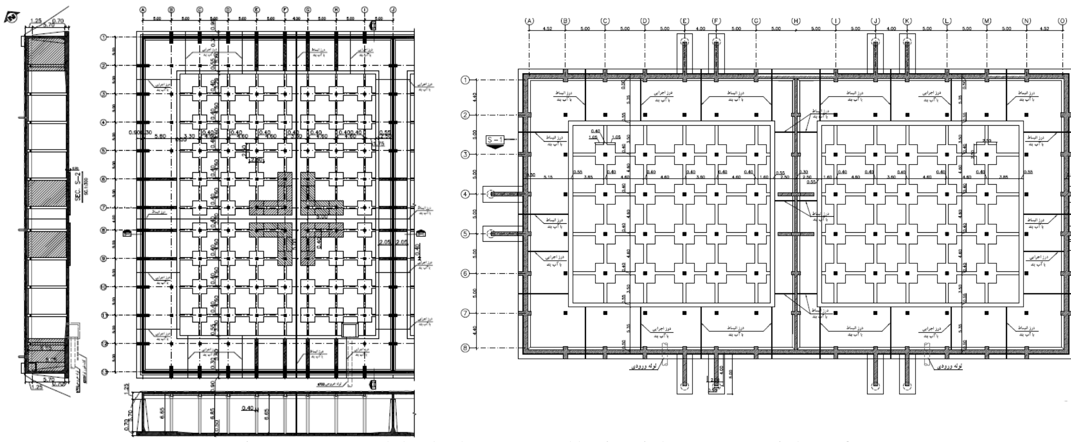

Figure 2- Added shear Walls inside or outside of storages

6.2. Performance gradation of existing members:

Related to the level of deficiencies, sometimes local structural gradation of members is more sensible and effective than added new members. There are including column jacketing, increasing bending and shear resistance of members with thickening. In figure 3, performance gradation of storage members are shown.

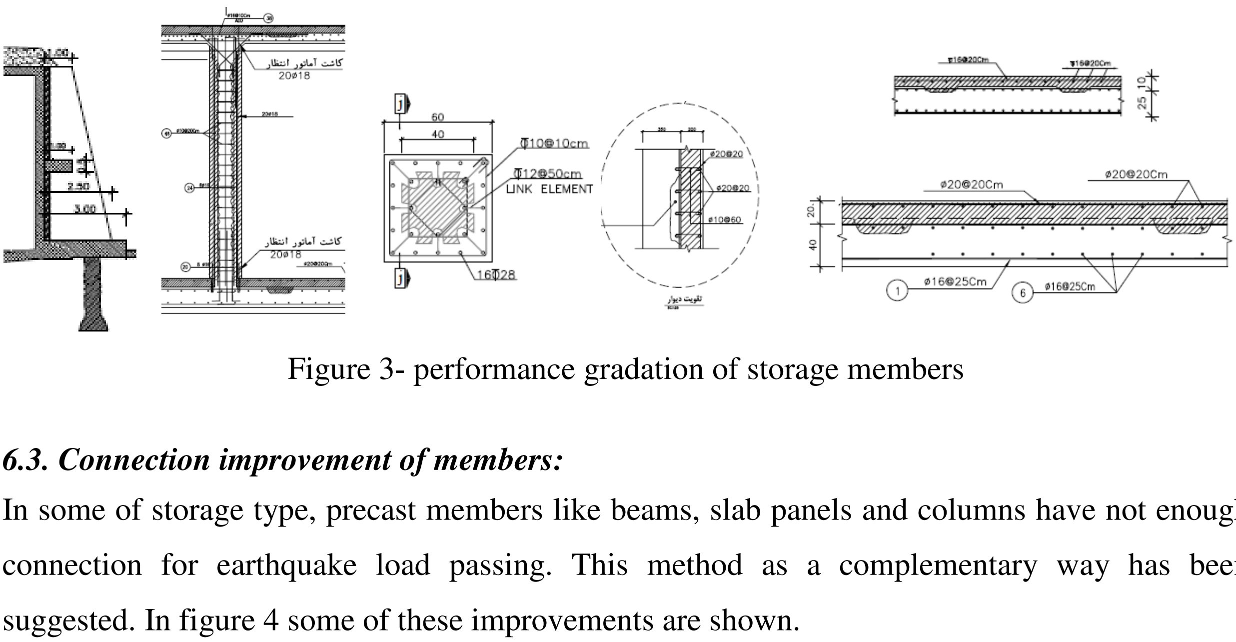

Figure 3- performance gradation of storage members

6.3. Connection improvement of members:

In some of storage type, precast members like beams, slab panels and columns have not enough connection for earthquake load passing. This method as a complementary way has been suggested. In figure 4 some of these improvements are shown.

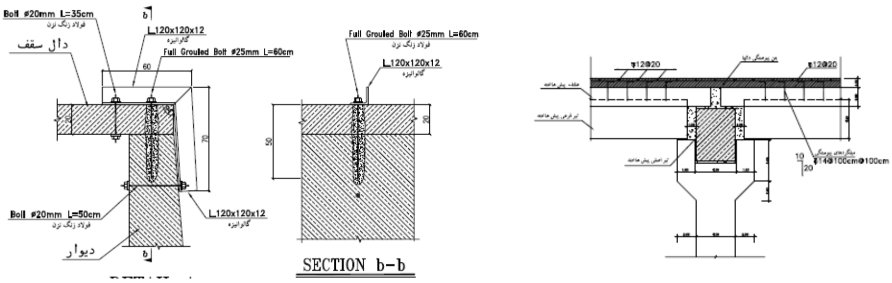

Figure 4- connection improvement of members

7. Selection proper method for rehabilitating

In this stage based on total technical and operational requirement for storages in Mashhad, proper method of rehabilitation reviewed. For selecting these methods, some points were considered as follows:

7.1. Technical consideration

Technical consideration has focused on satisfying acceptance criteria and seismic performance condition of storages and their members. As it was discussed in the last sections, regarding to the main deficiencies, rehabilitation methods for storages were selected.

7.2. Nontechnical consideration:

Beside technical points on selecting methods of rehabilitation, requests of beneficiaries and operational system are important for possibility of selected methods. The main points in this subject are including:

7.2.1. Disordering on operation

Regarding to the necessity of municipal water supplying, method of rehabilitation should have minimum effects on water system. Sometimes this point caused to change internal methods to external. However, proper managing on water system can help us to reduce this problem.

7.2.2. Practicability

For selecting methods of rehabilitation, proper accessibility or other limitation on material and specific execution methods can effect on final decision.

7.2.3. Cost

The final point on choosing of proper rehabilitation method is cost of executive activities, but it should be considered beside other consideration.

7.3. Comparing and final selection

In this stage, according to the total technical and nontechnical points, ore each storage, execution costs of proper methods was estimated. Total costs are including destruction, preparation and construction new or existing members. Finally based on cost of new storage with the same features, total rehabilitation cost was compared, rehabilitation cost, related to the main feature storages is between 15 up to 35 percent of cost of construction new one.

8. Conclusion

In this investigation regarding to the main characteristics of Mashhad storage, considerable points are as following:

8.1. The main seismic deficiencies of water storage in Mashhad were recognized strength and stiffness deficits which are often resolved by added new members.

8.2. Nevertheless usual expectation, maximum rehabilitation cost is less than 35 percent cost of construction new one.

References

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