Experimental Study on Uniaxial Compressive Strength of Concrete Incorporated with Cigarette Butts

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Abstract. Mixing cigarette butts into concrete to reduce the urban heat island effect caused by concrete while dealing with cigarette butts waste, the possibility of "one stone catches two birds" provides a new idea for urban environmental protection. The influence of cigarette butts content on the mechanical properties of concrete needs to be studied. The cigarette butts are cleaned and dried, then sealed and hardened by paraffin wax. Cigarette butts are mixed into concrete cubic block according to the content of 0kg/m³, 5kg/m³, 7.5kg/m³, 10kg/m³, 12.5kg/m³, 15kg/m³ and 20kg/m³ respectively. The cubic uniaxial compression test is carried out. With the increase of cigarette butts content, the concrete strength decreased continuously, if the cigarette content is not exceed 10kg/m³, the reduction of strength is slow, and the maximum strength loss is 13%. If the cigarette content is larger than 10kg/m³, the strength reduces faster, when the cigarette butt content achieves 20kg/m³, the strength loses 30%. For the concrete with no cigarette, it crushes into many pieces, with the increase of content of cigarette butts, the failure pattern shows better ductility.

1. Introduction

There are about 6 billion cigarettes a year in the world, forming 1.2 million tons of cigarette butts rubbish. As the global population increases, cigarette butts will have increased by more than 50% by 2025. Cigarette butts are made from cellulose acetate, a plastic type of material taken from wood. When smoking, the filter absorbs toxic substances such as cadmium, arsenic, zinc, iron and copper. Once the filter is discarded and exposed to water, the metal will be released into the environment, but will not decompose itself. Therefore, cigarette butts bring serious environmental problems to the Earth.

Urban heat island effect refers to the city due to a large number of artificial fever, buildings and roads and other factors such as high heat storage and green space, resulting in the city "high temperature". The city's temperature is significantly higher than the surrounding suburbs. The bedding of buildings and roads is made of concrete which constitute masonry, cement and asphalt. The concrete bedding has larger thermal capacity and larger thermal conductivity than the natural bedding in the suburbs. And concrete also has lower sun reflectivity but larger absorption rate than natural bedding. Therefore, the concrete absorbs more than 2000 times the heat of air. During the daytime, the surface temperature of the urban cushion is much higher than air temperature, such as the asphalt pavement and roof temperature can exceed 8°C~17°C. The impact of global warming can be reduced by using poorly thermally conductive paving materials.

Dr. Mohajerani of the RMIT university has put cigarette butts into clay bricks[1] and asphalt concrete[2]. His study found that using cigarette butts and asphalt to pave the road, not only can solve
the environmental pollution caused by cigarette waste, but also play a role in reducing the city temperature. His idea provides a solution to the problem of the treatment of cigarette butts and the mitigation of urban heat island effect. The reuse of cigarette butts has opened a new situation for both the environment and urban construction. It is of great significance to study the influence of cigarette butts on the mechanical and thermal properties of concrete.

A lot of studies on adding fiber in concrete to improve concrete properties have been carried out, such as adding basalt fiber [3-5], steel fiber [6], glass fiber [7], polypropylene fiber [8], carbon nanofibers [9], mixed fiber [10], etc.

In this paper, the cigarette butts are cleaned and then completely sealed and hardened by immersion in the paraffin liquid. Concrete cubes are made by adding cigarette butts into the concrete with different content. Then the concrete cubes are maintained under constant temperature and humidity for 28 days. The uniaxial compressive strength tests of concrete cubes are carried out for analyzing the effect of cigarette butts content on the uniaxial compressive strength of concrete. At the same time, different failure forms of concrete with different content of cigarette butts are compared.

2. Materials and preparation

2.1. Materials used for prepare concrete
The materials used for prepare concrete are listed as follows.

- **Cement**: Portland cement 42.5 (P.O 42.5)
- **Coarse aggregates**: using crushed stone, washing before use, the diameter is 5~20mm with continuous gradation.
- **Sand**: medium sand, the fineness modulus is 2.6.
- **Cigarette butts**: collected in Xi’an city.
- **Paraffin**: Kunlun No. 58th refined granule paraffin.
- **Concrete mix ratio**: cement, 400kg/m³; water, 180kg/m³; sand, 601kg/m³; coarse aggregates, 1219kg/m³; ratio of water to cement, 0.45.

2.2. Sample preparation steps
(1) Remove the residual tobacco from the cigarette butts and then dry to get the cigarette butts sample shown in Figure 1.

(2) After heating the wax to 50 degrees, pour the cigarette butts into the paraffin liquid, stir evenly, then cool, get the sealed and hardened cigarette butts as shown in Figure 2.

(3) In accordance with the "normal concrete mechanical properties test method standard GB/T 50081-2002" specification requirements for the preparation of concrete specimens, after the initial stirring to add cigarette butts, as shown in Figure 3. Further to fully stir evenly, the concrete into the mold, as shown in Figure 4. Then the mold is shaken by shaking table. When the shaken is finished, the sample is prepared as shown in Figure 5.

(4) The finished specimen is maintained by a standard maintain box for 28 days, and the specimen after demoulding is shown in Figure 6.
Figure 3. Mixing cigarette butts into concrete

Figure 4. Concrete in the mold

Figure 5. Concrete after shaken

Figure 6. Cubic specimen of concrete

The dimension of cubic specimen is 100mm×100mm×100mm. The contents of cigarette butts added into the concrete are 0kg/m³, 5kg/m³, 7.5kg/m³, 10kg/m³, 12.5kg/m³, 15kg/m³ and 20kg/m³. Every content has 3 cubic specimens. There are 21 specimens in total as shown in Table 1.

Table 1. The content of cigarette butts

| No. Of cubic specimen | Content of cigarette butts (kg/m³) |
|-----------------------|-----------------------------------|
| A1, A2, A3            | 0                                 |
| B1, B2, B3            | 5                                 |
| C1, C2, C3            | 7.5                               |
| D1, D2, D3            | 10                                |
| E1, E2, E3            | 12.5                              |
| F1, F2, F3            | 15                                |
| G1, G2, G3            | 20                                |

3. Uniaxial compression test

3.1. Test of cubic specimen

The uniaxial compression test is carried out after the completion of maintenance by using universal testing machine as is shown in figure 7. The results of uniaxial compression test are shown in table 2.

Figure 7. Uniaxial compression test of concrete cubic
Table 2. Results of uniaxial compression test

| No. of specimen | Ultimate load/kN | Compressive strength/MPa | Strength assessment/MPa |
|-----------------|------------------|--------------------------|------------------------|
| A1 1            | 296.33           | 29.3                     |                        |
| A2 2            | 304.34           | 30.4                     | 29.3                   |
| A3 3            | 324.84           | 32.5                     |                        |
| B1 4            | 295.26           | 29.5                     |                        |
| B2 5            | 285.09           | 28.5                     | 27.8                   |
| B3 6            | 298.35           | 29.8                     |                        |
| C1 7            | 280.89           | 28.1                     |                        |
| C2 8            | 269.66           | 27.0                     | 26.1                   |
| C3 9            | 272.95           | 27.3                     |                        |
| D1 10           | 273.24           | 27.3                     |                        |
| D2 11           | 262.10           | 26.2                     | 25.5                   |
| D3 12           | 269.25           | 26.9                     |                        |
| E1 13           | 229.75           | 23.0                     |                        |
| E2 14           | 245.36           | 24.5                     | 23.5                   |
| E3 15           | 264.75           | 26.5                     |                        |
| F1 16           | 228.10           | 22.8                     |                        |
| F2 17           | 213.70           | 21.4                     | 20.9                   |
| F3 18           | 218.90           | 21.9                     |                        |
| G1 19           | 221.90           | 22.2                     |                        |
| G2 20           | 209.80           | 21.0                     | 20.4                   |
| G3 21           | 212.25           | 21.2                     |                        |

The relationship between the concrete cube compressive strength with the content of cigarette butts is shown in Figure 8. As can be seen from the figure, with the increase in the amount of cigarette butts, concrete strength continued to reduce. When the content of cigarette butts is not more than 10kg/m³, the reduction of strength is slow, the maximum strength loss is 13%. Wherein when the content of cigarette butts if 5kg/m³, the strength loses only 5%. When the content of cigarette butts is greater than 10kg/m³, the strength decreases rapidly. When the content of cigarette butts reaches 20kg/m³, the strength loses 30%. For the contents of 15kg/m³ and 20kg/m³, the strength losses are equal. It can be concluded that if the content of cigarette butts is less than 5kg/m³, the influence of cigarette butts to the strength of the concrete is not strong, whereas the content of cigarette butts is larger than 15kg/m³, the strength of the concrete is reduced obviously.

Figure 8. The relationship between compression strength and the content of cigarette butts

3.2. Load-displacement curve

Fig. 9 shows the relationship between the uniaxial compression strength with different cigarette butts content. It can be seen from the figure that the load-displacement curve of concrete with cigarette is consistent with the load-displacement curve of the normal concrete. With the increase of the amount of
cigarette butts, the maximum load of concrete can be reduced gradually, and the maximum load corresponding displacement decreases. At the same time with the increase of cigarette butts content, the softening of concrete after the peak shows a stronger ductility, indicating that cigarette butts enhance the plastic behavior of concrete.

3.3. Failure pattern

Figure 10 shows the failure pattern of concrete cubes for different cigarette butts content. As can be seen from the figure, for the concrete cubic without cigarette butts, a large number of pieces cracked. With the increase in the content of cigarette butts, the integrity of the concrete in the destruction is still better, showing a better ductility, only a small amount of peeling debris.

4. Conclusions

The cigarette butts are cleaned and then sealed and hardened by paraffin. Add cigarette butts according to the content of 0kg/m$^3$, 5kg/m$^3$, 7.5kg/m$^3$, 10kg/m$^3$, 12.5kg/m$^3$, 15kg/m$^3$, 20kg/m$^3$ into concrete, then the uniaxial compression test of concrete cube is carried out. The following conclusions are obtained.

1) With the increase in the amount of cigarette butts, the strength of concrete continues to decrease, if the content of cigarette butts is less than 10kg/m$^3$, the strength decreases slowly, and the maximum strength loses 13%. If the content of cigarette butts is greater than 10kg/m$^3$, the strength decreases faster, once the content of cigarette butts reaches 20kg/m$^3$, the strength loses 30%.
(2) After adding cigarette butts, the load-displacement curve of concrete is consistent with the load-displacement curve of the normal concrete. With the increase of the amount of cigarette butts, the maximum load of concrete can be reduced gradually, and the maximum load corresponding displacement decreases. And with the increase of cigarette butts content, the softening of concrete after the peak shows a stronger ductility, indicating that cigarette butts enhance the plastic behavior of concrete.

(3) For the concrete cubic without cigarette butts, a large number of pieces cracked after failed. With the increase in the content of cigarette butts, the integrity of the concrete in the destruction is still better, showing a better ductility, only a small amount of peeling debris.

In this paper, cigarette butts are mixed into concrete, and the effect of cigarette butts on concrete cubic compression strength is studied. The effect of cigarette butts on the concrete mechanical properties, thermal properties and durability need to be further studied in order to comprehensively evaluate the effect of cigarette butts on concrete.

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