Research Article

Study on the Compressive Properties and Factors of Recycled Mixture with High Content of Iron Tailings Sand

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This paper focuses on the disposal of iron tailings sand (ITS) and recycled aggregate of inorganic (RAI) and proposed the “ITS plus RAI” solid waste treatment methods, which uses ITS and RAI as a new base course material to replace new aggregates by 100% to apply in the pavement renovation project of national and provincial roads in Linfen city, Shanxi Province. In this paper, the compressive strength characteristic of recycled mixture with different ratios is studied for the dual waste treatment methods, and the influence factors are analyzed by multiple regression analysis. Results show that the strength of the recycled mixture composed of a high content of ITS (the mass ratio to RAI exceeds 60:40) ups to 7 MPa, which can meet the pavement requirements of 7d unconfined compressive strength of inorganic stabilized base material under various traffic load conditions. The factors affecting the strength of recycled materials include the content of various components, while the particle size of iron tailings sand is the most significant influence factor. Therefore, the proportion of iron tailings sand in the recycled mixture can be further improved by screening coarse iron tailings sand so as to maximize the content of iron tailings sand, which will lead to an excellent engineering value.

1. Introduction

With the rapid development of China’s highway transportation industry, the concept of sustainable development deeply rooted in people’s hearts, industrial waste residues, and other secondary resources in road construction recycling has become a new trend in the current project construction application. This technology measure can not only effectively solve the massive consumption of manpower faced in the treatment of wastes but also save resources, but it can also protect the environment, and it is an excellent environmental-friendly technology that most engineers and technicians get involved in at present.

ITS is the waste slag produced after iron ore beneficiation and is one of the huge amounts of waste in the iron and steel industry [1]. ITS is mostly in the form of fine-grained soil, and is mainly deposited in tailings ponds. According to the statistics, nearly 2 billion tons of ITS exist in China, and the annual discharge exceeds 75 million tons. The water contained in iron tailings sand is often rich in a variety of agents, and the large number and volume of tailings sandbanks not only occupy a large amount of land space and pollute the environment, but also cause chemical hazards. The comprehensive use of iron tailings in foreign countries starts early and has achieved obvious achievements in the recovery of valuable components, construction materials, road base course materials, land use, soil improvement, and other fields [2, 3]. Compared with other countries, the regenerative use of iron tailings sand in China is relatively lagging. The 2019 National Annual Report on the Prevention and Control of Solid Waste Pollution and Environment in Large and Medium-sized Cities shows that the
comprehensive interest rate of tailings in key published survey industrial enterprises in 2018 is only 27.1%, while a large number of iron tailings are not effectively reused and more are reused in construction and forestry, so pavement engineering recycling research is relatively short [4, 5].

Studies have showed that it is feasible to replace some natural sand and aggregate with ITS in some pavement engineering materials [6], and some scholars [7] have studied the crack resistance performance of semirigid pavement base course including ITS material and found that when iron tailings are used as high-grade pavement base, it should be mixed with graded gravel for improvement to meet the requirements of crack resistance. Li Hongbin [8] found that cement can stabilize low percentage ITS mixing through the study of stabilizing ITS with cement, but when the material is mixed with a larger amount of ITS, the cement demand to meet the strength requirements is also larger, which is easy to cause cracking problems such as dry shrinkage and temperature shrinkage. Pan Baofeng [9] compared the shrinkage coefficients of iron tailings sand mixtures and conventional cement-stabilized aggregate by dry shrinkage testing and found that dry shrinkage and temperature shrinkage both have an effect on the mixtures while the dry shrinkage produced a greater effect than the temperature shrinkage. Lv Shaowei [10] studied the mechanical properties and recycling of iron tailings sand and found that the particle size distribution of ITS is the main factor to determine its mechanical properties, and points out that the addition of new materials should be considered to improve the mechanical properties of iron tailings sand. Hou Rui [11] studied the mechanical properties of ITS and cement composite soil and fitted the compressive and flexural strengths as a function by Matlab software. Now, the main problem is that the replacement ratio of ITS to aggregate is only within 10%, and the utilization rate is relatively low, which makes it difficult to solve the current problem of a large amount of ITS. Recently, Dong Y and others [12] found that the new ITS and RAI mixture is feasible for pavement engineering.

Meanwhile, a large amount of RAI will be generated from repair and reconstruction projects per year, and the treatments of untreated RAI generally include using as roadbed filler or subgrade and subbase of a low-grade road or even directly discarded, and these treatments make the added value of RAI low [13]. To sum up, this paper aims at the problems faced by the reuse of ITS in pavement engineering and proposes the “ITS plus RAI” solid waste treatment method. Through its compressive strength characteristic and influence factors, the optimal ratio of the recycled mixture to meet the strength requirements of the base course under high-grade pavement with heavy-load traffic is determined.

2. Experiments

2.1. Materials. The characteristics of the recycled mixture in this paper are as follows: (1) the incorporation of a high percentage of ITS; (2) ITS and RAI as a new base course material to replace new aggregates by 100%.

2.1.1. Iron Tailings Sand (ITS). The four types of ITS selected for this study are all from Xianfen County, Linfen City, Shanxi Province, where the project is located. Currently, there are many ways to classify ITS, but in this paper, the average particle size is used, the passing percentage results are shown in Figure 1.

The finer ones are referred to as ITSF, and the coarser ones are referred to as ITSC. The four types of ITS used in this paper are shown in Figure 2, and their technical indexes are shown in Table 1.

2.1.2. Recycled Aggregate of Inorganic (RAI). The RAI used in this paper comes from the recycled material of the base course of the Linxia section of the provincial pavement in Linfen City, Shanxi Province, whose gradations are shown in Table 2.

Considering that there are no relevant standards for this mixture with this high content of ITS in this paper, there is no reference for adjustment of the gradation. The coarse aggregate of RAI accounts for 56.2%, and the measured crushing value reaches 25.8%. The sand-equivalent reaches 75%, which proves that RAI has good cleanliness. Considering the previous maintenance project in the Linxia section, compared with the water absorption of RAI in different sections, and the results show that the difference is not significant, so the problem of unstable water content caused by the difference of water absorption is not under consideration in this paper.

2.1.3. Curing Agent. The curing agent used is provided by Nanjing Runcheng Traffic Science Research Institute Co. and produced by Henan Xin Run Cheng Traffic Material Technology Co. Its technical indexes are shown in Table 3 and Table 4.

2.2. Preparation Method. Before test, ITS and RAI are dried in an oven to constant weight at 105 °C and then cooled. After weighing the ITS and RAI, add the quantitative water, and mix by the manual for 2–3 mins until no ash. Then put the whole pot into a plastic bag and seal infiltration, and the infiltration time is not less than 4h. Add the curing agent before forming the specimens, and then mix annually for 2–3 mins. The forming speed is 10 mm/min, and the states of the recycled mixture before and after mixing are shown in Figure 3.

2.3. Experimental Plan and Test Methods. This paper intends to maximize the utilization of iron tailings sand under the strength design requirements. The compressive strength characteristic of the recycled mixture is studied through the unconfined compressive strength testing under different ratios. Considering that the recycled mixture belongs to the inorganic bonding material, the compaction test (moisture content from 7% to 11% with a gradient of 1%) and unconfined compressive strength test in this section refer to the relevant test requirements of the Test Methods of Materials Stabilized with Inorganic Binders for Highway Engineering.
Figure 1: Passing percentage results.

Figure 2: Four types of ITS.

Table 1: Technical indexes of ITS.

| Project name | Nature water content (%) | Apparent density (g/cm³) | Water absorption (%) | Cr (%) | Pb (%) |
|--------------|--------------------------|--------------------------|----------------------|--------|--------|
| ITSF1        | 14.4                     | 2.91                     | 3.6                  | 0      | 0      |
| ITSF2        | 13.7                     | 2.94                     | 3.5                  | 0      | 0      |
| ITSC1        | 6.4                      | 2.90                     | 3.1                  | 0      | 0      |
| ITSC2        | 7.5                      | 2.84                     | 3.2                  | 0      | 0      |

Table 2: RAI gradation.

| Sieve size (mm) | 26.5 | 19 | 16 | 13.2 | 9.5 | 4.75 |
|-----------------|------|----|----|------|-----|------|
| Passing percentage (%) | 100 | 97.0 | 92.2 | 86.9 | 63.7 | 43.8 |
| Sieve size (mm) | 2.36 | 1.18 | 0.6 | 0.3 | 0.15 | 0.075 |
| Passing percentage (%) | 23.2 | 14.5 | 7.7 | 3.3 | 1.4 | 0.5 |

Table 3: Technical Indexes of Curing agent.

| Apparent density (g/cm³) | Specific surface area (m³/kg) | Setting time (min) | Compressive strength of 7 days (MPa) | Rupture strength of 7 days (MPa) | Compressive strength of 28 days (MPa) | Rupture strength of 28 days (MPa) |
|--------------------------|-------------------------------|-------------------|-------------------------------------|---------------------------------|-------------------------------------|---------------------------------|
| 2.85                      | 350                           | 246               | 31.9                                | 6.7                             | 61.2                                | 8.8                             |
The compressive strength tests are conducted at 4%, 6%, 8%, and 10% (external mixing, it is curing agent/(ITS plus RAI)) curing agent mixing content, and ITS and RAI contain at ratios of 50%:50%, 60%:40%, and 70%:30%.

2.3.1. Heavy Compaction Test. In this paper, a heavy compaction test is used to determine the optimum water content (OWC) and maximum dry density (MDD) of the recycled mixture, according to the Test Methods of Materials Stabilized with Inorganic Binders for Highway Engineering T 0804–1994 (JTGE51-2009), the compaction test apparatus is shown in Figure 4, the hammer weight is 4.5 kg, the drop distance is 45 cm, and the compaction is done in three layers and the number of times each layer is 98.

2.3.2. Unconfined Compressive Strength Test. Based on the results of the compaction test, 150 mm × 150 mm cylindrical specimens are formed under the OWC by 2000 kN Press Machine (Figure 5) at a loading speed of 10 mm/min. Raise in a standard room at a temperature of 20 ± 2 °C and relative humidity of 95% for 6 days, after immersing in water for 24 hours. Determine its unconfined compressive strength by Pavement Material Strength Tester (Figure 6) at a loading speed of 1 mm/min.

3. Compressive Strength Characteristic

3.1. Effect of Curing Agent Content. The test data shows that the compaction test results of recycled mixture with different ratios are the same and the difference of data is very small, so this subsection selects ITS to RAI ratio of 50%:50% as an example for analysis. The heavy compaction test results are shown in Table 5.

The test results show that, with the increase of curing agent content, the OWC and MDD of the four types of recycled mixtures showed an increasing trend but not significant. The more curing agents, the more hydration products, which makes the ITS and RAI combine more closely during compaction, so the MDD of the recycled mixture increases. On the other hand, among the four types of iron tailings sands, ITSF has more fines particles and the
water absorption rate is greater than the coarser, so the OWC of ITSF is bigger than ITSC at the same ratio. Meanwhile, the test results of ITSF1 and ITSF2, ITSC1 and ITSC2 are similar, so ITSF1 and ITSC1 are chosen to represent the different thicknesses of iron tailings sand for the study of compressive strength characteristics.

Form cylindrical (Φ150 × 150 mm) samples under the OWC and using the unconfined compressive test to determine the optimum mix ratio. The results are shown in Figure 7.

The unconfined compressive test results show that the more curing agent content, the more hydration products which make the ITS and RAI combine denser, and the 7d unconfined compressive strength of both types of the recycled mixture increase with the increase of curing agent content. For ITSC1 recycled mixture (referred to as recycled mixture A), the strength grows rapidly with an average rate of 40% within the range of 4%–8% of curing agent content, and after the content exceeds 8%, the strongest growth rate slows down with an average growth rate of only 15%; while for ITSF1 recycled mixture (referred to as recycled mixture B), the growth rate of 8%–10% of curing agents content (about 40%) is greater than the growth rate of 4%–8% (about 30%).

On the other hand, the compressive strength of recycled mixture A is significantly higher than that of recycled mixture B under the same content of curing agents. Due to the better angularity of the coarse iron tailings sand compared with the fine iron tailings sand, according to Moore’s Coulomb theory, it will form a better embedding and crowding in the structure.

### 3.2. Effect of ITS Particle Size and Content.

Using the ITS content as the horizontal coordinate, the unconfined compressive strength results of the two recycled mixtures with different ratios are shown in Figure 8.

From Figure 8, under a certain amount of curing agent content, the unconfined compressive strength decreases with the increase of iron tailings sand content. It can be seen from the downward trend that for every 10% increase of iron tailings sand content, the decline rate of recycled mixture A under different curing agent content (about 10%) is smaller than that of recycled material B (about 20%). At the same time, the strength of recycled mixture A is 30%–60% higher than recycled mixture B under the same ratio. And the higher the ITS content is, the strength difference is more obvious. It is thought that mainly by the particle size of iron tailings sand, the finer the ITS, the larger the specific surface area. And under the same curing agent content, that is, when the hydration products are certain, the finer the ITS and the higher the content is more difficult to stabilize, resulting in a faster decline in strength. Compared with subsection 2.1, the thickness of ITS has the greatest influence on the field performance of this kind of mixture, followed by the content.

### Table 5: Compaction test results.

| Mixture proportion | Optimum water content (%) | Maximum dry density (g/cm³) |
|--------------------|---------------------------|-----------------------------|
|                    | 4  | 6  | 8  | 10 | 4  | 6  | 8  | 10 |
| ITSF1              | 9.32 | 9.38 | 9.51 | 9.63 | 2.117 | 2.123 | 2.128 | 2.133 |
| ITSF2              | 9.23 | 9.31 | 9.47 | 9.58 | 2.115 | 2.124 | 2.131 | 2.137 |
| ITSC1              | 9.08 | 9.20 | 9.27 | 9.38 | 2.077 | 2.082 | 2.089 | 2.096 |
| ITSC2              | 9.13 | 9.32 | 9.41 | 9.50 | 2.072 | 2.080 | 2.086 | 2.091 |

Figure 5: 2000 kN press machine.

Figure 6: Pavement material strength tester.

Figure 7: 7d unconfined compressive test results in different curing agent contents.

Figure 8: Effect of ITS particle size and content.
of curing agents, and the amount of ITS has the least influence.

According to the Specifications for Design of Highway Asphalt Pavement JTGD50-2017, the 7d unconfined compression strength requirement of inorganic binders stabilized base course materials under the secondary road with heavy-load traffic is 3~5 MPa. The mix ratio of ITS to RAI at 70%:30% in both recycled mixtures can meet the specification requirements, which recycled mixture A in the curing agent content of 6% when its strength is close to the normative representative value of the upper limit. Recycled material B with the curing agent content of 8% can get no more than 3 MPa, so the ratio 60%:40% of fine-grained ITS and RAI under 8% of curing agent is chosen to be the best.

3.3. Strength Increasing Characteristic. Taking recycled mixture B as an example, Figure 9 shows the unconfined compressive strength test results of each recycled mix at 8% of curing agent at the age of 3, 7, 14, 28, and 90d. The following conclusions can be drawn from the analysis of the test results.

From Figure 9, the compressive strength of the recycled mixture grows fastest from 3d to 7d. After 28d, the trend gradually slows down. The compressive strength of the three ratios of recycled mixtures at 7d of age reaches about 80% of the compressive strength at 90d of age, indicating that the curing agent can promote the rapid formation of early strength for the recycled mixture. Combined with Figure 7, the compressive strength of the recycled mixture can reach 7 MPa, which shows good compressive properties. Through adjusting the composition, we can obtain the different recycled mix ratios to meet the requirements of different load conditions of each grade of design strength.

4. Regression Analysis

The above study shows that the degree of thickness of ITS, blending ratio, and the content of the curing agent have some influence on the compressive strength of the recycled mixture. In this subsection, based on the results of the above study, we use SPSS 26.0 statistical software to conduct multiple linear regression analysis on the factors affecting the compressive strength, and then the degree of influence of each factor on the compressive strength is studied, and the conclusions in subsection 2.2 are verified.

4.1. Model Building. Suppose the dependent variable and the independent variable \( x_1, x_2, \ldots, x_{n-1} \) have a total of \( n \) sets of data, \( y \) is an observable random variable, which is affected by \( n-1 \) nonrandom factors and a random factor \( \varepsilon \). Suppose \( y \) and \( x_1, x_2, \ldots, x_{n-1} \) have the following linear relationship:

\[
y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_{n-1} x_{n-1} + \varepsilon. \tag{1}
\]

In the formula, \( y \) is the dependent variable, \( x_1, x_2, \ldots, x_{n-1} \) is the independent variable, \( \beta_0, \beta_1, \beta_2, \ldots, \beta_{n-1} \) is the unknown parameter, and \( \varepsilon \) is an error term, usually assumed \( \varepsilon \sim (0, \sigma^2) \) [14].

In this paper, the independent variable \( x_1 \) is the thickness of tailings (ITSC:1.9, ITS:1.0), the independent variable \( x_2 \) is the blending ratio of iron tailings sand (50%, 60%, 70%), the independent variable \( x_3 \) is the content of curing agents (4%, 6%, 8%, 10%), and the dependent variable \( y \) is compressive strength.

4.2. Model Validity Test. The F-test is a direct test of the significance of the regression equation from the regression effect based on the squared and decomposed equation, and the F-test has intuitive, precise properties [15]. In this paper,
Table 6: ANOVA results.

| Model | S2  | DF  | F  | P-value |
|-------|-----|-----|----|---------|
| A     | 80.219 | 3   | 26.740 | 0.001 |
| E     | 4.814   | 20  | 0.241 |
| T     | 85.033 | 23  |

The F-test is used to test the model, and the results of the regression ANOVA are shown in Table 6. By checking the F-test critical value table, (α = 0.05) shows that the critical value of F in this paper is 11.186 (much less than 111.086), which indicates that the model is valid.

In Table 6, S2 means the sum of squares, DF means the degree of freedom, 3 2 means mean-square deviation, P-value is used a significance test.

Table 7: Regression coefficient results.

| Model | B   | e   | Beta | T-value | P-value | CS |
|-------|-----|-----|------|---------|---------|----|
| C     | 0.682 | 0.459 | 1.485 | 0.153   | 1.000   | 1.000 |
| x1    | 1.749 | 0.200 | 0.465 | 8.733   | <0.001  | 1.000 |
| x2    | -731  | 0.123 | -0.317 | -5.957  | <0.001  | 1.000 |
| x3    | 1.333 | 0.090 | 0.792 | 14.883  | <0.001  | 1.000 |

The VIF values of all variables in this paper are 1 (between 0 and 5), indicating that there is no problem of multicollinearity between the variables and that the data can be further analyzed. The regression coefficient table shows that the p-values are all smaller than 0.05 (less than 0.05), indicating that all three factors have a significant effect on the dependent variable. According to the regression results, the fitted equation is shown in the following equation:

\[ y = 0.682 + 1.749x_1 - 0.731x_2 + 1.333x_3. \]  

The larger the absolute value of the nonstandardized coefficient B, the greater the impact on the dependent variable. From formula (2), it can be seen that the particle size of iron tailings sand has the greatest influence on the strength of the recycled mixture, followed by curing agent content, and iron tailings sand content has the least influence, which is consistent with the conclusion of subsection 2.2. Therefore, in the actual engineering application of iron tailings sand recycled mixture, attention should be paid to the relationship between the particle size of iron tailings sand and the blending ratio. Using larger particle size of iron tailings sand can appropriately increase the proportion so that to improve its regeneration utilization rate under the strength requirements.

5. Conclusions

In this paper, the compressive strength characteristic and the influence factors are discussed through the unconfined compressive strength test, and the strength influence factors are analyzed and evaluated by multiple regression analysis. The main conclusions are as follows.

1. The recycled mixture has good compressive strength. The strength characteristics of the recycled mixture with high content of iron tailings sand are determined by the content of the curing agent, the particle size of iron tailings sand, and the mixing proportion. The compressive strength increases with the increased content of the curing agent and decreases with the increased content of iron tailings sand. And the coarser the particle size, the higher compressive strength the recycled mixture is. The test results based on multiple regression analysis show that the key factor affecting the strength of recycled material is the particle size of ITS, while the content has the least influence. Therefore, the proportion of ITS in the recycled mixture can be improved by screening coarse iron tailings sand.

2. Under the condition of a certain amount of curing agent, the recycled mixture (with ITS and RAI mass ratio more than 60%;40%) can meet the 7d strength requirements of the base course of high-grade pavement with heavy-load traffic, which indicates that the recycled mixture can effectively reuse the iron tailings sand and improve its utilization rate in the project under the strength requirement.

In this paper, only the compressive strength characteristic of the recycled mixture is investigated, and other mechanical properties of recycled mixture and road properties, especially shrinkage, need to be further studied.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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References

[1] A. P. Liu, M. Cao, and X. Zhang, “The research status of large-scale utilization of iron tailings and its utilization methods,”
[2] J. Carvalho Izidoro, M. C. Kim, V. F. Bellelli et al., “Synthesis of zeolite A using the waste of iron mine tailings dam and its application for industrial effluent treatment,” Journal of Sustainable Mining, vol. 18, no. 4, 2019.

[3] B. C. Gayana and K. R. Chandar, “Sustainable use of mine waste and tailings with suitable admixture as aggregates in concrete pavements-A review,” Advances in concrete construction, vol. 6, no. 3, p. 221, 2018.

[4] Y. Y. Zeng, J. Pan, and X. Yang, “Application of iron tailings in road base materials,” Applied Chemistry, vol. 47, no. 02, pp. 358–364, 2018.

[5] C. Hu, S. Weiguo, S. Lai et al., “Situation of discharge and comprehensive utilization of iron railings domestic and abroad,” Concrete, no. 2, pp. 88–92, 2012.

[6] W. Liu, Y. Zhang, and S. Li, “Research on the influence of iron tailings sand on the performance of machined sand concrete,” Concrete and Cement Products, no. 12, pp. 84–86, 2020.

[7] W. Jiang, Research on the Strength Mechanism of Inorganic Binder Iron Tailings and the Optimization Design Application to the Base Layer[D], Harbin Institute of Technology, Harbin, 2018.

[8] H. Li, "Research on the Influence of Iron Tailings on the Performance of Cement Stabilized Crushed Stone Base Course," Highway, vol. 12, 2014.

[9] B. F. Pan, H. Y. Shi, and C. H. Zhou, “Experimental research on shrinkage properties of cement stabilized iron tailings sand mixture,” Applied Mechanics and Materials, vol. 423, 2013.

[10] S. Lu, P. Jiang, and B. Qian, "Research Progress on Mechanical Properties and Recycling of Iron Tailings Sand," Bulletin of the Chinese Ceramic Society, vol. 39, no. 2, pp. 466–470+512, 2020.

[11] R. Hou, S. Chen, and M. Xiao, "Study on the mechanical properties of iron tailing sand cement composite soil," China & Foreign Highway, vol. 39, no. 1, pp. 206–209, 2019.

[12] Y. Dong, H. Zhang, Y. Hou, Z. Qian, and J. Tian, "Study on mechanical properties of recycled mixture with high content of iron tailings sand," Advances in Materials Science and Engineering, vol. 2021, Article ID 7658444, 11 pages, 2021.

[13] F. Luxin, Study on Strengthening Treatment and Application of Cement Stabilized Aggregate Milling Material, University of Technology, Shandong, China, 2019.

[14] X. F. Qi, "A multiple linear regression model representing defensive driving technology and emotional intelligence improvement," Highway and Transportation Science and Technology, vol. 37, no. 6, pp. 151–158, 2020.

[15] W. M. Liu, L. P. Guan, and X. Y. Yin, “Prediction of incident duration based on multiple regression analysis,” Highway Traffic Science and Technology, vol. 22, no. 11, pp. 130–133, 2005.