Experimental study on mix proportion and the strength of low-grade magnesite hollow block

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Abstract: In this paper, the properties of test block and hollow block made of low-grade magnesite is analysed and studied. First, in order to get the results, the X-ray diffraction analysis was carried out on the phases composition of low-grade magnesite. Then, the influence is researched successively by orthogonal experimental design of water consumption, water-cement ratio, sand ratio and building gypsum on the compressive intensity of test block which can get the best Mix. Finally, the optimum mix ratio of magnesite hollow block is obtained by using the vibration extrusion method to prepare the traditional size distribution concrete hollow block, and the strength relationship between magnesite hollow block and traditional block is solved by linear regression equation. The conclusions shows: compressive strength of hollow block presents a tendency that decreased first and then increased, and strength ranks of all first group hollow blocks exceed MU10.

1. Introduction

Liaoning province yields 15 million tons of magnesite every year, 4.5 million tons of them is waste stone, accounting for 30% of the total, and most parts with mines use the traditional mining methods that are mining for the rich and abandoning the poor. Including some Low-grade Magnesite heaps in mining areas are over one million tons, resulting in the waste of resources, and the forming of white pollution, which is seriously affecting the local the environment[1-2]. Therefore, the effective use of low-grade magnesite has the realistic foundations and economic benefits, and the main advantages of magnesite is in building. Magnesia bricks have excellent high-temperature mechanical properties and anti erosion performance such as the cement clinker, thus it becomes the main cement kiln refractory material[3-4]. In practical engineering, materials of ordinary hollow blocks have problems of low strength, poor durability and poor heat-insulation properties. Many houses collapsed due to the low strengths of hollow blocks, and the trace elements contained in the Ca and Mg of magnesite may be appropriate to increase the strength of hollow blocks. Therefore, it is necessary to conduct the experimental research of low-grade magnesite hollow blocks, and measure mechanical properties[5-6].

At present, a large number of experimental studies have shown that low-grade magnesite can be used to produce building materials. In recent years, the studies on the test of low grade magnesite hollow block production both at home and abroad, and the abundant of low-grade magnesite resources, if we can make full use of it, it not only can solve the pollution problems to the environment, but also can substitute for clay, turning waste into treasure, it will protect arable land and save land resources[7-9].

In this paper, hollow blocks made of low grade magnesite are prepared, and the non load bearing hollow block of MU10 is also prepared by constant temperature and humidity curing processes. It is
beneficial to the development of new wall in China.

2. Test Situation

2.1 X ray diffraction phase analysis
X Pert PRO X ray diffractometer was used to analyze the phase after screening treatment to determine the phase composition of the original low grade magnesite, so as to avoid the influence of excessive content of MgO on the performance of the hollow block. The particle size of the test was analyzed by means of X ray diffraction analysis. The particle size was measured by using the HighScore Plus software. The test results are shown in Table 1 through 0.075 mm screening holes.

Tab. 1 Results of phase analysis of X-ray diffraction of magnesite

| Ingredient    | Chemical formula | Content (%) |
|---------------|------------------|-------------|
| Periclase     | Mg4.00 O4.00     | 0.0%        |
| Magnesite     | Mg6.00 C6.00 O18.00 | 89.7%      |
| Quartz        | Si3.00 O6.00     | 2.5%        |
| Dolomite      | Ca3.00 Mg3.00 C6.00 O18.00 | 3.0%      |
| Quartz        | Si3.00 O6.00     | 2.4%        |
| Calcite       | Ca6.00 C6.00 O18.00 | 0.1%      |
| Clinohlore    | Mg5.56 Fe0.44 Si2.56 Al1.44 O18.00 | 1.5% |
| Majorite      | Mg28.09 Ca3.91 Si40.00 O96.00 | 0.8% |

2.2 Orthogonal test scheme of test block
The length of the cube magnesite test blocks is 150mm. The experiment is divided into nine groups. The magnesite macadam is used instead of the natural gravel as the rough aggregate to prepare the test block. According to the experience of specimen density for $P_{om} = 2350 \text{ kg/m}^3$ calculation table, test mix see Table 2.

Tab. 2 The compressive strength of test block

| Test number | Water consumption | Water cement ratio | Sand rate | Building gypsum/% | Standard curing | Natural conservation | Compression strength/MPa |
|-------------|------------------|--------------------|-----------|-------------------|-----------------|----------------------|--------------------------|
| 1           | 1(185)           | 1(0.55)            | 1(0.39)   | 1(20)             | 18.1            | 19.7                 |                          |
| 2           | 1(185)           | 2(0.60)            | 2(0.40)   | 2(25)             | 19.6            | 20.2                 |                          |
| 3           | 1(185)           | 3(0.65)            | 3(0.41)   | 3(30)             | 12.9            | 13.6                 |                          |
| 4           | 2(180)           | 1(0.55)            | 2(0.40)   | 3(30)             | 15.1            | 14.4                 |                          |
| 5           | 2(180)           | 2(0.60)            | 3(0.41)   | 1(20)             | 10.3            | 9.5                  |                          |
| 6           | 2(180)           | 3(0.65)            | 1(0.39)   | 2(25)             | 12.3            | 11.5                 |                          |
| 7           | 3(175)           | 1(0.55)            | 3(0.41)   | 2(25)             | 12.2            | 13.1                 |                          |
| 8           | 3(175)           | 2(0.60)            | 1(0.39)   | 3(30)             | 11.1            | 12.9                 |                          |
| 9           | 3(175)           | 3(0.65)            | 2(0.40)   | 1(20)             | 9.7             | 10.2                 |                          |

Notes: In Table 2, $W$ is the first column, and the results of three standard maintenance tests corresponding to level “1” of this column are recorded as $M_{ij}, M = \sum_{i=1}^{n} \sum_{j=1}^{p} y_{ij} = 18.1 + 19.6 + 12.9 = 50.6$. By the same principle, $M_{21}, M_{31}, \ldots$, and so on can be obtained in turn. $R = \max - \min \{m_{ij}\} = m_{11} - m_{ij} = 16.9 - 11 = 5.9$. In the same way, $R_1, R_2$ and so on are calculated in turn. According to the order of range calculation, the order of each factor can be known as $W \rightarrow W / C \rightarrow S_p \rightarrow B$. 


2.3 The influence of various factors on the strength

Now, the actual state represented by the three levels of each factor is abscissa, and the average compressive strength corresponding to the three horizontal values is plotted as a vertical coordinate, as shown in Figure 1.

![Graphs showing the relationship between factors and compressive strength](image)

Fig. 1 The relationship between the factors and the compressive strength

As can be seen from Figure 1, when the water consumption increases between 175 and 180 kg/m³, the compressive strength increases slowly, with an increase in the water consumption and the compressive strength. With the increase of water to cement ratio, the compressive strength decreases gradually, and the decrease increases with the increase of water cement ratio. When 0.39<Sp<0.41 and 20%<B<30%, the compressive strength is first increased and then decreased, when the Sp is near 0.4, the compressive strength reached the maximum, Sp rounded to 0.4; similarly, 25% building gypsum. It is known that the optimum mixture ratio of the test block strength is W1W/C1Sp2F2.

3. Orthogonal test of low grade magnesite hollow block

In the mixing ratio, both the strength and the cost of the product should be taken into account. Therefore, scheme selection for the group I hollow block, use Table 2 in the second groups of mix ratios; for the group III hollow block, refer to Table 2 in the eighth groups of mix ratios; for II and IV considering to meet the strength requirements and to reduce the cost of production taken from the example in Table 3.

| Tab. 3 The proportion of hollow block with low-grade magnesite |
|-----------------|-----------------|-----------------|-----------------|
| Hollow block number | Aggregate type | Water consumption | Water cement ratio | Sand rate | Building gypsum |
|                  |                | W               | W/C              | Sp       | B%             |
| Ⅱ                | Coarse and fine | 210             | 0.65             | 0.38     | 25             |
| Ⅳ                | 1/5 Coarse and 4/5 fine aggregate | 230             | 0.70             | 0.36     | 25             |

In this experiment, the size of the hollow block is 390mm × 190mm × 190mm, with a row of 2 holes, the hole rate is 50%. Referring to the industrial parameters of the hollow block manufacturers in China, and then debugging, the selected extrusion stress is 4 ~ 4.2MPa, and the total extrusion force of each hollow block is about 300kN. Release as shown in Figure 2, and placed in constant temperature and humidity curing box, maintenance, as shown in Figure 3.
4. Failure phenomenon and strength analysis of hollow block

4.1 Phenomenon of destruction analysis of hollow block

The Magnesite hollow block compressive damage form and that of the ordinary hollow block are roughly the same, the failure process is: First, start the loading process, then short ribs cracks appear in the corners of the hollow block or on both sides of congenital defects. Surface cracks appear; with the increase in loading, second cracks appear in the surface and near the side wall; also with the increase in load. The cracks continue to extend and increase in width by local, then it finally gradually developed into full-length cracks with top surface or a surface substantially perpendicular, and the loads to the destruction of the hollow block. The final failure modes of the block are brittle failure, and the concrete at the surface of the strip shows different degrees of spalling, as shown in Figure 4.

![Fig. 2 The ejection of hollow block](image1)
![Fig. 3 Standard curing](image2)

4.2 Compressive strength analysis

According to the GB/T4111 «concrete block and brick test method»[10], it stipulates that the average strength, standard deviation, coefficient of variation and standard value should be calculated to evaluate the strength of the hollow block. The proportion of the four kinds of preparation of the hollow block in the test for compressive strength in Table 4 shows, I, II, III and IV, four types of hollow blocks can reach the MU5 level. The compressive strength increases with the increase in the aggregate an amount of 100% pieces of magnesite.

| Test number | Hollow block number |
|-------------|---------------------|
|             | I   | II  | III | IV  |
| 1           | 12.2| 10.1| 9.2 | 6.9 |
Because the magnesite aggregate has a certain discreteness, the relation between the early strength of the test block and the strength of the blocks after 28 days should be known when adjusting the mixing ratio of the hollow block, and the relation between the strength of the block and the hollow block should be determined. 12 groups of test block and hollow block were made according to the category of hollow block. The compressive strength, average value and standard deviation of the test block and the hollow block were measured, as shown in Table 4 and Table 5.

Tab. 5 The compressive strength of test block and hollow block (MPa)

| Number | Magnesite coarse aggregate | Magnesite coarse and fine aggregate |
|--------|-----------------------------|-----------------------------------|
|        | Test block                  | Hollow block                      | Test block                  | Hollow block                      |
|        | 7 day                       | 28 day                            | 28 day                       | 28 day                            | 28 day                            |
| A1     | 11.1                        | 17.9                              | 12.2                        | 9.8                              | 14.7                              | 10.1                            |
| A2     | 9.8                         | 15.4                              | 10.7                        | 8.5                              | 13.1                              | 7.9                             |
| A3     | 10.2                        | 16.5                              | 11.8                        | 9.3                              | 13.8                              | 9.2                             |
| A4     | 12.1                        | 17.3                              | 12.1                        | 11.9                             | 14.7                              | 10.3                            |
| A5     | 11.5                        | 14.8                              | 10.5                        | 9.4                              | 13.5                              | 8.6                             |
| A6     | 9.4                         | 15.5                              | 10.5                        | 10.8                             | 14.9                              | 10.5                            |
| A7     | 10.2                        | 15.3                              | 10.4                        | 9.0                              | 14.5                              | 10.1                            |
| A8     | 12.7                        | 15.9                              | 11.3                        | 9.6                              | 15.1                              | 10.7                            |
| A9     | 8.7                         | 14.1                              | 9.8                         | 8.6                              | 13.3                              | 8.5                             |
| A10    | 11.5                        | 16.6                              | 11.7                        | 9.1                              | 15.4                              | 11.2                            |
| A11    | 8.3                         | 16.3                              | 11.4                        | 9.0                              | 14.8                              | 10.6                            |
| A12    | 10.2                        | 15.5                              | 10.8                        | 8.2                              | 14.4                              | 9.9                             |
The compressive strength of coarse aggregate, coarse and fine aggregate test block and hollow block can be obtained by Table 5, as shown in Figure 5 and Figure 6.

![Graph of compressive strength vs test block strength](image1)
![Graph of compressive strength vs test block strength](image2)

**Fig. 5** The relationship between strength of block and test block

**Fig. 6** The relationship between strength of building blocks and content of aggregate

### 4.3 Relationship between strength and aggregate of hollow block

Hollow bricks are made by selecting different amounts of magnesite as aggregates. By establishing the relationship between the strength and aggregate volume of hollow blocks, the strength of the corresponding hollow blocks can be deduced from the relative content of any magnesite, which is convenient for practical application, as shown in Figure 6.

![Graph of compressive strength vs magnesite content](image3)

**Fig. 6** The relationship between strength of building blocks and content of aggregate

### 5. Conclusion

Compared with ordinary hollow blocks, the compressive strength of magnesite hollow blocks overall increase, but the larger the magnesite hollow blocks effect on the intensity of the smaller size of magnesite particles, in the actual project should reduce the content of magnesite in fine aggregate.

1. The strength of the hollow block first decreases then increases with the increase of the content of magnesite fine aggregate, and the strength of the hollow block can reach MU5, and the strength of the hollow block I of the group MU10 is above above;
2. Water consumption is the main factor affecting the compressive strength, and the increase of water consumption can increase the strength. Water cement ratio and sand rate are important factors, but the influence of construction gypsum content is minor;
3. The hollow block made of magnesite can be prepared by using constant temperature and humidity curing technology. The MU10 non bearing wall hollow block can be used in practical projects, which is beneficial to economic and social development.

### References

[1] Wang zhao min. Current situation and development trend of China magnesite[J]. China Nonmetallic Mining Industry Herald. 2006(5): 6-8, 23.
[2] Zhang yong kui. Development status and Prospect Analysis of China Magnesite[J]. Mining Forum.
2013(5): 424-425.

[3] Through-flow elrying of vertically perforated clay bricks and blocks. Dr-Ing. Kaisten Junge. ZL international. 2000, 000 (7).

[4] Cui hong tao, Cao yong min, Wang zhao et al. Experimental study on improving mechanical properties of magnesium products[J]. New building materials. 2006(11): 69-70, 71.

[5] Numerical study of heat transfer in a wall of vertically perforated bricks: influence of assembly method. B. Lacarriere, B. Lartigue and F. Monchoux. Energy and Buildings. 2003.

[6] Li cheng yuan. The status quo and Prospect of application of domestic magnesite resources development[J]. World nonferrous metals. 1997(12): 30-34.

[7] Cai zheng yong, Wang zu xian. The application of orthogonal design in concrete[M]. China Building Industry Press, 1985, 1.

[8] Hao dan. Experimental study on the mix proportion and basic performance of recycled concrete perforated brick[D]. Zheng zhou: Zhengzhou University, 2005.

[9] Yang wei wei. Study on the mixture ratio of recycled concrete perforated brick and its physical and mechanical properties[D]. Zheng zhou: Zhengzhou University, 2007.

[10] 《Test method for concrete block and brick》, GB/T4111.