Analysis of Cracks in an Underground Garage and Research on the Load Test of reinforced pavement

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Abstract. Cracks often appear in the process of construction and use of concrete structures. It is normal for concrete to have cracks, but the size and quantity of cracks exceed certain limits. Therefore, it is necessary to analyze the structural cracks. According to different cracks, corresponding treatment methods are given. Experiments can be done if conditions permit to verify the safety of the structure after reinforcement. The paper detected and analyzed the cracks appearing on the structure components by using an example of an underground garage project. And It was proposed about corresponding reinforcement treatment scheme. This project provides reference for similar projects or scientific research, and it provides a good research direction.

1 Project Overview

The main structure of the project is a two-story underground concrete frame structure. The project is about 130m long and 20m wide. There are design loads of garage as below. The basic snow pressure is 0.2kN/m²; The basic wind pressure is 0.55kN/ m²; The standard value of dead load of the first underground floor is 40kN / m²; The standard value of live load is 15kN / m²; The standard value of dead load of the second underground floor is 8kN / m²; The standard value of live load is 5kN / m².

2 Identification and Analysis

2.1 Inspection of the Project

According to Standard for appraisal of reliability of civil buildings^[1] (GB 50292-2015) we collected and checked all kinds of construction data. First we check the layout of the building structure. Secondly, the safety of foundation is checked. Finally, the strength, reinforcement and connection of the superstructure are tested. The statistics on the failure forms of various components is as shown in Table 1. Appraisal statistics is shown in Table 1. According to Technical specification for inspection and treatment of cracks in buildings^[3] (CECS293-2011), the statistics on the failure forms of various components is as shown in Table 1. Appraisal statistics is shown in Table 1.

Table 1 Failure Category of Components

Testing items		Engineering Status	Number of members
Frame Column	First Kind	The maximum crack width is less than 0.1mm, and there are few cracks	10
	Second Kind	The maximum width of the crack is less than 0.3mm, with a large number and irregular distribution.	18
	Third Kind	The maximum width of crack is more than 0.3mm, the number is large and the distribution is irregular.	24
Frame Beam	First Kind	The maximum crack width is less than 0.1mm, and there are few cracks	24

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	Second Kind	The maximum width of cracks is greater than 0.2mm, with a large number of cracks in vertical and oblique directions.	36
Cast-in-place slab	First Kind	The maximum crack width is less than 0.1mm, and there are few cracks	10
	Second Kind	The maximum crack width is greater than 0.2mm, and the direction is inclined to the span direction.	23

2.2 Analysis of Crack Causes and Reinforcement Methods

There are many cracks in beams, plates and columns. It does not meet Code for quality acceptance of concrete structures ^[2] (GB 50292-2015). Reasons are discussed from two aspects: Firstly, the cracks of each component of the project are shrinkage cracks of concrete itself, which are caused by the restraint of concrete shrinkage deformation.; Secondly, There are Improper maintenance during construction. The curing time is shorter and more water is used after concrete pouring.

In Table 1, class II and class III columns are strengthened by increasing section; in Table 1, class II beams and class II slabs are strengthened by pressure grouting and sticking up carbon fiber.

3 Research on Load Test after Reinforcement

3.1 Selection of Experimental Parts and Parameters

Figure 1 Schematic Diagram of Test Parts

3.3 Test Process and Precautions

Each working condition is graded loaded. The loading is increased according to the test vehicle in each lane. The stabilization time of each stage is 5 to 10 minutes. The real-time monitoring readings of the instrument shall prevail, the engine is turned off for 5 to 10 minutes for each loading after the loaded vehicle is loaded in place. The collection after the data is completely stable. In order to restore the elastic deformation of the structure, repeated loading is performed 5-10 minutes after unloading to reduce the influence of plastic residual

Through the static load test, the static effect (static strain, displacement) of the structure under the test load is measured. The standard value of the dead load of the first underground floor is $42\text{kn} / \text{m}^2$, and the standard value of the live load is $15\text{kn} / \text{m}^2$. According to Standard for test method of concrete structures ^[5] (GB / T 50152-2012), the test load shall be the permanent combination. The test is shown in Figure 1.

3.2 Test Load and Loading Position

The dynamic deflection and dynamic coefficient of the structure are measured by dynamic load test. The dump truck is used for loading. The finite element model is established. Three vehicles with a dead weight of 50 tons are used. The model is shown in Figure 2. 9# measuring points are taken in this inspection, including 8# strain measuring points and 9# displacement measuring points. 8# and 9# measuring points are respectively on the north and south sides of the column top. The displacement measuring point is to measure the vertical deformation of the beam end.

Figure 2 Model Diagram of Loading Vehicle

deformation. Real-time monitoring is also required.

3.4 Data Analysis of Static Load Test

(1) Strain data analysis

The measured and calculated values of the tested section strain are shown in Table 2. The strain is positive in tension and negative in compression.

Table 2 Comparison of Measured and Calculated Strain Values

Measuring Point	Full load measured value ($\mu\epsilon$)	Residual Strain ($\mu\epsilon$)	Relative Residual Strain (%)	Elastic Value ($\mu\epsilon$)	Calculated value ($\mu\epsilon$)	Check coefficient
1#	32.50	0.40	1.23	32.10	38.10	0.84
2#	41.30	0.60	1.45	40.70	44.44	0.92
3#	23.70	0.40	1.69	23.30	28.57	0.82
4#	32.90	0.90	2.74	32.00	36.10	0.89
5#	41.60	0.60	1.44	41.00	47.62	0.86
6#	48.90	0.40	0.82	48.50	49.30	0.98
8#	-4.70	-0.60	12.77	-4.10	-18.46	0.22
9#	-8.70	-0.10	1.15	-8.60	-15.38	0.56

According to table 2, the strain calibration coefficient is between 0.22 and 0.98, and the relative residual strain is between 0.82% and 12.77%.

The measured and calculated displace values of the test section are shown in Table 3. The displace is positive upward and negative downward.

(2) Displacement data analysis

Table 3 Comparison of Measured Displacement Data under Full Load

Measuring Point	Full load measured value ($\mu\epsilon$)	Residual Strain ($\mu\epsilon$)	Relative Residual Strain (%)	Elastic Value ($\mu\epsilon$)	Calculated value ($\mu\epsilon$)	Check coefficient
1#	-0.37	-0.03	8.11	-0.34	-0.42	0.81
2#	-0.20	-0.02	10.00	-0.18	-0.42	0.43
3#	-0.22	-0.03	13.64	-0.19	-0.36	0.53
4#	-0.25	-0.01	4.00	-0.24	-0.28	0.86
5#	-0.65	-0.03	4.62	-0.62	-0.67	0.93
6#	-0.64	-0.08	12.50	-0.56	-0.69	0.81
7#	-0.64	-0.01	1.56	-0.63	-0.74	0.85
8#	-0.06	-0.01	16.67	-0.05	-0.10	0.50
9#	-0.08	-0.01	12.50	-0.07	-0.08	0.88

According to table 3, the displacement calibration coefficient is between 0.43 and 0.93, and the relative residual displacement is between 1.56% and 16.67%. no abnormality occurred to the components during test.

at the bottom of the middle span of the secondary beam. The determination of dynamic test load is based on the condition that let the excitation signal to sufficient strength.

3.5 Dynamic Load Test

3.5.1 Test Point Arrangement and Test Load

The measuring points of dynamic deflection are arranged

Figure 3 Dynamic Deflection Curve of 30 km / h Barrier Free Driving (one ehicle)

Figure 4 Dynamic Deflection Curve of 30 km / h Barrier Free Driving (two ehicles)

According to the barrier free driving test, the dynamic coefficients are 1.10 (1 vehicle) and 1.24 (2 vehicles). The measured maximum dynamic coefficient is 1.24 which is less than the theoretical calculation value of 1.39. The impact resistance of the structure is better.

3.5.2 Results and Analysis on Driving Test

The dynamic deflection time history curve of the structure under moving load is shown in Fig. 3 and Fig. 4.

3.5.3 Conclusion

According to the provisions of the code for Specification for Inspection and Evaluation of Load-bearing Capacity

of Highway Bridges ^[4](JTG/TJ21-2011), the calibration coefficients of the strain and displacement of the tested components are less than 1.00, so the strength and rigidity of the components meet the design requirements; the relative residual values of the strain and displacement of the tested components are less than 20%, so the tested components are in the elastic working state. Specification for Inspection and Evaluation of Load-bearing Capacity of Highway Bridges ^[4](JTG/TJ21-2011).

4 Summary

In this paper, the cracks in the concrete components of a garage project are detected and identified, and the causes of cracks are analyzed and discussed. In addition, it is the special situation of the project as under the urban road that a reasonable load test is selected for the top surface of the first underground floor of the project after reinforcement. It was studied and discussed respectively for the static load test and dynamic load test to verify the safety of the structure after reinforcement.

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References

1. Standard for appraisal of reliability of civil buildings (GB 50292-2015), Beijing, China Construction Industry Press.
2. Code for quality acceptance of concrete structures construction (GB 50292-2015), Beijing, China Construction Industry Press.
3. Technical specification for inspection and treatment of cracks in buildings(CECS293-2011), Beijing, China Planning Press
4. Specification for Inspection and Evaluation of Load-bearing Capacity of Highway Bridges (JTG/T J 21-2011), Beijing, China Construction Industry Press
5. Standard for test method of concrete structures (GB/T 50152-2012), Beijing, China Construction Industry Press