Analysis on Damage Detection of Gangue Silo and Structural Reinforcement Design

Chunmei Zhang
Department of Civil Engineering, Shenyang Urban Construction University, Shenyang, Liaoning Province, 110167, China
Corresponding author’s e-mail: 909016623@qq.com

Abstract. According to the damage of gangue bunker structure in FengXi coal industry production system in the process of using, through the corresponding instrument detection and data analysis, the reasonable repair and reinforcement design scheme is put forward for the gangue bunker cylinder wall with different degrees of damage such as concrete loosening and falling off, steel bar exposure, corrosion and so on. The research shows that the treatment scheme of adding a whole layer of warehouse wall and connecting it with the foundation and the upper and lower ring beam of the warehouse body can guarantee the strength and rigidity of the warehouse body to the greatest extent and meet the requirements of normal use and safe production of the gangue warehouse. It provides reference for the use and monitoring of other silo structures in coal industry production system.

1. Introduction
The gangue silo diameter of FengXi coal industry production system is 12m. The elevation of the top of the silo is 21.3m, and the main structure is silo structure and frame structure. It was built in 2011 and has been in use for 7 years. The concrete design strength grade of the barrel wall of the warehouse body is C30, and commercial concrete is used. During the use of this project, it was found that the concrete outside the gangue silo cylinder wall fell off locally and became more serious with the passage of time, so it was entrusted to a project quality testing center for testing and identification [1].

2. Field testing instrument
(1) HILTI steel bar detector (type RV10)
(2) HY225Y digital concrete rebound meter
(3) HZ-13 concrete core sampler
(4) Steel tape measure, camera, etc

3. On-site testing content [2]

3.1. investigation of concrete construction quality defects
Through on-site investigation, the damaged parts of the gangue warehouse's cylinder wall mainly occurred at the height of 7.0m above the cylinder wall, and the damage of the cylinder wall (see figure 1 and figure 2 below) was mainly manifested as poor concrete joints, uncompaction, empty surface and partial concrete falling off.
3.2. Testing the compressive strength of concrete at its age[3]

Because of the serious damage to the cylinder wall of the gangue silo, the compressive strength of the concrete at the age of the cylinder wall is tested by the method of drilling core. According to the actual situation on the site, 46 concrete core samples were drilled randomly in the gangue bunker, among which, 20 core samples were tested for compressive strength, 6 core samples were tested for frost resistance, 6 core samples were tested for F-CaO's influence on concrete, and 3 core samples were drilled at the construction joints (The appearance of the remaining core samples was defective). According to the relevant provisions of the 《Technical Specification for Testing the Compressive Strength of Concrete by Core Drilling》 (CECS03:2007), the test results are as follows:

Table 1. shows the testing results of the strength of drill core at the age of gangue silo concrete

| Serial No. | Core position No. | Concrete core strength representative value (MPa) | design strength class |
|------------|-------------------|--------------------------------------------------|----------------------|
| 1          | G17-5             | 31.9                                            |                      |
| 2          | G33-7             | 36.6                                            |                      |
| 3          | G16-8             | 36.3                                            |                      |
| 4          | G44-8             | 33.3                                            |                      |
| 5          | G45-8             | 29.7                                            |                      |
| 6          | G15-8             | 31.3                                            |                      |
| 7          | G31-9             | 20.9                                            |                      |
| 8          | G13-10            | 22.1                                            |                      |
| 9          | G43-10            | 19.6                                            |                      |
| 10         | G42-10            | 13.9                                            |                      |
| 11         | G12-11            | 15.7                                            |                      |
| 12         | G29-11            | 13.0                                            |                      |
| 13         | G40-11            | 26.3                                            |                      |
| 14         | G9-13             | 20.1                                            |                      |
| 15         | G38-13            | 26.0                                            |                      |
| 16         | G39-13            | 17.9                                            |                      |
| 17         | G25-15            | 26.6                                            |                      |
| 18         | G36-15            | 15.1                                            |                      |
| 19         | G23-17            | 19.0                                            |                      |
| 20         | G22-18            | 20.8                                            |                      |

The strength value cannot be estimated by test batch.

n=6, m=33.2, s=3.78
n=20, m=24.1, s=7.60
K1=1.17458, K2=2.39600
x1=15.2, x2=5.9

The appearance of the remaining core samples was defective.
1. The concrete drilling core sampling test results of gangue silos are discrete with poor homogeneity of concrete, which does not meet the requirements of the specification to provide the estimation interval according to the test batch. The compressive strength value of core sample is 13.0mpa ~ 36.6mpa, so the compressive strength of concrete at present age does not meet the design requirements.

2. According to the test results, the compressive strength of the core samples below the 8.0m height of the gangue silo cylinder wall basically meets the design requirements;The strength value of the core sample above the height of 8.0m is 13.0mpa ~ 26.6mpa, and the mean value of strength is 14.0mpa, and the standard deviation is 4.46mpa, which does not meet the design requirements.

3. The concrete outside the core sample is uncompacted within the range of 10-50mm, and bubbles exist on the surface of the core sample.

3.3. Measuring the spacing of reinforcement and the thickness of concrete protective layer
On the construction site, HILTI steel bar detector (RV10 type) is used to detect the spacing of reinforcement and the thickness of concrete protective layer in the gangue silo.In the 20 test points of gangue silo, the longitudinal bar spacing meets the design requirements, and the annular bar spacing of 5 test points does not meet the design requirements, and the concrete protective layer thickness of 20 test points does not meet the design requirements[4].

3.4. Inspection of construction quality at the concrete joint joint
On the site, a group of core samples were randomly drilled at the joint of concrete formwork on the wall of gangue bin. The inspection results of core samples' appearance and feeling are as follows:
1. The concrete in the 30-70mm range outside the core sample at the gangue bunker joints is not compact, and there are some bubbles in the core appearance.
2. According to the understanding with related personnel of the site construction unit, the main reason for the poor connection and rubbing of the warehouse body is improper control of sliding mode time and inadequate vibration during the construction of sliding mode technology.

3.5. The influence of F-CaO on the quality of concrete is tested
On the site, On site, concrete core samples were drilled from the cylinder wall of a gangue bin to make standard specimens, which were sent to the laboratory for F-CaO test on the influence of concrete quality. test on the influence of concrete quality. According to the relevant provisions in Appendix B of 《Technical Standards for Building Structure Inspection》 (GB/T 50344-2004), the test results are as follows:
(1) there was no cracking, porosity or collapse in the boiling thin section of concrete and core sample.
(2) the average percentage change of strength of the tested core samples is < 30%, indicating that f-cao on the wall of gangue silo has no effect on the quality of concrete.

3.6. Testing of freeze resistance of concrete on tube wall
On site, concrete core samples were drilled from the cylinder wall of a gangue bin and made into standard specimens, which were sent to the laboratory for antifreeze performance test. According to the relevant provisions of the code, the antifreeze test results were as follows: among the three sets of specimens, the strength loss rate of two was ≥25%, the antifreeze test results were unqualified, and the antifreeze test results of the other set were qualified.[6]

3.7. Determination of chloride ion and sulfur trioxide in concrete
Concrete core samples were drilled from gangue silos and sent to the laboratory for chlorine ion and sulfur trioxide content detection.According to the test, the content of chloride ions in the tested samples is 0.045% and the content of sulfur trioxide is 0.22%. The content of chloride ions in the tested samples meets the maximum content of chloride ions of environmental grade ii b specified in table 3.5.3 of the design code for concrete structures gb50010-2015.[5]
4. **Cause analysis of damage defect**

Reason one: the concrete of warehouse body has low compressive strength and uneven construction quality.

Reason two: tube wall concrete by water infiltration, expansion, after repeated freezing-thawing damage.

Reason three: not strictly in accordance with the sliding-form construction technology provisions for operation.

To sum up, the concrete damage on the wall of gangue silo is caused by the combination of low compressive strength of concrete, poor construction quality and external environment.

5. **Reinforcement design scheme**

According to the test results and cause analysis, the structure reinforcement of fengxi gangue warehouse body is completed by adding a layer of warehouse wall and connecting with the foundation and the upper and lower ring beam of the warehouse body. The reinforcement diagram is shown in figure 3 below. The details are as follows:[7]

1. **main materials**

   For the damaged part of the concrete of the warehouse body, repair with cement-based high-strength non-shrinkage grouting material. It is required to have early strength (compressive strength >40MPa) and micro-expansibility, and to meet the durability requirements.

2. **construction steps**

   (1) Thoroughly remove the defective concrete (take the part with the strength less than C25 as the defective part, and determine the compressive strength of the defective part according to the test result), cut the hole to the surrounding solid part of the extension of >100mm, and the total width of >250mm, the hole edge should be cut into a 1:3 slope of the bell mouth.

   (2) Branch mold and cement paste, plastic tape to seal the template connection to ensure that no slurry.

   (3) Before pouring the surface of the original concrete should be fully wet but there should be no water, pouring grouting material according to product requirements maintenance.

6. **Conclusion**

Based on the analysis of the damage detection and reinforcement design of the main structure of the gangue silo, it is shown that the damage detection is the premise of the repair and reconstruction, and the design and selection of reinforcement scheme is the main link of the reinforcement process and the key to ensure the reinforcement effect. Therefore, we should master the basic methods of on-site structural health monitoring, and can use the existing design knowledge and experience to choose a reasonable reinforcement scheme for the structure to be repaired.
References

[1] (2015) Technical Standards for Building Structure Inspection (GB/T 50344-2015). China Building Industry Press. Beijing.

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