Structure Safety Appraisal of Cafeteria in Certain School

Zhong Liu1,2* and Huaibin Li2
1Logistics Services Department, University of Electronic Science and Technology of China, Chengdu 611731, China; 2Sichuan Institute of Building Research, Chengdu 610081, China

*Corresponding author e-mail: liuzhong870714@163.com

Abstract: After a school canteen was completed and put into use, cracks appeared in some reinforced concrete beams and slabs of the frame structure. In order to understand the safety of its structure, the structural safety of the canteen was appraised. The appraisal results show that the structural safety of the school canteen does not meet the requirements of the norms. According to the appraisal results, the following suggestions are put forward: (1) strengthening the members whose concrete strength is lower than the minimum requirements of the code; (2) strengthening the structural members whose bearing capacity does not meet the requirements; (3) reinforcing the components with stress cracks; (4) repairing the cracks of the concrete members; (5) repairing the cracks of the filling wall; (6) The school canteen should be suspended and qualified units should be entrusted to reinforce the canteen.

1. Project overview

The cafeteria in certain school, completed in February 2015, is of two-storey reinforced concrete framework structure, Grade 6 seismic fortification intensity, seismic fortification category B, secondary structure safety grade, and 50-year service life of structure design. The layout plan of the cafeteria in the school can be seen in Fig.1, with horizontal column space of 4.50m and 9.00m respectively, longitudinal column space of 7.80m, 8.10m and 8.40m; the total length of the building is 34.15m, total width is 22.75m, storey height is 3.90m, ground floor indoor and outdoor height difference is 0.35m, and total building height is 8.15m.
The first floor is put into use in August 2015 but the second floor is not. Cracks are found on some floor and roof beams and slabs of the cafeteria. In order to know use safety of the structure, the structure safety appraisal is carried out.

2. Structure inspection

2.1 Ground foundation

The cafeteria adopts reinforced concrete single foundation under column. The strongly weathered sandstone is used as the bearing stratum of the foundation, fak=300kPa. On-site investigation shows no uneven settlement and cracks on site around the building, and no upper structure element deformation and cracks on foundation caused by ground foundation.

2.2 Reinforced concrete column

Not obvious deformation and visible crack is found on reinforced concrete framework column in the cafeteria. The section size of reinforced concrete framework column and rebar are checked at random, and the results can be seen in Table 1; the concrete crushing strength of reinforced concrete framework column shall be checked according to rebound method, and results can be seen in Table 2.
Table 1 Section size and rebar of framework column

| Checking position | Actually measured value of section size (mm) | Design value of section size (mm) | Actually measured longitudinal bar distribution | Designed longitudinal bar distribution | Actually measured stirrup spacing in intensified area (mm) | Actually measured stirrup spacing in non-intensified area (mm) | Designed stirrup spacing (mm) |
|-------------------|---------------------------------------------|----------------------------------|-----------------------------------------------|------------------------------------------|------------------------------------------------|------------------------------------------------|-----------------------------|
| 1F②/④ shaft post | 400×400                                     | 400×400                          | 3×3                                           | 3×3                                      | 95, 100, 110                                  | 205, 200, 200                                           | 100/200                    |
| 1F②/④ shaft post | 400×400                                     | 400×400                          | 3×3                                           | 3×3                                      | 110, 95, 100                                  | 200, 185, 170                                           | 100/200                    |
| 1F①/⑤ shaft post | 400×400                                     | 400×400                          | 3×3                                           | 3×3                                      | 110, 90, 80                                   | 195, 190, 200                                           | 100/200                    |
| 1F②/④ shaft post | 400×400                                     | 400×400                          | 3×3                                           | 3×3                                      | 90, 100, 90                                   | 200, 225, 190                                           | 100/200                    |
| 1F②/④ shaft post | Φ500                                       | Φ500                             | 12                                             | 12                                       | 120, 115, 110                                 | 155, 190, 190                                           | 100/200                    |
| 2F②/④ shaft post | 400×400                                     | 400×400                          | 3×3                                           | 3×3                                      | 70, 75, 75                                    | 145, 205, 190                                           | 100/200                    |
| 2F②/④ shaft post | 400×400                                     | 400×400                          | 3×3                                           | 3×3                                      | 85, 90, 85                                    | 155, 210, 190                                           | 100/200                    |
| 2F②/④ shaft post | 400×400                                     | 400×400                          | 3×3                                           | 3×3                                      | 100, 95, 110                                  | 210, 195, 190                                           | 100/200                    |
| 2F③/⑥ shaft post | 400×400                                     | 400×400                          | 3×3                                           | 3×3                                      | 90, 90, 100                                   | 130, 250, 175                                           | 100/200                    |
| 2F③/⑥ shaft post | Φ500                                       | Φ500                             | 12                                             | 12                                       | 120, 115, 110                                 | 210, 170, 240                                           | 100/200                    |

Table 2 Column concrete crushing strength

| Checking position | Estimated value of concrete crushing strength (MPa) | Designed concrete strength grade | Checking position | Estimated value of concrete crushing strength (MPa) | Designed concrete strength grade |
|-------------------|---------------------------------------------------|--------------------------------|-------------------|---------------------------------------------------|--------------------------------|
| 1F②/⑤ shaft post  | 20.5                                              | C30                            | 2F②/⑥ shaft post  | 18.9                                              | C30                            |
| 1F②/⑤ shaft post  | 26.7                                              | C30                            |                   |                                                   |                                |

2.3 Reinforced concrete beam

Some reinforced concrete beams on floor and roof slabs in the cafeteria cracked, and the maximum crack is 0.5mm wide. Main crack types on the concrete beams are as follows: Diagonal cracks are generated near the bearing; diagonal and vertical cracks are generated at the interface of secondary beams; several U-shaped cracks are generated in the mid-span area; several diagonal cracks are generated near mid-span; multiple vertical cracks are generated beside the mid-span beam. In which, the cracks extension drawings of E/2-3 reinforced concrete beam can be seen in Fig.2.

Fig.2 Crack extension drawing of reinforced concrete beam
The section size of reinforced concrete beam and rebar are checked at random, and the results can be seen in Table 3; the additional stirrup spacing of main beam on both sides of secondary beam are checked at random, and the results can be seen in Table 4; the concrete crushing strength of reinforced concrete beam shall be checked according to rebound method, and results can be seen in Table 5.

Table 3 Cross section size and rebar of reinforced concrete beam

| Checking position | Actually measured value of section size $b \times h_j$ (mm) | Design value of section size $b \times h_j$ (mm) | Number of actually measured longitudinal rebar on the first row at beam bottom | Number of designed longitudinal rebar on the first row at beam bottom | Protective layer thickness of reinforced concrete at bottom row at beam bottom (mm) | Actually measured stirrup spacing in intensified area (mm) | Actually measured stirrup spacing in non-intensified area (mm) | Design stirrup spacing (mm) |
|-------------------|----------------------------------------------------------|------------------------------------------------|--------------------------------|--------------------------------|---------------------------------|-------------------------------------------------|-------------------------------------------------|-----------------------------|
| 2F ○ 3 / ○ A - ○ B shaft slab beam | 250×48 0 | 250×48 0 | 4 | 4 | 38, 20, 20, 18 | 120, 115, 105, 90 | 165, 145, 150, 100 | 100/20 0 |
| 2F ○ 3 / ○ A - ○ B shaft slab beam | 250×63 0 | 250×63 0 | 3 | 3 | 32, 23, 18 | 190, 155, 95, 70 | 145, 125, 140, 100 | 100/15 0 |
| 2F ○ 6 / ○ A - ○ B shaft slab beam | 250×48 5 | 250×48 0 | 3 | 3 | 21, 21, 20 | 115, 125, 170, 160 | 145, 140, 195, 200 | 200 |
| ○ 6 / ○ A - ○ C Shaft roof slab beam | 250×53 0 | 250×53 0 | 4 | 4 | 17, 25, 17, 30 | 160, 155, 150, 130 | 125, 145, 160, 130 | 100/15 0 |
| ○ 6 / ○ A - ○ C Shaft roof slab beam | 250×48 0 | 250×48 0 | 2 | 2 | 11, 11 | 105, 105, 105, 105 | 140, 140, 140, 140 | 200 |
| ○ 6 / ○ A - ○ C Shaft roof slab beam | 250×63 0 | 250×63 0 | 4 | 4 | 37, 30, 30, 29 | 105, 105, 105, 105 | 155, 155, 155, 155 | 100/15 0 |
| ○ 6 / ○ A - ○ C Shaft roof slab beam | 250×63 0 | 250×63 0 | 4 | 4 | 21, 20, 20, 19 | 100, 95, 120, 120 | 200, 200, 200, 100 | 100 |
| ○ 6 / ○ A - ○ C Shaft roof slab beam | 250×53 0 | 250×53 0 | 4 | 4 | 25, 17, 20, 31 | 70, 85, 125, 125 | 155, 140, 140, 130 | 100/15 0 |

Note: In the table “b” is the width of beam cross section, and “$h_j$” means net height of beam cross section.
Table 4 Additional stirrup spacing of main beam on both sides of secondary beam

| Checking position | Actually measured additional stirrup spacing (mm) | | |
|------------------|-------------------------------------------------|---|---|
|                  | Additional spacing on one side | Mean value | Additional spacing on one side | Mean value |
| 2F slab main and secondary beam interface of ○/○/3 shaft | 65, 65, 90, 80 | 75 | 70, 110, 50, 70 | 75 |
| 2F slab main and secondary beam interface of ○/○/3 shaft | 85, 85, 95, 90 | 89 | 85, 95, 80, 80 | 85 |
| 2F slab main and secondary beam interface of ○/○/3 shaft | 60, 60, 145, 80 | 86 | 105, 100, 70, 60 | 84 |
| Roof slab main and secondary beam interface of ○/○/3 shaft | 270, 200, 200, 190 | 215 | 110, 205, 190, 210 | 179 |
| Roof slab main and secondary beam interface of ○/○/3 shaft | 160, 165, 145, 145 | 154 | 140, 125, 210, 135 | 152 |
| Roof slab main and secondary beam interface of ○/○/3 shaft | 185, 135, 120, 150 | 148 | 175, 170, 210, 120 | 169 |
| Roof slab main and secondary beam interface of ○/○/3 shaft | 70, 75, 80, 80 | 76 | 50, 100, 45, 75 | 68 |

Table 5 Beam concrete crushing strength

| Checking position | Estimated value of concrete crushing strength under spot check (MPa) | Designated concrete strength grade | Checking position | Estimated value of concrete crushing strength under spot check (MPa) | Designated concrete strength grade |
|------------------|-------------------------------------------------|---|---|---|---|
| 2F○/○/3-○/3 shaft slab beam | 22.8 | C30 | ○/○/3-○/3 shaft roof slab beam | 16.5 | C30 |
| 2F○/○/3-○/3 shaft slab beam | 15.0 | C30 | ○/○/3-○/3 shaft roof slab beam | 27.9 | C30 |

2.4 Reinforced concrete slab

Some reinforced concrete cast-in-situ slabs in the cafeteria cracked, and the maximum crack is 1.2mm wide. Main types of cracks are as follows: (1) Cracks are generated in parallel with long span or short span in the mid-span of some cast-in-situ slabs; (2) cracks are generated along the direction of bearing on the bearing point of cast-in-situ slab panel; (3) cracks are generated at the bearing position of some roof panel waterproof layer; (4) diagonal cracks along the opposite angle are generated at the bottom of some cast-in-situ slabs; (5) tangent cracks are generated in the corner of some cast-in-situ slabs; (6) irregular cracks are generated in local area of some cast-in-situ slabs.

The thickness and rebar of reinforced concrete cast-in-situ slabs are checked at random, and results can be seen in Table 6.
IOP Conf. Series: Materials Science and Engineering 768 (2020) 052056 doi:10.1088/1757-899X/768/5/052056

Table 6 Thickness and rebar of cast-in-site slabs

| Checking position of cast-in-site slab | Checking position of rebar | Actually measured value of rebar spacing (mm) | Actually measured value of concrete protective layer thickness (mm) | Actually measured value of slab thickness |
|----------------------------------------|---------------------------|---------------------------------------------|---------------------------------------------------------------|-----------------------------------------|
| 2F                                     | In parallel with 4 shaft   | 170, 120, 145, 115, 150                     | /                                                             | 121                                      |
| Surface                               | In parallel with 3 shaft   | 100, 135, 160, 130, 155                     | 48, 46, 45, 42, 43, 44                                      | 123                                      |
| Bottom                                 | In parallel with 3 shaft   | 170, 175, 130, 185, 240                     | 40, 42, 43, 42, 43, 44                                      | 122                                      |
| 2F                                     | In parallel with 3 shaft   | 170, 125, 170, 125, 140                     | /                                                             | 138                                      |
| Surface                               | In parallel with 3 shaft   | 160, 110, 115, 80, 170                     | 18, 17, 10, 26, 10, 10                                      | (Mid-span)                              |
| Bottom                                 | In parallel with 3 shaft   | 150, 205, 210, 200, 185                     | 47, 46, 41, 39, 36, 36                                      | 124                                      |
| 2F                                     | In parallel with 3 shaft   | 150, 145, 170, 125, 120                     | /                                                             | 117                                      |
| Surface                               | In parallel with 3 shaft   | 155, 155, 145, 150, 145                     | 20, 19, 19, 18, 16, 13                                      | (Mid-span)                              |
| Bottom                                 | In parallel with 3 shaft   | 160, 100, 150, 175, 180                     | 36, 36, 37, 40, 42, 44                                      | 127                                      |
| 2F                                     | In parallel with 3 shaft   | 90, 155, 160, 170, 130                      | 45, 43, 48, 45, 45, 43                                      | 137                                      |
| Surface                               | In parallel with 3 shaft   | 120, 130, 140, 190, 115                     | /                                                             | 128                                      |
| Bottom                                 | In parallel with 3 shaft   | 130, 160, 150, 170, 135                     | 14, 15, 17, 16, 18, 17                                      | (Mid-span)                              |
| 2F                                     | In parallel with 3 shaft   | 135, 155, 135, 125, 165                     | 19, 36, 39, 35, 37, 40                                      | 122                                      |
| Surface                               | In parallel with 3 shaft   | 160, 140, 230, 165, 150                     | 24, 28, 28, 34, 36, 35                                      | 116                                      |
| Bottom                                 | In parallel with 3 shaft   | 180, 120, 130, 115, 205                     | /                                                             |                                          |
| 2F                                     | In parallel with 3 shaft   | 165, 150, 135, 160, 150                     | 10, 10, 14, 14, 11, 10                                      |                                          |
| Surface                               | In parallel with 3 shaft   | 145, 160, 120, 140, 120                     | /                                                             |                                          |
| Bottom                                 | In parallel with 3 shaft   | 140, 165, 125, 160, 165                     | 8, 9, 11, 14, 17, 16                                        |                                          |
| 2F                                     | In parallel with 3 shaft   | 155, 160, 125, 90, 160                      | /                                                             |                                          |
| Surface                               | In parallel with 3 shaft   | 165, 155, 140, 135, 160                     | 9, 10, 11, 12, 13, 11                                       |                                          |
| Bottom                                 | In parallel with 3 shaft   | 190, 160, 150, 130, 170                     | /                                                             |                                          |
| 2F                                     | In parallel with 3 shaft   | 160, 135, 160, 135, 140                     | 13, 17, 14, 17, 17, 17                                      |                                          |

Note: “/” in the table means the item is not detected due to limited on-site conditions (waterproof layer and thermal insulation layer are applied to the roof slab surface).

2.5 Filler wall

No obvious deformation and dislocation is found in filler wall of the cafeteria. Interface seams and cracks are generated in some filler walls, with maximum crack width of 0.8mm. Specific types are as follows: (1) Interface seams are generated at the interface between filler wall and framework column and beams; (2) horizontal, vertical and diagonal cracks are generated at holes of doors and windows, and corners of the filler wall; (3) horizontal cracks are generated in local area of filler wall.
3. Calculation of bearing capacity

3.1 Calculation conditions
(1) In the calculation, the standard value and structural layout of floor and roof slab load shall be taken according to the design drawing; the dead load standard value, structural component cross section size and rebar shall be taken according to the design drawing in combination with on-site inspection results. (2) The concrete strength of structural components shall be confirmed as per on-site inspection results. (3) The designed seismic fortification intensity shall be 6-Grade, designed basic seismic acceleration is 0.05g, and designed earthquake group shall be Group 1. The construction site class shall be Class II; the basic wind velocity pressure shall be W0=0.35kN/m² and surface roughness class shall be Class B. (4) In accordance with the Standard for classification of seismic protection of building constructions, the seismic fortification class shall be key fortification class (Class B). The framework seismic grade shall be Grade III. (5) According to on-site inspection and inspection results, the bearing capacity of structural component in the cafeteria shall be calculated in accordance with PKPM2010 (V2.2) of China Academy of Building Research PKPMCAD Engineering Department (the impact of components cracks on the structure is not considered in this calculation).

3.2 Calculation results
(1) The bearing capacity of ground foundation could meet requirements; (2) the compressive bearing capacity and shear resistance of some reinforced concrete framework columns could not meet requirements; (3) the flexural bearing capacity and shear resistance of some reinforced concrete beams could not meet requirements; the bearing capacity of some main beams’ additional transverse rebar at the centralized load function point of secondary beams could not meet requirements; (4) the flexural bearing capacity of some cast-in-situ slabs on panel bearing position could not meet requirements; the shear resistance of cast-in-situ slabs could meet requirements.

4. Structure safety appraisal
The structure safety appraisal of cafeteria in the school shows the safety of found foundation meets requirements, but safety of reinforced concrete framework column, reinforced concrete beam and reinforced concrete cast-in-situ slabs is nonconforming. Therefore, the structural safety of structure of the cafeteria does not meet requirements. It is necessary to adopt measures to process nonconforming components, cracked structural components and filler walls.

5. Conclusion and suggestion
The structure safety of cafeteria in the school does not meet requirements of specifications. The following suggestions are proposed for appraisal results: (1) The components with concrete strength lower than minimum requirements of specifications shall be reinforced; (2) structural components with nonconforming bearing capacity shall be reinforced; (3) components suffering stressed cracks shall be applied with remedial treatment; (4) cracks of concrete components shall be repaired; (5) the cracks of filler wall shall be remedied; (6) the cafeteria of the school shall be closed temporarily and reinforced by qualified units under entrustment.

References
[1] Standard for classification of seismic protection of building constructions: GB 50223-2008 [S]. Beijing: China Architecture & Building Press, 2008.
[2] Standard for evaluation of concrete comprehensive strength: GB/T50107-2010 [S]. Beijing: China Architecture & Building Press, 2010.
[3] Code for quality acceptance of concrete structure construction: GB 50204-2015 [S]. Beijing: China Architecture & Building Press, 2010.
[4] Code for design of concrete structure (2015 Edition); GB 50010-2010 [S]. Beijing: China Architecture & Building Press, 2010.

[5] Code for load design of building structure; GB 5009-2012 [S]. Beijing: China Architecture & Building Press, 2012.