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Effect of fiber on mechanical properties of cement stabilized macadam mixture

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Effect of fiber on mechanical properties of cement stabilized macadam mixture

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Abstract: In order to improve the crack resistance of semi-rigid base materials, polyester fiber（PET）, polypropylene fiber（PP）, polyacrylonitrile fiber（PAN） and polyvinyl alcohol fiber（PVA） were selected to prepare cement-stabilized crushed stone mixture. The mechanical properties of fiber-cement stabilized crushed stone mixture were studied by unconfined compressive strength, splitting strength and compressive rebound modulus tests. The results show that the fiber can effectively improve the compressive strength and splitting strength of cement-stabilized crushed stone mixture when the fiber content is 0.05%-0.11%, and both the compressive strength and splitting strength of the mixture increase with the increase of fiber content. The compressive strength and splitting strength of the mixture with the same fiber and dosage showed a trend of slow growth first, then rapid growth, and then gentle growth during the curing period of 90d. Adding PET, PP and PAN reduced the compressive resilience modulus of cement-stabilized macadam mixture, while adding PVA increased the compressive resilience modulus of cement-stabilized macadam mixture.

1. Introduction

Cement-stabilized machetes are commonly used materials for semi-rigid base, which have the advantages of high strength, high stiffness and good integrity[1][2]. However, the practical engineering application shows that the semi-rigid base material is brittle and easy to produce dry shrinkage and warm shrinkage cracks, which leads to the penetrating crack of the base, and finally leads to the early destruction of the pavement. Therefore, how to effectively improve the crack resistance of semi-rigid base material is the key to improve the service quality and life of semi-rigid base asphalt pavement[3][4].

In recent years, referring to the successful experience of adding fiber to cement concrete to improve its mechanical properties, the study of adding fiber to asphalt mixture to improve its road performance has attracted widespread attention of highway workers. However, at present, there are few studies on the road performance of fiber-cement stabilized gravel base materials at home and abroad. Therefore, it is of great economic benefit and social value to study the performance of fiber-semi-rigid base materials[5].

In view of this, this paper selects four different kinds of fibers to prepare cement-stabilized crushed stone mixture, and uses unconfined compressive strength, splitting strength, compressive rebound modulus and other tests to study the mechanical properties of cement-stabilized crushed stone mixture, and analyzes and discloses the influence law of fibers on the mechanical properties of cement-stabilized crushed stone mixture.

2. Test

2.1. Main Raw materials

Ordinary Portland cement P·O42.5, product of Nanjing Zhonglian Cement Co., LTD., initial setting time 225min, final setting time 430min; Limestone aggregate, particle size of 19-31.5mm, 9.5-19mm, 9.5-4.75mm, 2.36-4.75mm, 0-2.36mm, aggregate quality are in line with JTG F20-2015 specification requirements; Polyester fiber（PET）, product of Shandong Taian Lingzhong Composite Material Co., LTD., length 19mm, equivalent diameter 25μm; Polypropylene fiber（PP）, product of Shandong Taian Lingzhong Composite Material Co., LTD., length 12mm, equivalent diameter 30μm; Polyacrylonitrile fiber（PAN）, manufactured by Nanjing Staibao Trading Co., LTD., length 6mm, equivalent diameter 12μm; Polyvinyl alcohol fiber（PVA）, manufactured by Jinan Haojie Trade co., LTD., length 12mm, equivalent diameter 25μm[6].

2.2. Main equipment and instruments

Microcomputer control constant stress and pressure testing machine (YAW-300YD) and microcomputer control electro-liquid servo universal testing machine are jinan Zhonglu Chang testing machine manufacturing Co., LTD.

2.3. Preparation of cement stabilized macadam mixture

According to the "Highway Engineering Inorganic Binder Stable Material Test Procedures" (JTG E51-2009) T0843 mixing molding, and in accordance with the regimen method of T0848 specimens regimen. The mineral ratio is 19-31.5mm: 9.5-19mm: 9.5-4.75mm: 2.36-4.75mm: 0-2.36mm=15:29:20:7:29, the cement dose is 4.0%, and the fiber content is the volume content of the mixture.

2.4. Performance Test

For unconfined compressive strength, follow T0805 in JTG E51-2009. Indirect tensile strength, as per T0806 in JTG E51-2009. The springback modulus of compression was carried out according to the T0808 top surface method in JTG E51-2009.[7][8].

3. Results and discussion

3.1. Analysis of unconfined compressive strength

An experimental study was conducted on the unconfined compressive strength at the three curing ages of 7d,28d and 90d, as shown in the figure below.

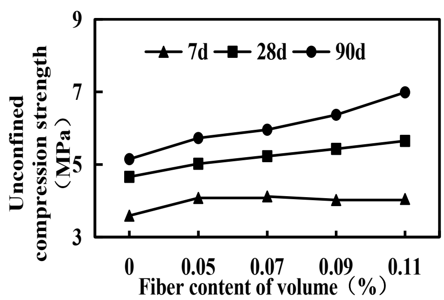

Figure 1. Unconfined compressive strength test results of PET - doped cement stabilized macadam mixture

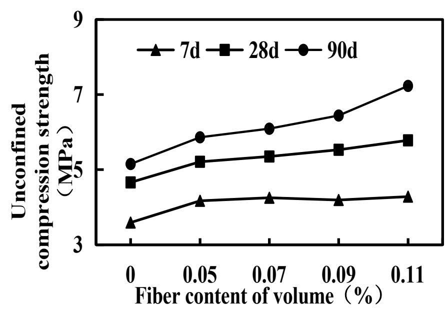

Figure 2. Unconfined compressive strength test results of PAN - doped cement stabilized macadam mixture

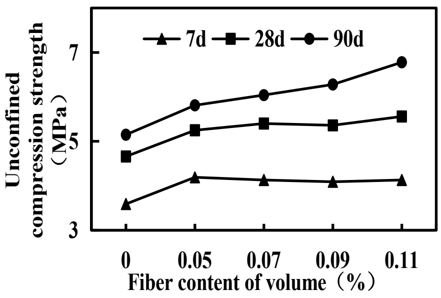

Figure 3. Unconfined compressive strength test results of PP - doped cement stabilized macadam mixture

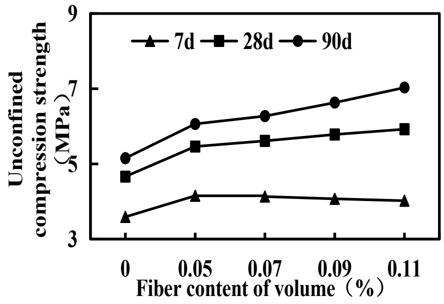

Figure 4. Unconfined compressive strength test results of PVA - doped cement stabilized macadam mixture

The results above show:

(1) With the increase of fiber content, the 7d strength of the mixture does not increase significantly. When the curing age is 28d and 90d, the unconfined compressive strength of the cement-stabilized crushed stone mixture increases gradually with the increase of fiber content. Taking polyvinyl alcohol fiber as an example, the unconfined compressive strength of fiber-cement stabilized macadam mixture with 7d curing age increased by 15.6%, 15% and 12%, respectively, when the fiber content was 0.05%, 0.07% and 0.11%, respectively. The unconfined compressive strength of the fiber-cement stabilized macrubble mixture with curing age of 28 days increased by 17.2%, 20.4% and 27%, respectively, and that of the fiber-cement stabilized macrubble mixture with curing age of 90 days increased by 17.7%, 21.7% and 36.5%, respectively.

(2) The unconfined compressive strength of four kinds of fiber-doped cement-based stabilized macadam showed an increasing trend with the increase of the curing age. Under the condition of the same fiber content, the compressive strength of cement-based stabilized macadam increased rapidly before 28 days, but the increasing trend slowed down obviously after 28 days. Taking PP as an example, when the fiber content was 0.07%, the unconfined compressive strength of cement-stabilized macadam increased by 1.27mpa during the curing period from 7d to 28d, and the compressive strength increased by 0.64mpa during the curing period from 28d to 90d.

(3) The unconfined compressive strength values of the four kinds of fiber-cement stabilized crushed stone mixtures have little difference, and the early performance of fiber varieties is less affected. PVA has the largest increase in unconfined compressive strength, followed by PAN and PP. PET has the worst performance among the four kinds of fibers.

3.2. Analysis of splitting strength

The tensile splitting strength at 28d,90d and 120d ages of four kinds of fiber-doped cement stabilized crushed stone mixtures was tested and studied, and the test results are shown in the figure below.

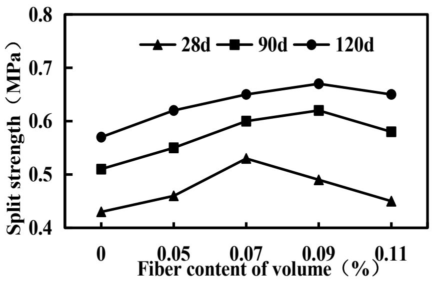

Figure 5. Test results of splitting strength of PET cement stabilized macadam mixture

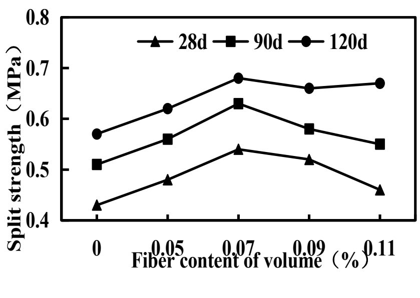

Figure 6. Test results of splitting strength of PAN cement stabilized macadam mixture

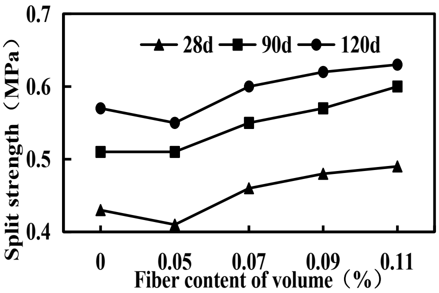

Figure 7. Test results of splitting strength of PP cement stabilized macadam mixture

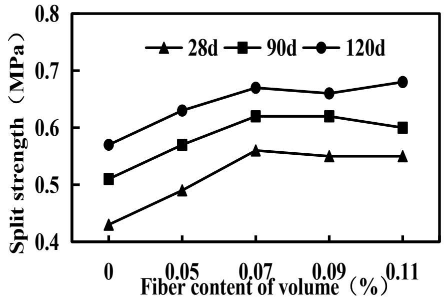

Figure 8. Test results of splitting strength of PVA cement stabilized macadam mixture

The results above show:

(1) When the fiber content is 0.05%~ 0.11%, the splitting tensile strength of the mixture can be improved by adding the four kinds of fibers into the cement-stabilized macadam. When the fiber content is less than or equal to 0.07%, the split tensile strength of the mixture increases gradually with the increase of the fiber content; when the fiber content is greater than 0.07%, the increase range of the split tensile strength decreases obviously; when the fiber content is greater than 0.09%, the split tensile strength of most of the mixture with fiber does not increase but decreases. Taking polyester fiber as an example, when the curing age is 28 days and the fiber content is 0. 05%, 0. 07%, 0.09% and 0.11%.

(2) The splitting strength of fiber-doped cement stabilized macadam mixture increases rapidly before 90d, while the increasing trend of compressive strength slows down obviously after 90d age. Taking PAN as an example, when the fiber content was 0.007%, the splitting strength of the mixture increased by 0.09mpa during 28d to 90d, and the pressure increased by 0.03mpa during 90d to 120d.

(3) The improvement effect of PET and PAN on the splitting strength of the mixture is small, the effect of PP is the worst, and the effect of PVA is higher than the other three kinds of fibers.

3.3. Springback modulus analysis under pressure

The compressive springback modulus of 28d, 90d and 120d of four kinds of fiber-doped cement stabilized crushed stone mixtures was studied, and the test results are shown in the figure below.

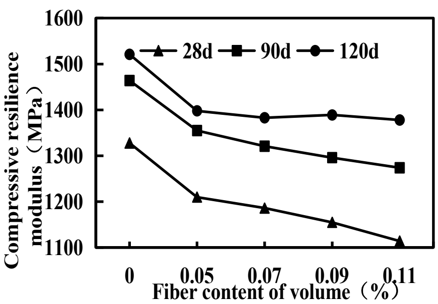

FIG. 9 Test results of springback modulus of PET cement stabilized macadam mixture

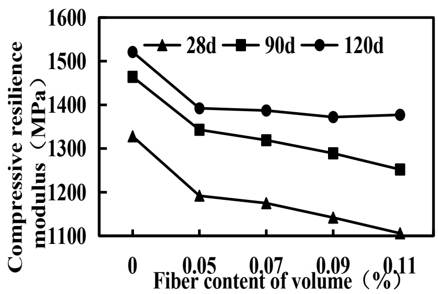

FIG. 10 Test results of springback modulus of PAN cement stabilized macadam mixture

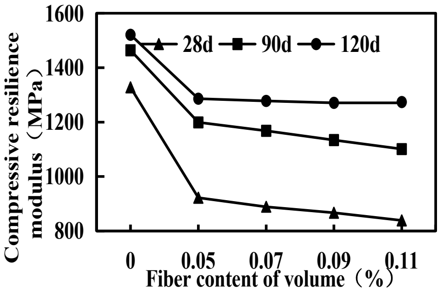

FIG. 11 Test results of springback modulus of PP cement stabilized macadam mixture

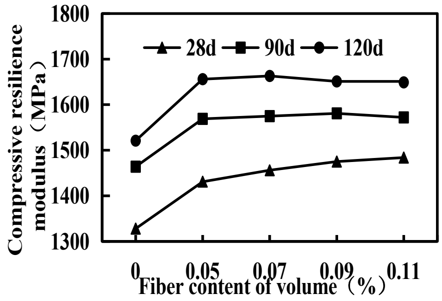

FIG. 12 Test results of springback modulus of PVA cement stabilized macadam mixture

The results above show:

(1) When the fiber content is 0.05%-0.11% and the curing period is the same, the compressive rebound modulus of the three fiber mixtures of polyester fiber, polypropylene fiber and polypropylene fiber decreases gradually with the increase of the fiber content. The compressive resilience modulus of cement stabilized macadam mixture is gradually increased after adding PVA .

(2) The change of fiber content has a great influence on the cement-stabilized macadam in the early stage, and the change of fiber content has a small influence on the compressive elastic modulus of cement-stabilized macadam in the later stage with the increase of the strength and stiffness of cement-stabilized macadam mixture. Taking polyester fiber as an example, when the content of polyester fiber is 0.05%, 0.07%, 0.09% and 0.11%, the resilience modulus of fiber mixture with curing age of 28 days is decreased by 8.9%, 10.7%, 13.0% and 16.1%, respectively, compared with ordinary cement-stabilized crushed stone. The springback modulus of fiber mixture with curing age of 120d decreased by 8.1%, 9.1%, 8.7% and 9.4%, respectively, compared with that of ordinary cement-stabilized crushed stone.

(3) The springback modulus of fiber-doped cement stabilized macadam mixture increases with the increasing of age. The 28d age is the main period in which the springback modulus of the mixture increases. With the increasing age, the increase of the springback modulus of the mixture decreases gradually. Taking PAN as an example, when the content is 0.05%, the 28d springback modulus is 1192MPa, the 90d springback modulus is 1343MPa, and the 120d springback modulus is 1392MPa. During 28d to 90d, it increased by 12.67% and during 90d to 120d, it increased by 3.65%[9][10].

4. Conclusion

(1) Adding fiber can effectively improve the unconfined compressive strength of the mixture. When the fiber content is 0.05%-0.11% and the curing age is 28d and 90d, the unconfined compressive strength of the mixture increases gradually with the increase of the fiber content, but the fiber content has little influence on the early compressive strength of the mixture. Under the same age and dosage, the influence degree of fiber on the compressive strength of the mixture is as follows: PVA>PAN >PP> PET.

(2) Adding fiber can effectively improve the splitting tensile strength of the mixture. When the fiber content is 0.05%-0.11% and the age is 28d and 90d, the splitting strength of the mixture increases gradually with the increase of the fiber content, but the fiber content has little influence on the early splitting strength of the mixture. Under the same age and dosage, the influence degree of fiber on the splitting strength of the mixture is as follows: PVA >PAN = PP > PET.

(3) When the fiber content is 0.05%-0.11% and the curing period is the same, the compressive springback modulus of the mixture of PP, PAN and PET decreases gradually with the increase of the fiber content. The resilience modulus of the mixture increases with the increase of the content of PVA . At the same age and dosage, the decreasing amplitude of the fiber's compressive rebound modulus to cement-stabilized macadam is as follows: PAN = PP > PET.

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