The Bearing Capacity of The Recycled Concrete Two-Way Composite Slab Tests

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Abstract. In this paper, recycled aggregate from waste concrete is used as coarse aggregate, and fly ash is added to replace part of cement. According to the mixture performance and 28 day compressive strength of ordinary concrete, the optimal mix proportion of recycled concrete is obtained, and then the composite plates of two materials are designed and manufactured by ourselves. By testing the compressive strength of recycled concrete and ordinary concrete, and calculating the bearing capacity of the composite plate, the results show that the recycled concrete designed in this paper has the advantages of good compressive strength, good workable slump and low cost. The composite plate has good bearing capacity in theory and meets the design requirements.

1. Introduction

Prefabricated construction with its high degree of prefabricated, convenient construction and environmental protection, economic advantage such as less pollution has been widely applied both at home and abroad and development [1]. Although the prefabricated floor has the characteristics of short construction period, the overall performance and seismic performance of the building are not good. During the earthquake disasters such as the 1994 Northridge Earthquake in the United States and the 2008 Wenchuan Earthquake in China, prefabricated buildings have various degrees of damage and collapse, so prefabricated buildings cannot be used directly in areas with high seismic intensity [2]. Cast-in-place floor slab overall performance and seismic performance is superior, but the large casting construction ways in order to fully show its advantage. Superimposed slab by precast slab and post-pouring layer, combining with the advantages of the precast floor slab and the cast-in-place floor slab are widely used in recent years and this kind of floor is becoming a hot spot of domestic and foreign scholars research, and obtained some research results. Such as xu-hong zhou and fang-bo wu developed a "PK prestressed concrete composite plate," professor jian-guo nie, such as high strength concrete composite plate is studied in this experiment, put forward the silent type pressure type steel - concrete composite slab calculation formula, improve the bearing capacity calculation method of the new type of composite slab [3]. Composite plate of different material, related research is less, through physical model experiment, this paper will be of recycled concrete and ordinary concrete composite two-way slab on the bearing capacity of related research.

2. Test materials and methods

2.1. Test materials

(1) Cement: PO42.5 ordinary portland cement, produced by Jilin Yatai Cement Co., Ltd.;
(2) Fly ash: Yanji City Class II fly ash, produced by Yanji Tienan Heating Company;
(3) Sand: Yanji City sand with a particle size of 5mm or less;
(4) Natural coarse aggregate: natural crushed stone with a particle size of less than 5-25mm;
(5) Recycled coarse aggregate: The waste concrete test block of Yanbian Prefecture Construction Engineering Quality Inspection and Appraisal Center is used for screening after crushing and sieving with a jaw crusher, and the size range of the recycled aggregate is 10-25mm;
(6) Water: ordinary tap water in Yanji City;
(7) Additives: high-efficiency polycarboxylic acid water reducer produced by Fangsheng Building Materials Co., Ltd .;
(8) Reinforcement: The reinforcement used in this test is HRB335 rebar with a diameter of 6mm purchased by Yanji City.

2.2. Test block making
The preparation process of this test piece adopts the two-time stirring method. In order to reduce the edges and corners and the old mortar wrapped in the process of crushing the recycled coarse aggregate, the first stirring time is appropriately increased [4]. The specific method is: use mechanical stirring method, first add sand and recycled coarse aggregate for 60 seconds, then add half of water and stir for 90 seconds, then add cement and fly ash for 30 seconds, and finally add the remaining water and stir for 120 seconds. After discharge, the slump of freshly mixed concrete was tested in accordance with the current standards [5] and the mechanical properties were measured in accordance with the current test methods [6]. This test produced 2 test blocks in total, each with 12 test blocks and one. The test pieces consisted of 8 cubes and 4 prisms, and were tested for compressive strength, split tensile strength, and elastic modulus.

2.3. Recycled concrete way Composite slab design
According to the literature research [7], in order to compare the experimental data, two slabs (trussed reinforced concrete laminated slabs, including one cast-in-place slab and one double-ply laminated slab) were researched. B-1 cast-in-place plate 3000mm×3600mm×120mm; B-2 double split plywood 3000mm×1800mm×120mm (two pieces) (precast layer is 60mm recycled concrete, cast-in-situ layer is 60mm ordinary concrete). The specific dimensions are shown in Figure 1:

![Figure 1](image1.png)

**Figure 1.** Floor reinforcement

3. Mix ratio design and strength test of two-way laminated floor

3.1. Mix ratio design
In this test, ordinary concrete and recycled concrete with strength class C30 were designed according to the current industry standard [8]. The specific design steps are shown in Table 1.

### Table 1. C30 general concrete mix design

| Name                           | Formula                                    | Result | Supplementary note                                      |
|-------------------------------|--------------------------------------------|--------|--------------------------------------------------------|
| Concrete trial strength       | \( f_{cu,0} = f_{cu,k} + 1.645\sigma \)    | 38.2Mpa|                                                        |
| Determine the water-to-gel ratio | \( W/B = \frac{\alpha_a f_b}{f_{cu,0} + \alpha_a \cdot \alpha_b \cdot f_b} \) | 0.46   | 1: \( \sigma \): Standard deviation of strength, value 5.0 Mpa  |
| Determine water consumption   | \( m_{w0} \)                               | 220kg  | 2: Flyash content: 5.0%, influence factor: 0.85        |
| Calculate the amount of gelling material | \( m_{b0} = m_{w0}/(W/B) \)         | 478.26kg/m³ | 3: Additive dosage: 0.75%, influence factor: 0.85 |
| Sand rate                     | \( S_p \)                                  | 43%    | 4: Recycled aggregate in the test mix needs water spray to pre-wet |
| Calculate the amount of sand  | \( m_{s0} \)                               | 796 kg/m³ |                                            |
| Calculate the amount of stones| \( m_{g0} \)                               | 1055 kg/m³ |                                            |

#### 3.2. Concrete mixture performance test

According to theoretical calculations, when the amount of cementitious material is 478.26kg / m³, and the water consumption is 220kg, the concrete appears slightly segregated, and the water-binder ratio is unchanged. At the same time, the amount of cement and water is reduced, and no segregation occurs. The slump of the concrete is 135mm, and the fluidity is excellent, meeting the initial design requirements. The adjusted mix ratio design is shown in Table 2.

### Table 2. Actual usage of each material of one cubic ordinary concrete and recycled concrete

| Number | Water (kg) | Cement (kg) | Flyash (kg) | Sand (kg) | Natural crushed stone (kg) | Recycled-aggregate (kg) |
|--------|------------|-------------|-------------|-----------|---------------------------|------------------------|
| Ordinary concrete           | 171.67     | 315         | 75.33       | 796       | 1055.33                   | No                     |
| Recycled Concrete            | 171.67     | 315         | 75.33       | 796       | 738.73                    | 316.5                  |

#### 3.3. 28d compressive strength of concrete

The concrete test block was made according to the standard model of 150mm×150mm×150mm, and it was cured in the curing room, and the compression strength of the test block was measured for 3 days, 7 days, and 28 days. The software produces the intensity-age chart as shown in Figure 2. (Unit: Mpa)

### Table 3. Compressive strength of each block

| Number | Compressive strength (Mpa) | Average compressive strength (Mpa) |
|--------|----------------------------|----------------------------------|
|        | 3d  | 7d  | 28d  | 3d  | 7d  | 28d  |
| OC-1   | 19.53 | 28.24 | 43.31 |   | 20.59 | 28.23 | 43.81 |
| OC-2   | 21.64 | 28.21 | 44.3  |   | 20.59 | 28.23 | 43.81 |
| RC-1   | 17.73 | 27.43 | 42.30 |   | 18.03 | 28.10 | 42.02 |
| RC-2   | 18.33 | 28.76 | 41.73 |   | 18.03 | 28.10 | 42.02 |
From Figure 2, it can be obtained that the compressive strength and age of C30 ordinary concrete designed in this experiment satisfy \( y = 18.02 + 1.24x \) (\( R^2 = 0.91 \)); the recycled concrete with a replacement rate of 30% meets the compressive strength and age \( y = 16.52 + 1.24x \) (\( R^2 = 0.97 \)). According to Figures 1 and 3, it can be seen that the design strength and service strength of the C30 concrete and recycled aggregate with 30% substitution rate designed in this paper meet the test requirements; in addition, the natural crushed stone large-size particles used in this test Larger, coarser coarse aggregate size has a certain effect on the strength of recycled concrete, making the strength of recycled concrete lower than ordinary concrete.

4. Calculation of bearing capacity of two-way laminated floor

In this test, the strength grade of the precast slab and cast-in-place concrete is C30, and the strength grade of the reinforcing steel is HRB400. The reinforcement arrangement in the model is shown in Figure 1. The value of the material strength is based on the design value or the value in the test. The reinforcing steel at the bottom of the transverse floor of the laminated floor is broken due to the splicing of the prefabricated board. According to China's current code [9], the calculation of the bearing capacity of the normal section of the recycled concrete laminated slab is shown in Table 4.

Based on the measured compressive strength of the recycled concrete cube, the above formula was used to calculate the axial compressive strength of the recycled concrete. If the calculated value is greater than the C30 concrete compressive strength design value given in the Code for Design of Concrete Structures (GB50010-2010), for safety calculation, the compressive strength design value of ordinary C30 concrete is \( f_c = 14.3 \text{N/m}^2 \) for calculation [10]. If the calculated value is less than the C30 concrete compressive strength design value given in the code, adjustments are required.

| 4. Calculation of bearing capacity of two-way laminated floor |  |  |  |
|---|---|---|---|
| Number | Formula | Calculation results |
| 1 | \( M_{\text{max}} \leq \alpha_1 f_c b x \left[ h_0 - \frac{x}{2} \right] \) | \( M_u = 1.0 \times 14.3 \times 1000 \times 4.76 \times \left( 102 - \frac{4.76}{2} \right) = 6.78 \times 10^6 \text{N.mm} \) |
| 2 | \( \alpha_1 f_c b x = f_y A_s \) | \( h_0 = h - 15 - \frac{6}{2} = 120 - 15 - 3 = 102 \text{mm} \) |
| 3 | \( x = \frac{f_y A_s}{\alpha_1 f_c b} \) | \( x = \frac{360}{1.0 \times 14.3 \times 1000} = 4.76 \text{mm} \) |
| 4 | \( M = \frac{1}{12} y_0 q l^2 \) | Live load-based: \( M_1 = \frac{1}{12} y_0 q l^2 = 5.583 \text{kN.m} \) |

Dead load-based: \( M_2 = \frac{1}{12} y_0 q l^2 = 6.018 \text{kN.m} \)
It can be seen from the theoretical calculations that the maximum bending moment value that the recycled concrete slab can withstand is $6.78 \times 10^6 N \cdot mm$, which is close to the maximum bending moment value that the floor slab must withstand $6.018 \times 10^6 N \cdot mm$. If conditions allow it can carry out the plate bending performance test and further carry out the test analysis of the bearing capacity.

5. Conclusions
(1) When the recycled coarse aggregate replaces 30% natural coarse aggregate and is configured for recycled coagulation, the compressive strength test results of the recycled concrete test block are analyzed with the origin software to obtain the strength of the recycled concrete-the age-fitting equation and based on The test data is compared with the formula for calculating the strength of ordinary concrete. A design formula for the strength of recycled concrete with a correction coefficient $\alpha = 0.95$ is proposed. $f_{cu,0} = (f_{cu,k} + 1.645\sigma) \cdot \alpha$

(2) The compressive strength of the recycled concrete designed in this paper is about 4% lower than that of ordinary concrete. Although the strength of the recycled concrete meets the strength design value, in order to ensure the strength of the two materials is unified when the two types of concrete are stacked, the materials of the recycled concrete can be used. Continuous grading is further optimized.

(3) According to the current "Specifications for the Design of Concrete Structures", the calculation of the bearing capacity of the normal section of the recycled concrete laminated slab is performed to meet the design requirements. However, whether the calculated value of the theoretical ultimate bending moment is consistent with the actual test value under normal load conditions remains to be studied through the measured model.

References
[1] Huang Hong, Liu Yufei, Hu Longjiang, Gu Xiaochuan(2019) Research on Construction Technology of Prefabricated Building. Architectural Technology Development, 19: 7-8.
[2] Liu Yang, Li Zhiwu, Yang Sizhong, Wang Wenjing(2019) Research Progress on Prefabricated Building Slab. Journal of Concrete and Cement Products, 01: 61-68.
[3] Su Yanjiang, Xue Shoubin(2019) Summary of development and research of superposed floor. Journal of Housing and Real Estate, 23: 22-28.
[4] Zheng Zhiyi(2017) Application Research of Prefabricated Frame Structure Recycled Concrete Wall Panel. Wuhan Engineering University Degree Thesis.
[5] Standard Test Method for Performance of Common Concrete Mixtures(2002) China Construction Industry Press(GB/T50080-2002), Beijing.
[6] Test method for mechanical properties of ordinary concrete(2002) China Construction Industry Press(GB/T50081-2002), Beijing.
[7] Zhang Xiang (2016) Research on the mechanical properties of superimposed two-way floor slabs, Degree Thesis of Anhui Jianzhu University.
[8] Design Regulations for General Concrete Mixing Rate(2011) China Construction Industry Press (JGJ55-2011), Beijing.
[9] Code for Design of Concrete Structure(2010) China Construction Industry Press(GB 50010-2010), Beijing.
[10] Wu Jin, Jiang Yehao, Wang Hao(2009) Experimental Research on Mix Proportion Design of Recycled Concrete. Journal of Low Temperature Building Technology, 02: 13-15.