

Title: Introduction to the Earthquake Resistance Capacity Assessment and Reinforcement of Taipei Water Department Office Building.

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Introduction to the Earthquake Resistance Capacity Assessment and Reinforcement of Taipei Water Department Office Building

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ABSTRACT

Taiwan is located along the Circum-Pacific seismic zone where the earthquake happens frequently. The evaluation of seismic force has been adopted in the Building Code and Regulations since 1974. Along with the updated technical rules, the government authorities have gradually realized whether the old public facilities are able to meet the seismic capacity provided by the existing code. Therefore, the government regulated that, the seismic capacity of all the public buildings established before 1997 should be assessed. The case introduced Shui Yuan Market Building, established in 1980, which is a RC building with two underground floors and ten floors on the ground. Its exterior wall was designed by an Israeli artist, Yaacov Agam, using a variety of color into the first giant wall of public art in the world. Prior to a detailed assessment of seismic capacity in 2011, because of they did not meet the statutory standards by existing code, it is necessary to reinforce the building. But the proposed of reinforcement design at that time had seriously affecting the traditional market on 1st and 2nd floor and the circulation of other floors of office space. It had to postpone due to the residents' opposition. Therefore, we decide to change from the seismic reinforcement design of strengthening the internal structures of buildings to external structural reinforcement in this case so that it reduces the impact of the use of interior space. It will supplement by the internal reinforcement if the seismic strength is still not raised to the statutory standard. In summary, the requirements of the existing market and user should be considered into the program design of seismic capacity evaluation and retrofitting. In addition, the limitation of public artistic work modification will also affect the program design. Therefore, setting 4 steel structural frames per floor into the interior of 1st and 2nd floors and the constructed 25cm shear walls will be used in the four exterior corners from 1st to 3rd floors that has been proposed. The original seismic capacity is expected to be increased from 0.186G to 0.242G in x direction and 0.210G to 0.279G in y direction. The estimated amount of total expense is about 1 million US dollars and the project is under progress from 2014 to 2016.

Keywords: Earth Quake, Water Supply Facility, Seismic Resistance Capacity, Assessment

FOREWORDS

Taiwan is located **along the Circum-Pacific Seismic Zone** and occurrence of earthquake is very frequent. The requirements on considering of seismic force in the building design were begun only from 1974. With the frequent update of **Building Code and Regulations**, confirming existing buildings' seismic capacity in satisfying the present statutory required seismic capacity become an

important works of the government in promoting earthquake disaster preventing services, especially after earthquake occur, public-owned buildings need to maintain normal functioning and be a shelter for victims.(eg. train stations, power plants, water utilities, schools, gym, medical facilities, police station, firework station and government institutions.) In view of this, as from 2000, government agencies in Taiwan started to promote “Seismic Resistance Capacity Reinforcement Programs for Building” and established that public buildings built before 1997 must be included in the scope of seismic resistance capacity assessment and reinforcement. According to statistics, total 26,399 public buildings in Taiwan shall be assessed and among them 25,536 building has completed preliminary. After the assessment, 7,397 needs be worked to reinforce and 1094 shall be demolished and rebuild. The portion needs be reinforced or demolished accounts for 33% of the number completed assessment.

The **Shui Yuan** building as presented in this case is located in Zhongzheng Dist., Taipei City. The Building was completed in 1980 and is therefore 35 years old. In 2010, the exterior wall was renovated by Mr. Yaacov Agam, an Israeli master in kinetic arts to be a giant compound drawing, a public art. The building has 2 levels underground and 10 levels above ground, an RC structure building. The basement is for parking and 1st and 2nd floor above ground are for conventional market and 3rd through 9th floors are offices for government agencies and the 10th floor is a theater. In 2009, **Shui Yuan** Building was determined as with doubt of insufficient capacity in seismic resistance in the preliminary assessment of seismic resistance capacity. In Exhaustive assessment of 2011, it is determined as failed the statutory standard and must undergo reinforcement work. At that time, the proposed reinforcement design program affects the space, circulation of conventional market at 1st and 2nd floors and the offices of other floors seriously and was objected by most of the tenants and the proposed reinforcement design program was unable to carry out. Therefore, the design program changed from reinforcing interior than reinforcing exterior, so as to reduce the impact on usable space inside, and when the seismic resistance capacity is still less than statutory standard, there will be internal reinforcement, so that the required capacity will be attained and the impact on the tenants will be minimized and the reinforcement work can be carrying on smoothly.

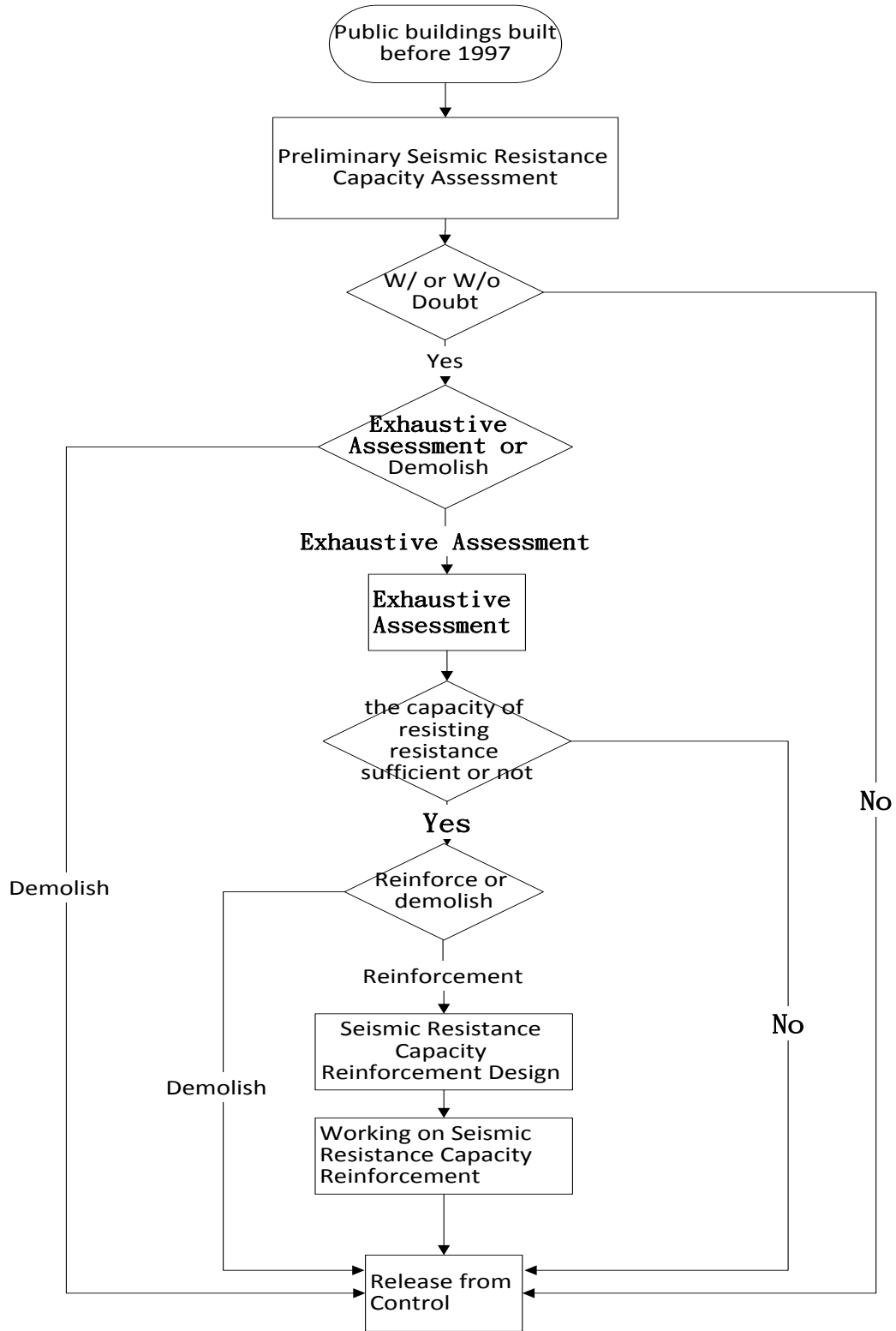


Fig 1- Operation Flow of Building Seismic Resistance Capacity Assessment and Reinforcement for Buildings in Taiwan

Table 1- Overview of Seismic Resistance Assessment and Reinforcement for Public Buildings in Taiwan

Preliminary Assessment		Exhaustive Assessment		Reinforcement Work		Demolish	
No. under control	No. & Percent of completion	No. under control	No. & Percent of completion	No. under control	No. & Percent of completion	No. under control	No. & Percent of completion
26,339	25,536 (97.0%)	13,359	10,429 (78.1%)	7,397	3,344 (45.2%)	1,094	583 (53.3%)



Fig.2 Appearance of Shui Yuan Building



Fig. 3-Inside of Shui Yuan Building (Market)

BRIEF OF THE CASE

1. Basic information of Shui Yuan Building

The structure is a ten floors RC building with two underground floors. The plot plan of structure is rectangular, approximately 55.2m in length and 45.5m in width.

Underground area of the building is used as emergency bunker and parking space, 1st to 2nd floor as Market area, 3rd to 9th floor as office space, and 10th floor is used as theater. The description of the building is as follows:

Table 2- Basic information of Shui Yuan Building

Building name	Shui Yuan Building
Number of floors	Ten floors on the ground and two underground floors
The total height of the floor	33m
Year built	Established in 1977, completed in 1980
Area	26723.04m ²
Structural materials and systems	Reinforced concrete / Mat Foundation
Layout and shape	It is a beam-column rectangular system and the four corners of stairs are made of shear wall.
Status of investigation	(1) Its exterior wall was designed by Yaacov Agam in 2010, creating a 4-d art wall. (2) Internal rate of usage achieve to 100%. (3) All of floors are used as public agencies office space except 1st and 2nd floor.
Status purpose	Underground area is used as emergency bunker and parking space, 1st to 2nd floor is used as Market area, 3rd to 9th floor are all office space, and 10th floor is used as Theatre.

2. Reinforced Project Evaluation and Options

The primary purpose of Reinforce Method options is to be able to make the seismic capacity of buildings to meet the existing code, and then take into consideration the status of use, lighting, ventilation and circulation.

Table 3- The main topics and solutions of Shui Yuan Building

No	Topics	Solutions
1	<p>Discussion the reason of original structure with lack seismic capacity.</p> <p>(1) Concrete with insufficient comprehensive strength</p> <p>(2) No toughness design requirements in early days.</p>	<p>The building that is lack of seismic capacity can be considered reinforcing budget, economic efficiency and the usage status of subject matter, therefore using the reinforcing method such as exterior Adding shear wall and the internal steel bracing system.</p>
2	<p>To consider the Reinforce Method by the tenants side</p>	<p>The factors to be considered when making decision of seismic method of reinforcement is as follows:</p> <p>(1) Whether the position of reinforcement would affect the feature of usage status, lighting and reduce the hinder of moving line to a minimum.</p> <p>(2) Whether the position of reinforcement would affect the escape routes</p> <p>(3) Due to the migration issues of Hydropower pipeline by reinforcing positions, resulting in the extension of duration</p>
3	<p>During construction of reinforcement may affect the market operations and the use of office functions</p>	<p>Construction scheme of the staging and partition can be taken, such as the regional construction. Reducing the impact of the period of use, it may also adopted the staging and partition construction during reinforcement</p>
4	<p>It should be match with the environment after reinforcing</p>	<p>The position of reinforcement in the future should take into consideration the original form of structure. To avoid the material of reinforcement interference with the original one, using the similar material to the original decoration.</p>
5	<p>Cost-saving design program</p>	<p>According to the subject matter that need to improve earthquake-resistant capacities, in compliance with existing code under the seismic capacity of reinforcement, it is the first priority in order not to waste the funds.</p> <p>(1) Select the method to minimize recovery problem after the demolition of Hydropower pipeline.</p> <p>(2) Select the method to minimize the original decoration materials of knockouts and recovery in order to reduce expenditure</p>

3. Reinforcement Program

(1).After consideration the status, the principles of structural reinforcement position are as follow :

- A.**Set of symmetric reinforcement component in order to conform to rules of structural system.
- B.** It would reduce the impact of interior usage by considering the interior line.
- C.** Steel metal frame set-up needs to consider the impact or damage to the surrounding structural environment. Spacing between metal frame and surrounding structures need to be at least 15cm apart, and adding shear studs on the iron frame. With rebar-planting around the existing RC beams and columns, dispose spiral stirrups that touch the surrounding beams and columns closely in the middle in case that the deformation of the steel frame may cause damage directly to the surrounding structure.

(2). Recommended reinforcing method :

Shear wall and steel frame bracing(Shear wall for surrounding and steel frame inside of building)

The way of reinforcement :

Adding shear wall : four places of each floor from 1st to 3rd floor in x and y direction

Steel frame bracing : two places of each floor from 1st to 3rd floor in x and y direction

The material of reinforcement :

Concrete $f_c'=280\text{kgf/cm}^2$

Reinforce $f_y=2800\text{ kgf/cm}^2$ (#5 or less) 、 4200 kgf/cm^2 (#6 above)

Steel CNS SN400B , $F_y=2400\text{ kgf/cm}^2$

The plans of reinforcing components are as follows :

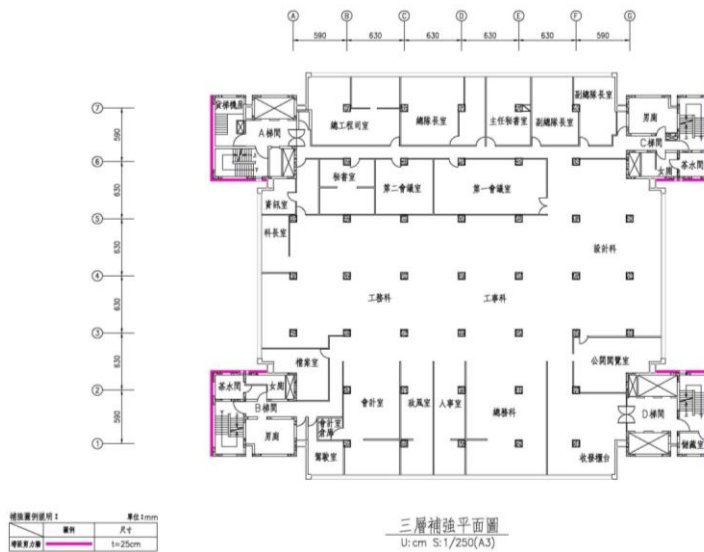
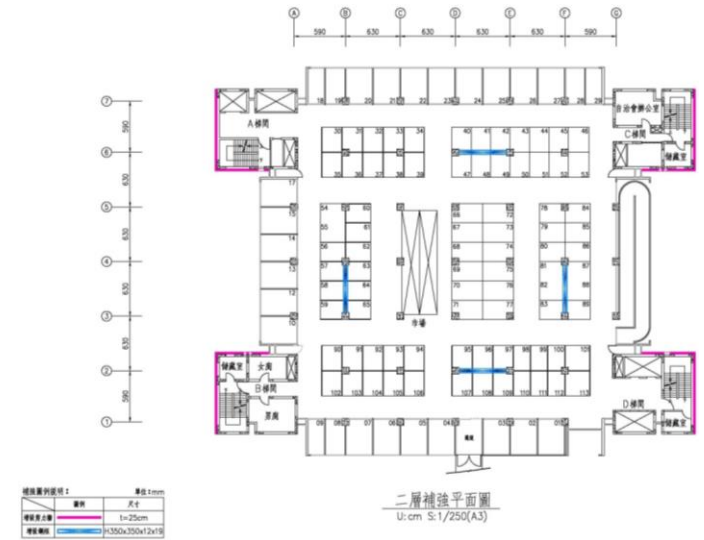
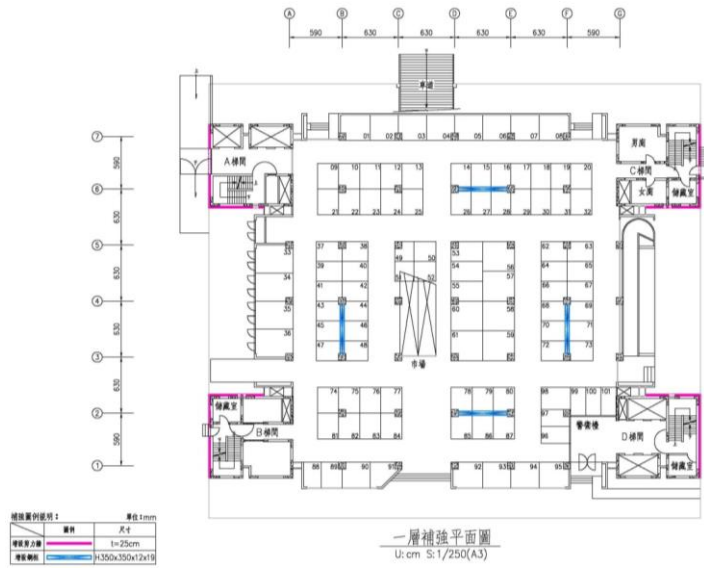


Fig. 4-The plans of reinforcing components

4. Promoting Process

While this program is mainly of external reinforcement and assisted with internal reinforcement, but in the process of promotion, there are still many difficulties need to be overcome. For example the Art Work of Yaacov Agam, the Israel kinetic art master. The work used a variety of color and combined with aluminum and plastic compound board. It is an artistic highly valued by Taipei City Government and placed under control. Based on considerations of seismic resistance and disaster prevention and respect for the art works of Yaacov Agam, we have explained the importance of seismic resistance and reinforcement, and simulated drawings to show the minimal change of the overall visual scene to his work and we assured him that the work will be reinstated in original color and original form. We have received his consent on Oct. 31, 2014. In the part of internal reinforcement, since it will affect the vendors' business, many presentations had been held (Jan. 26, 2015, Mar. 16, 2015 and June 15, 2015) and presented them with the purpose and design concept of the reinforcement work as well as clarified their doubts and understood their needs. The approaches taken are: 1. Providing temporary business premises for the vendors affected by the work; 2. Interior steel structure frame will be worked in phases and maximum 2 frames are allowed to work at the same time, so as to avoid affecting vendors due to working in large scale; 3. Suspend the work during the boom time of business, such as Chinese New Year period, total 1.5 months before and after, to minimize the impact of the reinforcement work on vendors. With such effort in communication and in coordination, the reinforcement work has design completed on May 27, 2015 and works have been contacted out on Aug. 7 and commencement is expected in October and completion is scheduled in June 2016.

CONCLUSION AND SUGGESTION

In order to ensure that the public building will maintain its function after earthquake, Taiwan has implemented "Seismic Resistance Capacity Assessment and Reinforcement Program for Buildings" in 2008 and all public buildings built before 1997 shall be included in the assessment and reinforcement. **Shui Yuan** Building of TWD Engineering Division is one of them. Since the floors in the building have different use of space (including market, office, theater) and are controlled by different agencies, and there are many interfaces. So the key points of this case are to integrate needs of all the tenants, adopting the reinforcement program with minimum impact so that the work may be performed smoothly and successfully.

In the selection of reinforcement manner, in addition to consider the statutory standards of seismic resistance capacity needs to be reached, the tenant's needs shall also be satisfied. In this case, the usual internal reinforcement approach is not used but changed to external structure reinforcement based on earthquake destruction simulation results. If the new approach cannot reach the target, the internal reinforcement will be performed to assist. So as to reduce the needs of installing shear wall inside building, or steel frame of expanding column, and all of them will have impact on internal space and movement line, and this has won support from the market vendors and tenants.

Due to scarcity in land for public work, the public buildings are mostly designed for multipurpose and / or for joint use of multiple agencies. In this case, the External Reinforcement based and Internal Reinforcement as support mode for building reinforcement to provide for reference in reinforcement in seismic resistance, so that the target of promoting seismic resistance capacity will be attained and the inconvenience to the tenants will be minimized.

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