Finite element analysis of flexural performance of different strength basic magnesium sulfate cement concrete beams

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Abstract. In this paper, through ANSYS finite element simulation analysis, the effects of initial cracks, mid-span bending moment and deflection of different grades of basic magnesium sulfate cement concrete beams are studied. The research results show that as the grade of basic magnesium sulfate cement concrete increases, the mid-span bending moment during initial cracking gradually increases overall, while the bending stiffness increases while the deflection decreases. As the grade of basic magnesium sulfate cement concrete increases, the mid-span bending moment at yield gradually increases, and the mid-span deflection decreases gradually. Research shows that basic magnesium sulfate cement concrete has good toughness and strength, and can effectively improve the bending performance of its beam members.

1. Introduction
In recent years, concrete materials have been widely used as the main building structural materials due to the advantages of easy access to local materials, good plasticity and high compressive strength. However, due to the low tensile strength of concrete itself, easy cracking and other reasons, the tensile strength of concrete is neglected in the ultimate state design of the actual component bearing capacity. The maximum crack width needs to be controlled in the limit state design of normal use, thereby increasing the project cost. In order to improve these concrete defects, people have done a lot of experimental research by changing the polymer ratio or properties. For example, in 2013, Yu Hongfa and others [1-5] developed basic magnesium sulfate cementitious materials with fast setting, early strength, high tensile strength and flexural strength. In 2016, He Liang et al. [6] systematically studied the mix ratio design method and cubic compressive strength law of basic magnesium sulfate cement concrete. According to literature investigation and analysis, we have done a lot of basic research on basic magnesium sulfate cementitious materials at home and abroad in terms of chemical and physical properties, gelatin, mortar, concrete, etc., and formulated basic magnesium sulfate glue with good basic properties. However, there is little research on the application of basic magnesium sulfate cementitious materials in the structure. The general concrete structure is easily affected by its own composition, and its stress condition also changes complicatedly with the change of the composition. Therefore, the application of basic magnesium sulfate cement concrete structural members needs further research.

In order to expand the application of basic magnesium sulfate cement reinforced concrete, this
paper uses ANSYS finite element simulation analysis to study the influence of different strength basic magnesium sulfate cement content on the initial cracks, mid-span bending moment and deflection of concrete beams under yield state. In the future, it will provide a theoretical reference for the research on the flexural performance of basic magnesium sulfate cement concrete beams.

2. Test plan design
The experiment designed and produced 4 groups of beams with a length of 1500mm, with a clear span of 1200mm and a cross-sectional dimension of 150mm×180mm (see Figure 1 for details). 2C8 is used for the vertical reinforcement in the beam, the steel grade is HRB400, and the stirrup is B8@150 HRB335 steel. The elastic modulus of the steel bar is 200GPa. In this paper, 4 different grades of basic magnesium sulfate cement concrete are changed, and ANSYS finite element simulation is performed on 4 groups of concrete beams to analyze the initial cracks of the beams, the load under the yield state, and the mid-span deflection. See Table 1 for details.

![Fig.1 The structure diagram of the specimen](image)

| Specimen number | Water glue ratio | Cement type | Tensile steel | Experimental value of compressive strength (60d/MPa) | Splitting tensile strength (MPa) | Elastic Modulus (GPa) |
|-----------------|------------------|-------------|---------------|-----------------------------------------------|-------------------------------|----------------------|
| L01             | 0.31             | B32.5       | 2D16          | 22.38                                         | 1.66                          | 22.61                |
| L02             | 0.29             | B42.5       | 2D16          | 42.42                                         | 3.11                          | 33.28                |
| L03             | 0.24             | B52.5       | 2D16          | 54.16                                         | 4.04                          | 38.90                |
| L04             | 0.21             | B52.5       | 2D16          | 68.05                                         | 5.62                          | 60.69                |

3. Finite element simulation
In this paper, because the compressive capacity of recycled high-strength concrete is far greater than the tensile capacity, the SOLID65 element is selected, and the longitudinal reinforcement and stirrup are both LINK8 bar elements. Since there are few domestic experimental studies on the constitutive relationship of basic magnesium sulfate cement concrete, this paper uses the stress-strain curve equation proposed by Professor Guo Zhenhai [7], and the concrete Poisson's ratio is 0.25. The reinforcement in the beam in the finite element simulation analysis adopts the bilinear BKIN follow-up strengthening model, and the corresponding parameters are determined according to GB50010-2010 "Specification for Design of Concrete Structures", and the Poisson ratio of the reinforcement in the beam is 0.3. The relationship between stress and strain is linear before the cracking and crushing of concrete during compression, and the William-Warnke failure criterion is used after cracking and crushing. And the complete Newton-Raphson equilibrium iteration is used for nonlinear solution.
4. Finite element simulation results and analysis

4.1 Analysis of mid-span bending moment and deflection when the component is initially cracked

4.1.1 Analysis of mid-span bending moment during initial cracking

Figure 2 and Figure 3 are respectively the stress cloud diagram and mid-span bending moment diagram of different strength basic magnesium sulfate cement concrete beams when initial cracking. It can be seen from the figure that when the strength of basic magnesium sulfate cement concrete is C20, C40, C50 and C60 at the initial cracking, the mid-span bending moments are 2.31 kN•m, 3.09 kN•m, 3.97 kN•m, 5.36 kN•m, respectively. That is, when the strength of basic magnesium sulfate cement concrete is low, the corresponding mid-span bending moment is also small, while the cracking moment of the beam corresponding to the high-strength basic magnesium sulfate cement concrete increases, and the bending bearing capacity is significantly improved. This is because as the strength of basic magnesium sulfate cement concrete increases, the crack resistance and shear resistance of the beam increase, the deformation becomes smaller, but the ductility decreases.

4.1.2 Analysis of mid-span deflection during initial cracking

Figures 4 and 5 show the deflection cloud diagram and the mid-span deflection of different strength basic magnesium sulfate cement concrete beams when they initially crack. As can be seen from the figure, the beam’s mid-span cracking deflection tends to decrease as the concrete strength increases. From C20 to C40, the deflection decreases from 0.21mm to 0.19mm, and from C50 to C60, the deflection decreases from 0.21mm to 0.19mm. Because as the concrete strength increases, the bending stiffness of the beam's cross-section increases, which in turn reduces the beam's mid-span deflection.
4.2 Analysis of mid-span bending moment and deflection when the member yields

4.2.1 Analysis of mid-span bending moment at yield

As shown in Figure 6, Figure 7 shows the stress cloud diagram and the mid-span yield bending moment of different strength basic magnesium sulfate cement concrete beams. It can be seen from the figure that the change of the mid-span bending moment value at yielding is unusually obvious with the change of the concrete grade. When the concrete grade is C20, the mid-span bending moment at yield is the smallest, which is 5.32 KN•m. When the concrete grade increases to C40, the mid-span bending moment at yield reaches the maximum, which is 10.32 KN•m. This is because basic magnesium sulfate cement concrete has better mechanical properties, and its tensile strength is about twice as large as that of ordinary concrete of the same grade. In addition, the basic magnesium sulfate cement concrete beam has good ductility when resisting bending. After the steel bar yields, the concrete height in the compression zone continues to decrease, but the basic magnesium sulfate cement concrete can still work until it is crushed. It can be seen that as the strength of concrete increases, the mid-span bending moment of the beam at yield also increases.
4.2.2 Analysis of mid-span deflection at yield

Figure 8 and Figure 9 are the deflection cloud diagrams and deflection diagrams of different strength basic magnesium sulfate cement concrete beams when yielding. It can be seen from the figure that when the beam yields, the mid-span deflection tends to increase as the strength of the basic magnesium sulfate cement concrete increases. When the concrete grade is C40, its deflection is the largest, which is 1.51mm. As the strength of concrete increases, the ability of the concrete part in the compression zone of the beam to resist deformation decreases, and the deflection of the concrete beam is greater when it yields.

5. Conclusion

In this paper, ANSYS finite element simulation is used to analyze the flexural performance of different strength basic magnesium sulfate cement concrete. The research results show:

(1) As the grade of basic magnesium sulfate cement concrete increases, the mid-span bending moment of the initial crack gradually increases; when the concrete grade reaches C60, the mid-span bending moment increases the most, which is 22.6%.

(2) As the grade of basic magnesium sulfate cement concrete increases, the deflection in the middle
span of the initial crack gradually decreases; as the strength of the concrete increases, the bending stiffness of the beam's section increases and the deflection decreases.

3) As the grade of basic magnesium sulfate cement concrete increases, the mid-span bending moment at yield gradually increases; when the concrete grade increases to C40, the mid-span bending moment at yield reaches the maximum, which is 10.32 KN•m.

4) As the grade of basic magnesium sulfate cement concrete increases, the mid-span deflection increases as a whole when yielding; when the concrete grade is C40, its deflection is the largest, 1.51mm.

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