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Study on Mortar Rebound Method for Masonry Structure Blocks of Concrete Products

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Abstract. The relevant provisions of the mortar rebound method in the national code GB/T50315 "Technical Standards for site testing of masonry engineering" is only focus on mortar rebound method of sinter bricks, but whether the rebound curve of sintered brick mortar can be used for non-sintered brick mortar is uncertain. Therefore, the rebound curve of non-sintered brick mortar needs to be further studied. The mortar rebound method of sintered bricks is used as a model for the research process for mortar rebound method of other blocks, and the mortar of three widely used blocks of concrete products in masonry structures is selected as the research object. In the end, the mortar rebound curves for mortars of three widely used blocks are obtained through relevant tests, the results showed that the mortar rebound curves of sintered brick and non-sintered brick are completely different, thus broadening the application area of the mortar rebound method.

Keywords. Blocks of concrete products; mortar; rebound method; mortar rebound curve.

1. Introduction

Sintered bricks are also known as clay bricks. Due to its low price, simple process, design, mature construction techniques and people's inertia of use, it dominates masonry projects [2]. On September 26, 2012, the National Development and Reform Commission announced that China will gradually restrict the use of clay products or solid clay bricks in hundreds of cities and counties, including Shanghai, during the 12th Five-Year Plan period. In this context, today's wall materials began to shift to non-sintered brick blocks. Before this, there is no technical standard for on-site inspection of non-sintered brick masonry engineering in our country, which makes it difficult to make accurate judgment on many quality disputes and quality accidents of this kind of engineering. It can only blindly apply GB/T50315-2011 "Technical Standards for site testing of masonry engineering" [1] (which is referred to as national standard in the later text) to carry out quality inspection, which will inevitably cause

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miscarriage of justice to the quality of the project. Therefore, it is necessary to carry out the research on the technical standard of the on-site inspection of non-sintered brick masonry engineering. Based on the above situation, Sichuan Academy of Building Science has carried out the compilation of "Technical Standards for On-site Inspection of Non-soused Brick Masonry Works". In this paper, several common concrete blocks are selected as the research objects of non-sintered bricks, and the mortar rebound method in the masonry structure blocks of concrete product is studied.

2. Design and Process of the Testing

The proposed test methods, adjusted for the relevant standards and specifications, are as follows. Three strength grades of mortar are used respectively (It includes 1:5.5 high strength mortar, 1:7 medium strength mortar and 1:8.5 low strength mortar. Concrete Common Block, 1:4.5 Ultra High Strength Mortar and 1:9.5 Ultra Low Strength Mortar with ratios of grey to sand. In the latter, the proportions are defaulted to the grey to sand ratio.). Each mortar was used to build one concrete wall of plain bricks, one concrete wall of porous bricks, one concrete wall of small blocks and one sintered plain bricks, for a total of 12 walls [3-7], see figure 1 for the walls. Cement of Mount Emei was used with a strength number of 42.5. coarse sand was used for the fine aggregate. A small amount of early strength agent was mixed into the mortar. The mortar test blocks were made of common bricks of concrete as the base mould. The production of the walls and mortar test blocks took a total of two months. During this period, the mortar test blocks were maintained naturally in situ and properly watered and moistened. The surface of the test block needs to be kept largely moist for the first period (7d). In September 2012, a rebound test was carried out in accordance with the national standard, see figure 2. In November 2012, the strength of the mortar blocks was tested with a press [8-12].

Figure 1. Test wall.

Figure 2. Rebound testing.

3. Establishment of Mortar Rebound Curves for Masonry Structures with Concrete Products Blocks

It has been clearly concluded that the effect of carbonation depth can be ignored in the mortar rebound method for sintered bricks, thus improving the accuracy of the rebound curve and simplifying the process of field testing [13]. This is because sintered bricks differ from non-sintered bricks only in terms of material (this difference is mainly due to the difference in water absorption). They are similar in other aspects of performance, so we can further conclude that the mortar rebound method can ignore the effect of carbonation depth. Therefore, the effect of carbonation depth is not considered in the tests in this paper.

3.1. Common Brick Masonry Mortar for Concrete

The normal brick mortar for concrete does not show rebound in 1:7 walls, 1:8.5 walls and 1:9.5 walls, its only valid data that can be produced in 1:5.5 walls and 1:4.5 walls. The reason for the presence of 2 average strength values in the 1:5.5 wall in the valid data is that two plates of mortar were used in the masonry process for the 1:5.5 wall as one plate of mortar was not sufficient. Therefore, two sets of mortar test blocks were made (a similar situation is found in the data later on).

The form of the curve with the highest correlation index was chosen for the fit, see figure 3, the horizontal coordinate and Equation x are the average rebound values of the mortar; the vertical coordinate and Equation y are the average mortar strength in MPa; and Equation R2 is the correlation index (x, y, R2 in the later section are taken as default).

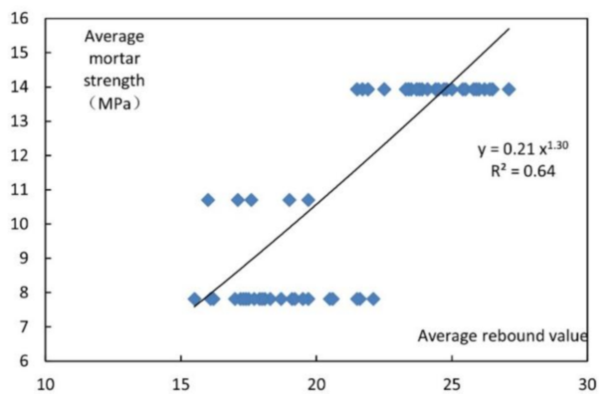

Figure 3. Fitting curve in accordance with the highest correlation coefficient of common brick masonry mortar for concrete.

The fitting curve and correlation indices are derived from figure 3, which is shown below:

$$y = 0.21x^{1.30} \tag{1}$$

The index of correlation is 0.64 < 0.85, which indicates that the fitting is poor at this point and that it is not acceptable for mathematical statistics. The main reasons for this situation are as follows:

(1) There was less data. Throughout the course of the test, the plain bricks of concrete were in an unresilient condition the most often. This resulted in no more valid data being available. When comparing this situation with the sintered common brick, valid rebound values were obtained for the sintered common brick in all five cases, whereas the concrete common brick only had rebound values when the strength was

high. This indicates a difference in the hardness of the mortar in the two cases. The higher hardness of the sintered plain bricks may be due to the fact that the sintered plain bricks have a better water absorption, thus allowing the mortar to show hardness earlier and faster.

(2) The values of the valid data are more concentrated. In the valid data for the plain bricks of concrete, the rebound values are all concentrated between 16 and 27. The concentration of values has a negative impact on the curve fitting.

(3) The variability in the compressive strength of the mortar test blocks for the two groups of 1:5.5 walls is large. The mean values of the compressive strengths of the mortar specimens for the two groups were 10.34 MPa and 7.97 MPa respectively, with a large variability.

3.2. Mortar for Porous Brick Masonry with Concrete

Effective rebound values were obtained for each grade of mortar for the porous blocks of concrete and to summarize these data for fitting, please see figure 4, from which it can be roughly seen that when the mortar strength is low, the differences in average rebound values are small.

The curve form with the highest correlation index was chosen to be fitted, resulting in equation (2):

$$y = 0.59x - 2.65 \tag{2}$$

The correlation index R2 of the fitted curve was 0.87. Its high but the average rebound value of the mortar for a 1:7 wall and a 1:8.5 wall was essentially indistinguishable. This results in a poor rebound curve. Judging from the fact that the average rebound values of the 2 mortars for the 1:7 wall are essentially the same, it should be the high rebound value of the 1:8.5 mortar that is responsible. Also here there is a large difference in the compressive strength of the two mortars. However, this difference is acceptable because of the small strength of the mortars.

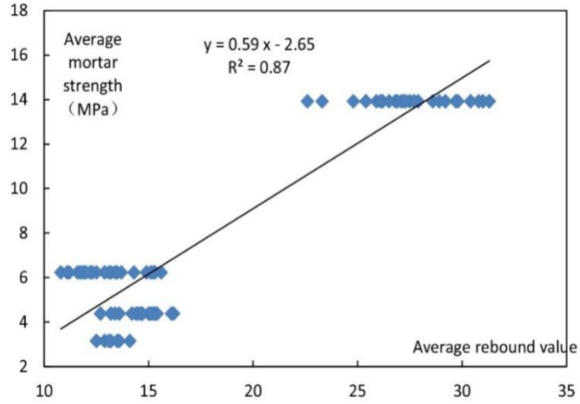

Figure 4. Fitting curve in accordance with the highest correlation coefficient of mortar for porous brick masonry with concrete.

3.3. Masonry Mortar for Small Concrete Blocks

The only walls with small blocks for which valid mortar data were available were the 1:5.5 walls and the 1:7 walls, which had the least valid data. The curve form with the highest correlation index was chosen for the fit, see figure 5.

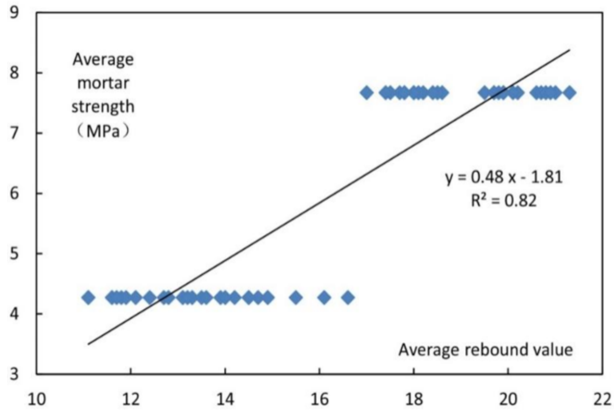

Figure 5. Fitting curve in accordance with the highest correlation coefficient of masonry mortar for small concrete blocks.

Equation (3) can be obtained from the diagram. Although there are too few valid data, the correlation index is 0.82 and the curve fit is satisfactory.

$$y = 0.48x - 1.77 \tag{3}$$

3.4. Summary

From the specific analysis of mortars for non-sintered bricks, it was found that a number of unexpected conditions occurred in the fitting process for each type of wall, and the reasons for these surprises are as follows.

(1) Defects in test design. In the experimental design stage, the ratios of 1:5.5, 1:7 and 1:8.5 were determined to simulate the low-strength mortar, medium-strength mortar and high-strength mortar in the field. In the process of the test, the specific bricks were added with 1:4.5 and 1:9.5 two grades of mortar to simulate ultra-high strength mortar and ultra-low strength mortar. This design is very good for the mortar of sintered common bricks, which is manifested in the effective rebound value of each strength grade, so that the fitting curve with high correlation index can be obtained. However, for non-sintered bricks, such strength definition is obviously low, which is manifested as that the medium-strength mortar has no rebound value, which has a great impact on data fitting. It can be concluded that the initial strength of mortar rebound method for concrete products should be higher than that of mortar rebound method for sintered bricks. From the point of view that the compressive strength of all mortar blocks is only two lower than 3 MPa, the initial strength of mortar rebound method for concrete products can be increased to 3 MPa.

(2) There is no detailed test log. At the beginning of the test, the test log should be done to facilitate future analysis. Although we have made the corresponding test log on

this point, its content is simple and it is not enough to make us analyze the test results effectively. This makes some unexpected conclusions unable to be explained. For example, the rebound values of concrete perforated bricks at medium strength and low strength are no difference, which is theoretically impossible. However, due to the lack of detailed records, the reason why the rebound value is not different cannot be found.

4. Establishment of Mortar Rebound Curve of Concrete Masonry after Classification

Because these three blocks are made of recycled concrete, so these three blocks have certain similarities. When they are analyzed, these three blocks can be appropriately summarized and classified for further analysis.

4.1. Mortar of Concrete Products

Concrete common brick, concrete perforated brick and concrete small block are all made of concrete. Because their materials are the same, their properties are similar. Therefore, the above three kinds of brick mortar are classified as mortar of concrete products, and they are analyzed. All the data are put on a figure, and the curve form with the highest correlation index is selected for fitting (figure 6).

The fitting curve and correlation index are obtained from figure 6, and the fitting curve is as follows.

$$y = 0.72x - 4.53 \tag{4}$$

It can be seen from figure 5 that with the increase of effective data, the correlation index increases. And it can reach the acceptable range of mathematical statistics, which shows that the curve is representative. However, it is more general to classify the three kinds of blocks only by the same material, so the blocks of concrete products can be classified.

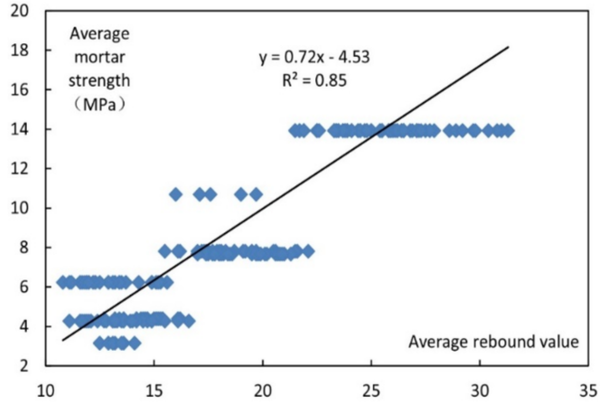

Figure 6. Fitting curve in accordance with the highest correlation coefficient of mortar of masonry of concrete products.

4.2. Mortar Rebound Curve of Concrete Common Brick and Concrete Porous Brick Masonry

Because the contact area between concrete blocks and mortar joints is very small (only the longitudinal and ribs of small blocks have slight contact with mortar joints. If the grinding wheel is used to grind it out of a certain distance according to the national standard, the contact surface will be smaller. Therefore, it is different from common concrete brick and concrete perforated brick. After the mortar data of concrete common brick and concrete perforated brick masonry are combined, the fitting curve with the highest correlation coefficient is taken to obtain equation (5), and the correlation index is 0.83.

$$y = 0.69x - 3.43 \tag{5}$$

4.3. Comparison of Several Fitting Curves

There are 6 curves obtained from the testing. Four representative curves are selected from the six curves and drawn on a graph, see figure 7. The following conclusions can be drawn from the analysis in figure 7.

(1) There is a certain difference between the mortar joint of small concrete block and that of common concrete brick and concrete perforated brick. In the diagram, the slope of the mortar rebound curve of concrete small block is significantly lower than the common rebound curve of concrete common brick and concrete perforated brick mortar, that is, under the same rebound value, the mortar strength of concrete small block is low. The reason for this situation is that the contact area between mortar and small concrete blocks is relatively small. The mortar joint after grinding with grinding wheel is very thin. When the mortar rebound tester is used for testing, there is a situation that the mortar joint that have not been fully loaded have been perforated. Even if there is no perforation, the rebound value is low. Therefore, the mortar rebound curve of small concrete block cannot be combined with common concrete brick and concrete perforated brick, and it should be classified separately.

(2) With the increase of rebound value, the mortar rebound curve of concrete block masonry has no obvious change. After data fitting, it is found that the mortar rebound curves of block masonry of concrete products are linear (the correlation index is the highest at this time), that is, the mortar strength increases linearly with the rebound value, and its growth is very average.

(3) The mortar rebound curve of block masonry of concrete products cannot be combined with the mortar rebound curve of fired brick masonry (which appears in “Study on the influence of carbonation depth in mortar rebound method of sintered brick”) into a curve. In the figure, the two curves are quite different. When the rebound value is high, the mortar strength of sintered brick is significantly higher than that of concrete products. When the rebound value is not high, the situation is the opposite. When the rebound value is low, the strength of the two is basically the same.

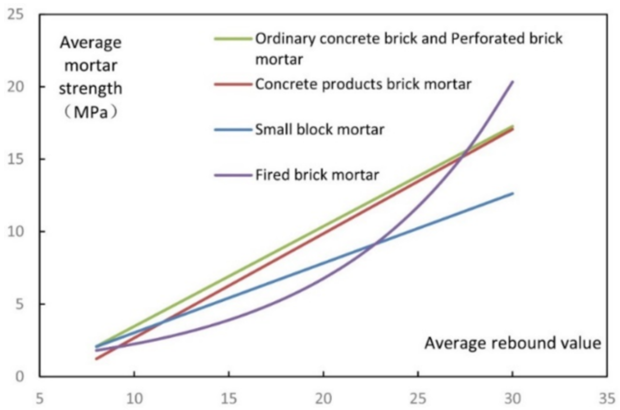

Figure 7. Four mortar fitting curves.

4.4. Summary

The rebound curve of each kind of concrete brick is analyzed separately, but it is not suitable for this work because of the few test data. After it is classified as concrete products, the average regression analysis is more satisfactory. At the same time, among the three kinds of concrete products mentioned in this paper, the contact area between small concrete blocks and mortar is too small to be classified into one category with the other two kinds of blocks. Therefore, the mortar rebound curve of masonry structure blocks of concrete products should be divided into two categories.

(1) Large contact area between brick and mortar (such as concrete common brick, concrete perforated brick, etc.)

$$y = 0.69x - 3.43 \tag{6}$$

(2) Smaller contact area between brick and mortar (such as small concrete blocks)

$$y = 0.48x - 1.77 \tag{7}$$

5. Conclusion

Considering the actual situation in China, at least in recent decades, the housing in rural areas and the partition wall of multi-storey and high-rise buildings in cities in China will be built in masonry form. From this point of view, the mortar rebound method will at least play a pivotal role in engineering testing in recent decades. Under the background of gradually reducing the use of sintered ordinary bricks in China, the concrete products made of recycled concrete will gradually replace the status of sintered ordinary bricks and be widely used because of their practical and environmental protection characteristics. Therefore, the mortar rebound detection of concrete blocks will also be widely used in engineering detection. In this paper, based on the research process of mortar rebound method of sintered ordinary brick, the mortar of three widely used concrete products in masonry structure is selected as the research object, and the mortar rebound method of concrete products is studied, and the following conclusions are obtained.

(1) The initial mortar strength of concrete products is 3MPa. Through the comparison of experiments, it can be seen that the mortar hardness of concrete products is smaller than that of sintered ordinary brick. In the test, the mortar with small strength cannot appear the corresponding rebound value. Therefore, it is necessary to use the mortar rebound method to detect the blocks of concrete products, and the initial strength of mortar must be improved.

(2) The mortar fitting curve of concrete products should be divided into two according to the size of the contact area between the block and the mortar.

(a) When the contact area between block and mortar is large (such as concrete common brick, concrete perforated brick, etc.)

$$f_{2ij} = 0.69R - 3.43 \tag{8}$$

(b) Smaller contact area between block and mortar (such as small concrete block)

$$f_{2ij} = 0.48R - 1.77 \tag{9}$$

where f_{2ij} is Mortar strength value (MPa) at position j of the i testing zone, R is Average rebound value of the jth position in the i testing zone

In this paper, the non-sintered brick mortar rebound method is discussed. In the process of discussion, the blocks of concrete products widely used in Sichuan are selected as the research objects. The scope of research has been artificially narrowed. At the same time, the effective data obtained by the experiment is less, so that the correlation index is low when the data is fitted. Based on the above two reasons, in further research, if the formula of mortar rebound method for non-sintered bricks can be further studied from the following aspects, the formula will be more accurate and the application range will be wider.

(1) The scope of application of brickwork should be extended. In this thesis, only three concrete brick types that are more widely used within Sichuan were selected for the study, which is narrow in scope. In further research, if several more brick types could be considered, the scope of application of the mortar rebound method for non-sintered bricks would be more extensive.

(2) The mortar strength should be increased in further tests. As several of the mortar strengths identified in the design phase of the tests were not available for rebound values, the data was fitted with less valid data, which resulted in a relatively low correlation index. In further research, if the mortar strengths could be increased appropriately and more valid data obtained, the mortar rebound curves for non-sintered bricks would be more accurate. Particularly for cases where the contact area between the brick and mortar is small, more valid data would undoubtedly lead to a more accurate mortar rebound curve.

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