THE OVERVIEW OF SEISMIC DAMAGE AND THE ANALYSIS OF THE REASONS OF DIFFERENT STRUCTURES IN YINGXIU TOWN –THE HEAVY DISASTER AREAS OF WENCHUAN 8.0 EARTHQUAKE

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ABSTRACT :
On 12 May 2008, a magnitude 8.0 earthquake happened in Wenchuan, Sichuan province, China .It was the most serious earthquake in china since 1949, causing very huge casualties and engineering damages to the buildings. The epicenter was in Yingxiu town (N31. 015°，E103. 365°). The structure style of buildings in Yingxiu was abundant. It comprised reinforced concrete structure, masonry structure, bottom frame structure, industrial workshop. The buildings were designed by the different periods of Code for Seismic Design of Buildings. The seismic fortification intensity of the most buildings was seventh degree, the other was eighth degree. As the great seismic intensity of Yingxiu town, the buildings were destroyed most seriously. The engineering damage of the buildings was characteristic. The earthquake provides a lot of valuable information for the seismological investigation。The research of engineering damage is important to the investigation on theory and engineering.

KEYWORDS:
Wenchuan earthquake, Yingxiu town, the engineering seismic damage

1、Introduction

On 12 May 2008, a magnitude 8.0 earthquake happened in Wenchuan, Sichuan province, China .According to the earthquake administration, the earthquake was in Yingxiu – Beichuan fault, ruptured from the beginning of Yingxiu. The epicenter was near Yingxiu town. It was the most serious earthquake in china since 1949. The direct and serious disaster-stricken areas were 100,000 square kilometers. The victims: 69,197 persons, injured: 374,176 persons, disappearances: 18,403 persons [1].

Yingxiu town was located in the south of Wenchuan County, near the national highway NO. 214 and provincial highway NO 303, abut against the Wolong Nature Reserve. It was the Only Road to Jiuzhaigou, Wolong, and Siguniang tourism. The area of Yingxiu town was 115.12 square kilometers in size, there were 10,000 people in Yingxiu town, exempted nine administrative villages, 31 groups of villagers. Minjiang River and Yuzixi River flows through the town in which water conservancy resources was rich, built Yingxiu bay power plant, Huaneng Pacific Station power plant, Futang Hydropower Plant were built recent years.

The seismic fortification intensity of Wenchuan was seven degree, the design basic acceleration of ground motion was 0.1g, the classification of design earthquake was the first group [2]. As the more developed economies, the seismic fortification intensity of the normal constructed buildings in the town centre were 7 degree, a few were 8 degree, some individual buildings without fortification. In the quake, the macroscopic intensity was 11 degree in Yingxiu town. Now, the failure phenomena of various structure forms are analyzed, the mechanism of the damage are given.

2、Reinforced concrete frame structure

2.1、The review of the engineering seismic damage of reinforced concrete frame structure

There are about ten buildings of reinforced concrete frame structure in Yingxiu town. Medium grade damage are 10%, serious damage are 10%, collapse are 40%, damage completely are 40%.The main seismic damage are ： the collapse and shearing cracks of filling wall , the concrete peels off and the reinforced bar leaks out the top of the column ,disappearance of the first floor ;integral decline[3、4、5].

2.2、Description of the engineering seismic damage of the typical building

2.2.1、the office building of the Yingxiu secondary school

2.2.1.1.The review of the building

The office building of the Yingxiu secondary school was built in 2005.The building area is 1180.44 ㎡.It is the main three local four-storey and building with level roof. Seismic fortification intensity is 7 degree, it is a formal construction, concrete grade is: column C30, beam C30, plate C30, reinforced: I-reinforced HPB235, II-class steel HRB335, floor pillar size: 400 mm × 400mm, filling wall is masonryed by MU10 hollow block and M5 Mortar. The thickness of the walls of each floor are 200 mm, roof and floor are cast-in-place. The height of the first floor is 4.05 m, the height of the second floor is3.60 m, the height of the third floor is 3.90 m, the height of the fourth floor is 3.60 m. the basis is individual footing of column, the foundation depth is 3 m.

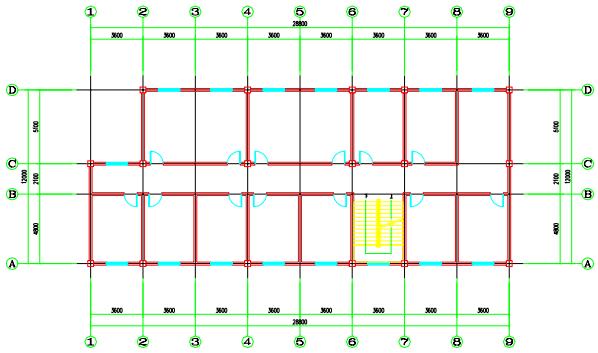

Fig1.the plane sketch of the office building of the Yingxiu secondary school

2.2.1.2.describing the engineering seismic damage

The two frames building are used for the office，the bay is relatively smaller. In the earthquake, the main structure of the framework are basically undamaged; the back of the office building are serious damage by the collision with the complex building that collapsed ; shear cracks appear in filling wall serious on each floor; parapet partial collapse; the prominent wall of the appearance partial collapse. The building belongs to the middle damage, local serious damage is caused by collision.

Fig2. the office building of the Yingxiu secondary school(Local 1)

Fig3. the office building of the Yingxiu secondary school(Local 2)

2.2.2.The complex building of the Yingxiu secondary school

2.2.2.1.The review of the building

The complex building of the Yingxiu secondary school was built in 2005.The building area is 3618.3 ㎡. It is the five local four-storey and building with level roof. It is a formal construction, concrete grade is: column C30; beam C30; plate C30, reinforced: I-reinforced HPB235, II-class steel HRB335, floor pillar size : 400 mm × 400mm, filling wall is masonryed by MU10 hollow block and M5 Mortar. The thickness of the walls of each floor are 200 mm, roof and floor are cast-in-place. The height of the first floor is 4.05 m, the height of the other floors is3.60 m. The basis is individual footing of column, the foundation depth is 3 m.

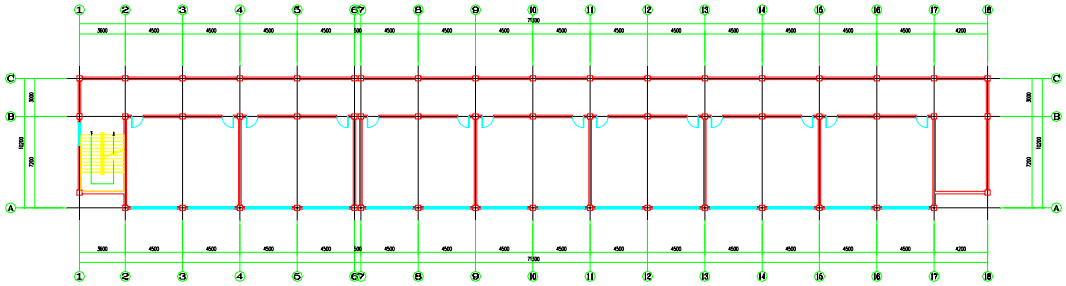

Fig4.the plane sketch of the complex building of the Yingxiu secondary school

2.2.2.2.Describing the engineering seismic damage

The two frames building is composed of two parts with a seismic joints in the middle. It is mainly use for classrooms. the bay is relatively larger. In Fig5, the right portion of the building is destroyed completely, the left portion of the building inclines to the right portion and serious deform, the disappearance of the first floor. On the second floor , the concrete peels off and the reinforced bar leaks out the top of the column ,; The filling wall of second floor partially collapsed, lots of perforative and permeate oblique crack appear in window belly wall. A large number of external decoration fall. The building is already destroyed.

Fig5.the complex building of the Yingxiu secondary school(Global 1)

Fig6.the complex building of the Yingxiu secondary school(Local 1)

2.2.3、Aba tobacco company warehouse

2.2.3.1.The review of the building

Aba tobacco company warehouse was built in 2005. It is the main three local four-storey building with level roof. Seismic fortification intensity is 8 degree, it is a formal construction, concrete grade is: C30; reinforced is: HPB235, floor pillar size is : 400 mm × 400mm, filling wall is masonryed by MU10 hollow block and M5 Mortar. The thickness of the walls of each floor are 200 mm, roof and floor are cast-in-place. The height of the first floor is 3.9 m, the height of the other floors is 3.3 m.

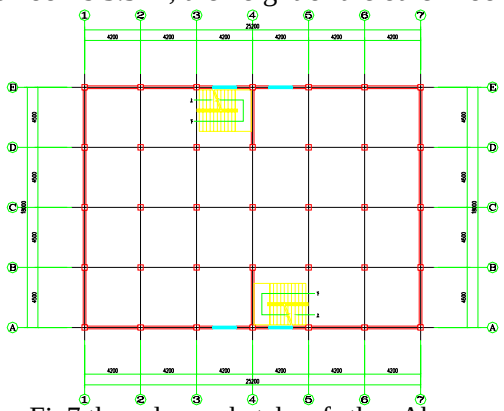

Fig7.the plane sketch of the Aba tobacco company warehouse

Fig8. the Aba tobacco company warehouse

2.2.3.2 .The describing the engineering seismic damage

The concrete is crashed, reinforced serious bend even broken or larger shift The filling wall of second floor partially collapse. The building has a severely damaged.

2.3、Comparative analysis of the reason for the engineering seismic damage

1)Compare with the office building and the complex building, the two building are both standard designed , standard constructed with the same site conditions, section size and reinforcement of the load-bearing structure, materialand thickness of the filling wall .In the earthquake, the office building belongs to the middle damage, local serious damage caused by collision. The complex building is already destroyed. The reason is that: The first to fifth floor of the complex building are the classroom, bay reaches 9 meters , the filling wall is less , excessively spacious, lateral stiffness is relatively poor. According to the shearing force distribute by triangle principle, the ratio of shearing force and stiffness at the bottom of the uniform vertical rigidity building in heavy disaster areas is maximal, the bottom floor is cut off. The bay of the office building room is smaller, the filling wall is more, and the lateral stiffness is bigger. The filling wall consume the partial earthquake energy, gets the effect having arrived at protection major structure.

2) The Aba tobacco company warehouse is a standard designed and constructed building with level roof, the flat surface form is regular, stiffness scatters homogeneously, design and arrange reasonableness. Seismic fortification intensity is 8 degree; the seismic resistance exceeding locality at present fortifies intensity 1 degree. In Yingxiu town, multitudinous windows are the false window, the hole in the filling wall is less and the integrity of the wall is strong since considering local Qiang race customs and habits. According to the shearing force distribute by triangle principle, the ratio of shearing force and stiffness at the bottom of the uniform vertical rigidity building in heavy disaster areas is maximal, the bottom is cut off.

When the frame stratified deformation is too big, the filling wall attempt to arrests framed structure deformation , but because of the limit deformation of the masonry is very small , under the reciprocating load. The filling walls collapse and consume away the part of earthquake energy. When lots of filling wall collapsing, the earthquake effect is undertake by the frame completely.

Under the combined effect of the larger moment, shear force, axial force, the concrete peels off and the reinforced bar leaks out the top of the column. The column lose the carrying capacity.The plastic hinge appearance.

According to the 3 given examples, increasing the fortification intensity is an effective means to reduce disaster. At the same time, decreaseing bay, keeping the stability of the non-bearing wall in the earthquake are also effective means to reduce disaster.

3、Masonry structure

3.1、The review of the engineering seismic damage of masonry structure

There are about thirty buildings of masonry structure in Yingxiu town. Serious damage are 10%, collapse are 40%, damage completely are 50%.The main seismic damage are ： lots of perforative and permeate oblique cracks appear in bearing wall、window belly wall、spandrel wall；partly collapse；the disappearance of the first floor ； damage completely； partly collapse of the outstanding roof structure[3、4、5].

3.2、Description of the engineering seismic damage of the typical building

3.2.1、The student dormitory of the Yingxiu secondary school

3.2.1.1 The review of the building

The student dormitory of the Yingxiu secondary school was built in 2005.The building area is 3171.22 ㎡. It is the five -storey building with level roof. Seismic fortification intensity is 7 degree, it is a formal construction, concrete grade:C25, reinforced: HPB235.The bearing wall of the first floor and the second floor are masonryed by MU10 common sintered bricks and M10 Mortar, the bearing wall of the other floors are masonryed by MU10 common sintered bricks and M7.5 Mortar. The thickness of the walls of each floor are 240 mm, roof and floor are cast-in-place. The setting of the structure column and ring beam is reasonable.The height of each floor is 3.2 m. the basis is strip foundation, the foundation depth is 2.5 m.

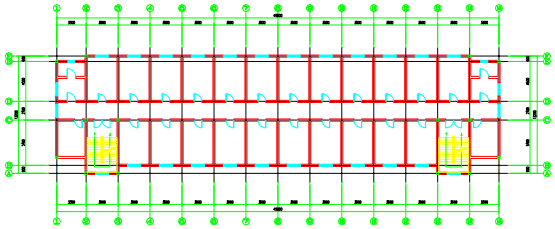

Fig9.the plane sketch of the student dormitory of the Yingxiu secondary school

3.2.1.2 Tthe describing the engineering seismic damage

Lots of perforative oblique crack and crossed crack appear in window belly wall、spandrel wall； serious shear cracks appear in some bearing wall,partly collapse of the outstanding roof structure, the disappearance of the

first floor ,The building is already destroyed.

Fig10. the student dormitory of the Yingxiu secondary school

Fig12. the teachers residential building of the Yingxiu secondary school

3.2.2、The teachers residential building of the Yingxiu secondary school

3.2.2.1 The review of the building

The teachers residential building of the Yingxiu secondary school was built in 2005.The building area is 1874.70 ㎡. It is the five -storey building with level roof. Seismic fortification intensity is 7 degree, it is a formal construction, concrete grade:C25, reinforced: HPB235 , the bearing wall of the first layer and the second layer are masonryed by MU10 shale bricks and M10 mortar, the bearing wall of the other layers are masonryed by MU10 shale bricks and M7.5 Mortar, The thickness of the walls of each floor are 240 mm, roof and floor are cast-in-place. The setting of the structure column and ring beam is reasonable.The height of each layer is 3.0 m. the basis is strip foundation, the foundation depth is 2.5 m.

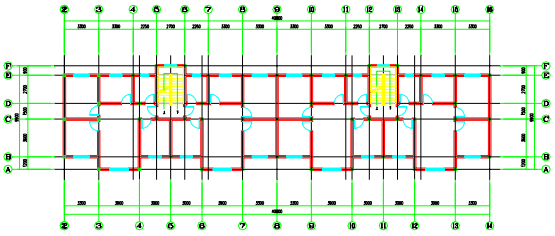

Fig11.the plane sketch of the teachers residential building of the Yingxiu secondary school

Fig13. the office building of the power station

3.2.2.2 Tthe describing the engineering seismic damage

Serious shear cracks appear in some bearing wall of the first floor and the second floor . lots of perforative oblique cracks and crossed cracks appear in window belly wall、spandrel wall.The building has a severely damaged.

3.2.3 The office building of the power station

3.2.3.1The review of the building

The office building of the power station which did not taken preventive measures against earthquake was built in the 1980s. In the 1990s, the building was reinforced by the structure column and ring beam in exterior. It is the five -storey building with level roof. It is a formal construction, concrete grade: C25, reinforced: HPB235, the bearing wall are masonryed by common sintered bricks and mortar. The thickness of the walls of each floor are 240 mm, roof and floor are precast slab. The height of each layer is 3.0 m. The basis is strip foundation.

3.2.3.2 the describing the engineering seismic damage

Partly collapse; the concrete peels off and the reinforced bar leaks in structure column

3.3、Comparative analysis of the reason for the engineering seismic damage

1) Compare with the student dormitory and the teachers residential building, the two building are both standard designed , standard constructed with the same site conditions, section size and reinforcement of the structure column and ring beam, thickness of the bearing wall .In the earthquake, the teachers residential building belongs to the severely damaged. The student dormitory is already destroyed. The reason is that: firstly the materials of the two building are

different, the material of the student dormitory is common sintered bricks, the material of the teachers residential building is shale bricks.Secondly, the structure column of the student dormitory are set up at the four corner of the exterior wall and the staircase.At the same time, the structure column of the teachers residential building are set up at the four corner of the exterior wall and the staircase, the junction of the exterior wall and unit cross wall, the junction of the gable and interior longitudinal wall, the junction of the interior wall and exterior wall, local wall pier in the interior wall. The number of the structure columns in the teachers' residential building is more than the number of the student dormitory.It is obvious that, if adopt different construction measure , the buildings designed by the same seismic fortification intensity are also different in behaviour in the same time of earthquake. Under equal condition, the more the structure column are set up, the better the ability that architectural entirety resisting to collapse was.

2) The office building of the power station which did not taken preventive measures against earthquake was built in the 1980s. In the 1990s, the building was reinforced by the structure column and ring beam in exterior. The holistic seismic behavior of the office building of the power station is not as good as the building designed by the Code for Seismic Design of Buildings

4、Bottom frame structure

4.1、The review of the engineering seismic damage of bottom frame structure

There are lots of buildings of bottom frame structure in disaster area. The bay and door hole of the buildings are big for using function, so the bottom layer is adopt reinforced concrete frame structure,other layers is adopt masonry structure for reducing cost. There are about sixty buildings of masonry structures in Yingxiu town. The disappearance of the floor is very universal in the stiffness conversion floor[3、4、5]

4.2、Description of the engineering seismic damage of the typical building

4.2.1、The Yingxiu hotel

4.2.1.1、The review of the building

The Yingxiu hotel is a three-storey building with level roof. Seismic fortification intensity is 7 degree. It is a formal construction, concrete grade:C25, reinforced: HPB235, floor pillar size: 350 mm × 350mm. The filling wall is masonryed by common sintered bricks and M5 Mortar. The bearing wall of 2-4 layer is masonryed by common sintered bricks. The thickness of the walls of each floor are 240 mm, roof and floor are cast-in-place. The height of the first floor is 3.6 m, the height of the other floors is3.0 m. The setting of the structure column and ring beam is reasonable.

4.2.1.2、Describing the engineering seismic damage

The disappearance of the second floor. Serious shear cracks appeared in the bottom layer. In Fig.9 and Fig.11, the Yuanyuanyuan tea house near the Yingxiu hotel is also bottom frame structure, and the second floor also disappear. It is very general.

Fig14. the Yingxiu hotel (Global 1)

Fig15. the Yingxiu hotel (Global 2)

4.2.2.The credit cooperative

4.2.2.1.The review of the building

The credit cooperative which was not taken preventive measures against earthquake was built in the 1980s. The c Fig8. the Aba tobacco company warehouse redit cooperative is a two-storey building with level roof. Concrete grade:C25, reinforced: HPB235, floor pillar size: 350 mm × 350mm.The filling wall is masonryed by common sintered bricks and Mortar. The thickness of the walls of each floor are 180 mm, roof and floor are precast slab. The height of each layer is 3.0 m.

4.2.2.2. The describing the engineering seismic damage

Fig16. the Yuanyuanyuan tea house

Fig17. the credit cooperatives

4.3、Comparative analysis of the reason for the engineering seismic damage

As a bottom frame structure, the stiffness of the bottom layer is more than the second layer, the stiffness occurrence mutation at the second layer. the second floor is a weak story.In the heavy disaster areas , weak story was sheared break by huge horizontal earthquake action, the second floor also disappear.

The credit cooperative with the poor quality of construction is not taken preventive measures against earthquake. In the heavy disaster areas , The credit cooperatives damaged by huge horizontal earthquake action.

Whether or not to consider seismic fortification, the bottom frame structure does not have the reasonable stiffness transition in stiffness conversion layer,the performance of the bottom frame structure was poor in heavy disaster areas.

5.Industrial workshop

5.1.The review of the engineering seismic damage of industrial workshop

There are about six industrial workshop in Yingxiu town. They are all serious damage or damage completely.The main seismic damage are ： the collapse of filling wall , the column inclined, top failure , integral decline[3、4、5].

5.2.Describing the engineering seismic damage

5.2.1.Factory building 1

The factory building 1 is a single frame structure. The length is 42m, the widthis12m, the height is 11m. The factory building is consisted by reinforced concrete column , steel roof truss and large roof board.The section of the column is 600mm×500mm. Concrete grade: C30, reinforced: HPB235. The thickness of the exterior wall is 240 mm. There is no inner partition in factory building 1.

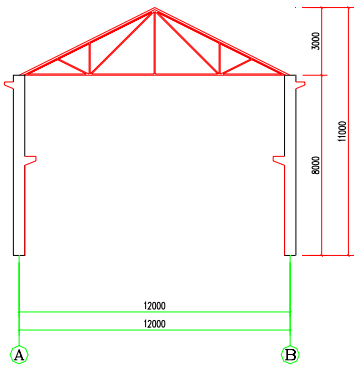

Fig18. the profile of factory building 1

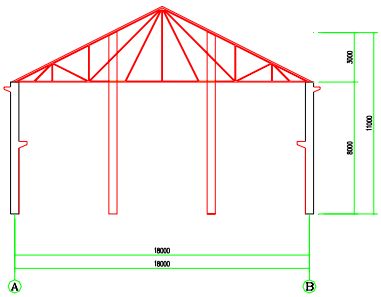

Fig19. the profile of factory building 2

5.2.2 .Factory building 2

The factory building 2 is a multi-frame frame structure. The length is 42m, the widthis18m, the height is 11m. The factory building is consisted by reinforced concrete column , steel roof truss and large roof board.The section of the column is 600mm×500mm. Concrete grade: C30, reinforced: HPB235. The thickness of the exterior wall is 240 mm. There is no inner partition in factory building 2.


Fig20. the factory building (Global 1)


Fig21. the factory building(Global 2)

The main seismic damage are ： the collapse of filling wall , the column inclined, top failure , integral decline

5.3 Comparative analysis of the reason for the engineering seismic damage

Compare with the factory building 1 and factory building 2, the two building are both standard designed , standard constructed with the same site conditions, section size and reinforcement of the load-bearing structure, materialand thickness of the filling wall .In the earthquake, the factory building 1 is already destroyed, the factory building 2 still stand . The reason is that: the lateral stiffness of the single frame structure is poor the multi-frame frame structure, so it heavy damaged.

6.Conclusion

Through the above analysis, the following conclusions are given:

1)The damage of the building which taken preventive measures against earthquake is lighter than the building which did not taken preventive measures against earthquake.

2)The damage of the building with high level earthquake resistance protection is lighter than the building with low level earthquake resistance protection.

3)The damage of the building with the same level earthquake resistance protection is different ,there are lots of influencing factors, such as using function, construction quality, material quality.

4)The exhibition of various structure styles is different, reinforced concrete structure is the best, the next is masonry structure, bottom frame structure is the poorest.

5) The bottom frame structure must be limit use

6) The exhibition of the industrial workshop in heavy disaster area is quite poor

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