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To cite this article: Zhengxun Yang *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **233** 022014

Study on Fabrication and Characteristic of Green Concrete by Using Natural Graded Gravel

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Abstract. To find a way to solve the growing shortage of natural raw materials in building industry, this research adopted the method to fabricate green concrete by using as raw material instead of traditional natural stone and sand. Comparison tests like flexual strength, compressive strength and freeze-thaw resistance were carried out. By the introduction of new type cement, both the flexual strength and compressive strength of this kind of green concrete of 28d could meet the requirement of concrete standard. And green concrete showed a better freeze-thaw resistance than that of Ordinary Portland cement concrete. The microstructure of green concrete and common concrete were also investigated by a digital microscope.

1. Introduction

With the fast economic development, infrastructure construction has been developing rapidly all around China. But the huge construction process leads to a shortage of natural resources, ecological destruction and a series of environmental problems. The construction industry has always been an energy-consuming industry. Under the green environmental protection promotion of the whole society, the construction companies become much more concerned on the research and development of green building materials, which could realize energy conservation and emission reduction. Natural gravel is a traditional construction material, which is with high bearing capacity and good water damage resistance. But the natural gravel needs to be sieved and graded before construction to reach a good compactness. The natural gravel contains fine particle material such as soil and sand which would effect the compactness and strength in the concrete structure. If the natural gravel could be used directly without sieving and grading, the cost will be reduced and the time limit for the project will be shortened.

2. Experimental

The green cement was fabricated by adding a new type of cementitious materials call green cement. This kind of material could bind the fine particles on the surface to generate gel material at room temperature to solidify the structure. The main components of this material are CaO, SiO_2, Al_2O_3, Fe_2O_3 and activator. The composition could be adjusted to have different adaptive performance which could be able to bind most kinds of low liquid limit soil, shale, clay, sand, soil mixture, construction waste mineral slag and etc. Compared with traditional cement, the concrete fabricated with this kind of cementitious material have higher strength, lower cost and shorter construction time.

Raw materials

Cement: Ordinary Portland cement 42.5# and green cement 42.5# were used as binding material in this paper. According to the test specification, the standard consistency water consumption, initial and final condensation time, stability and strength of the two kinds of cement were tested and analyzed. The test data are shown in Table 1:

Table 1. Basic properties of cements

	Test projects	Green Cement	Ordinary Portland Cement	Specification values
	Standard Consistency (%)	137	151	/
	Initial condensation time (min)	192	150	≥45
	Final condensation time (min)	252	180	≤600
	Stability	Qualified	Qualified	Qualified
	Fineness（%）	6.22	9.89	＜10
3d	Flexural Strength (MPa)	4.3	3.5	≥2.5
	Compressive strength (MPa)	30.5	25.2	≥10
28d	Flexural Strength (MPa)	7.8	6.6	≥6.5
	Compressive strength (MPa)	51.9	45.9	≥42.5

Natural gravel: The natural grade gravel used in the experiment is a typical natural gravel. The water sieve method was used to screen the natural grade gravel sample No.1 and No.2. The screening result was shown in Table.2 as below:

Table 2. Aggregate Screening table

Sieve hole size（mm）Grading Range	31.5	26.5	19	9.5	4.75	2.36	0.6	0.075
Specification	100	90~100	72~89	47~67	29~49	17~35	8~22	0~7
1#	97.8	94.4	89.1	75.5	63.7	54.6	43.7	18.2
2#	100	100	97.0	87.9	72.5	55.7	34.1	8.2

Mechanical properties test of cement concrete was carried out by national standard GB/T 50081-2002. Concrete was fabricated according to C30 standard. The water/cement ratio is 0.65. First mixed the aggregate and cement evenly for 3mins and then water was added. The slump test was carried out immediately after 3mins mixing. The slump range was controlled in 18cm~20cm, and the mixed concrete was poured into the mold of 150*150*150mm and 150*150*550mm then moulded with vibration. After curing for 24h in room temperature, the samples were demoulded and cured in standard circumstance.（Temperature is 20±2℃, relative humidity is 95%）After cured for 7d and 28d, the compressive strength, flexural strength and anti-freeze-thaw test were carried out.

3. Results and discussion

As shown in Table.1, the performance indexes of ordinary cement met the requirements of the specification and the performance indexes of green cement were better than ordinary cement. The standard consistency water consumption of green cement could save about 10% compared with ordinary cement. The initial condensation time of green cement was 28% and 40% higher than that of ordinary cement. The compressive strength of green cement was 17% higher than ordinary cement, and the flexural strength was increased by 20%. The main reason was that green cement particles were smaller than ordinary cement particles, so the hydration reaction with sand was more complete, and the consolidation capacity of cement was maximized. The standard consistency water consumption of green cement was less than that of ordinary 42.5# ordinary cement under the same label. The chemical ion exchange reaction occurred to reduce the water absorption effect caused by capillary, powder voids and surface tension of soil powder. And make the treated soil powder from "hydrophilic" into "hydrophobic" which directly reduced the water demand greatly.

From Table.2 data analysis, the 1# sample was mixed with some large particle size gravel. Caused the screen rate of 31.5mm and 26.5mm sieve size was less than the standard value. The remaining screening indicators basically meet the requirements of the specification. 2# natural gravel through the comparison and analysis of the screen rate of each sieve hole for the finer size. The percentage of aggregates of 0.075mm, 0.6mm, 2.36mm exceeds the standard value. Among them, the mud content of 1# and 2# was 9% and 17%, respectively. Far greater than the specification of concrete mud content which is no more than 1%.

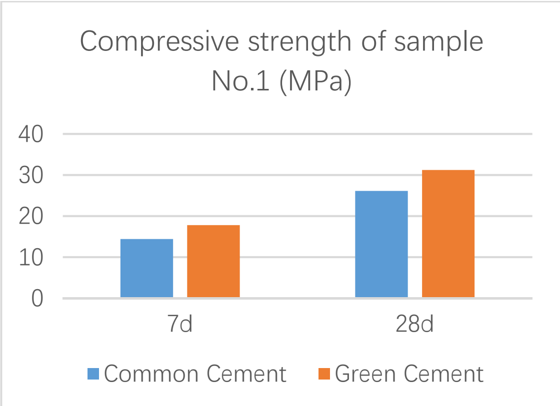

Fig 1. Compressive strength of No.1 sample

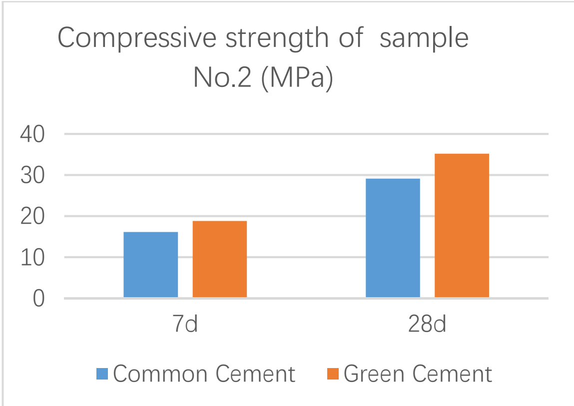

Fig 2. Compressive strength of No.2 sample

As shown in Fig.1 and Fig.2, the compressive strength of natural graded gravel with green cement curing was higher than that of ordinary cement concrete. The hydration reaction between cement and the minerals in the aggregate could be fully operated at room temperature. At the same time, the water content of green cement is small which would reduces the voids caused by water evaporation in the process of cement concrete curing process. And due to the smaller particle size of green cement, the larger specific surface area made the cement particles could surround the fine soil powder and formed gel which was the precursor of a solid network structure. Fig.3 and Fig.4, the flexural strength comparison of green cement concrete and ordinary cement also showed the result.

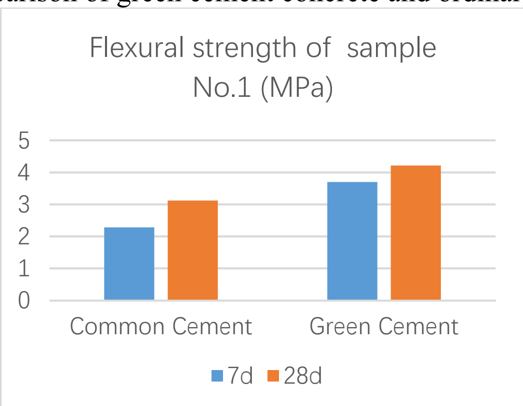

Fig 3. Flexural strength of sample No.1

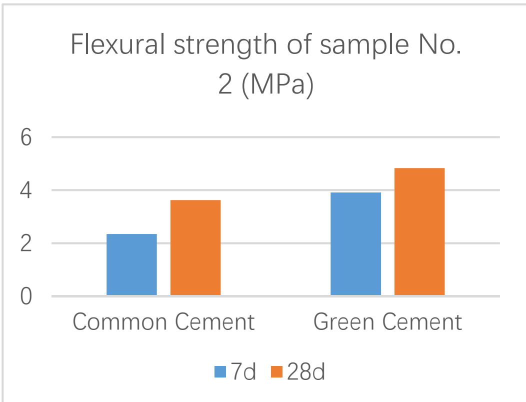

Fig 4. Flexural strength of sample No.2

There was no difference in quality loss in parallel tests. In the case of sample No.1, as the cycles of freeze-thaw increases, the green cement could stand 10 more freeze-thaw cycles than ordinary cement as shown in Table 3. And in the case of sample No.2, after 40 freeze-thaw cycles, the residual modulus of ordinary cement specimens was less than 60%. and residual modulus of green cement specimen was 66.8% and 63.6%, respectively, Natural grade gravel contains gravel, soil, sand and other substances, while the higher compactness reached, the better freeze-thaw resistance of concrete could get. The activator in green cement could generate electric charge on the surface of cement and soil particles, so the cement particles could wrap the soil particles completely. Green cement had a small water-ash ratio, in the process of forming and curing, the open voids in the cement concrete could be reduced, and the water could hardly penetrate into the specimen structure. The less residual water existed, the high modulus would get. So the freeze-thaw resistance could be enhanced.

Table 3. Freeze-thaw cycle experiment of specimens

Category	Number of freeze-thaw cycles				
	0	10	20	30	40
	Residual modulus				
Ordinary 1-1	100	91.1	81.3	73.2	collapsed
Ordinary 1-2	100	95	80.4	72.1	collapsed
Green 1-1	100	97	83	77.6	65.3
Green 1-2	100	97.5	82.5	77.3	66.1
Ordinary 2-1	100	92.6	82.9	71.9	59.1
Ordinary 2-2	100	94.6	85.3	74.2	58.5
Green 2-1	100	96.5	89	78.7	66.8
Green 2-2	100	95.7	85.6	77.7	63.6

Fig 5. Microstructure of ordinary concrete

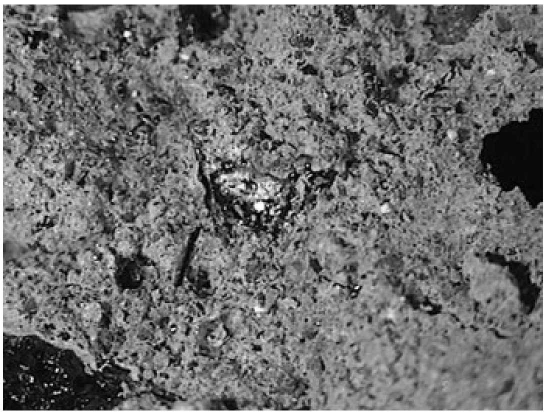

Fig 6. Microstructure of green concrete

Fig.5 and Fig.6 showed the microstructure comparison of ordinary concrete and green concrete. A porous structure was found in ordinary concrete structure, which led to a lower strength and poor freeze-thaw resistance. By the aid of smaller particle size and activator, the green concrete showed a much more homogeneous and poreless structure. The cement and fine powder in the raw gravel material bonded together compactly, formed a solid network structure. This kind of structure made green concrete a higher strength and better freeze-thaw resistance.

4. Conclusion

To investigate the effect of green cement, two kinds of natural graded gravel was used as raw material for concrete fabrication. The measurements like flexural strength, compressive strength and freeze-thaw resistance were compared. The green concrete showed excellent performance in all tests. The conclusion is as below:

1. The 7d and 28d strength of green cement concrete specimen is higher than Ordinary Portland cement concrete. And the green cement and concrete satisfies the designing standard index. It shows that green cement not only has good physical and mechanical properties, it also has a good adaptability for raw materials.

2. The green concrete could bear more freeze-thaw cycles than that of ordinary concrete. Smaller W/C ratio made the structure compact, and residual water, which would affect the structure of

specimen, is also reduced in green concrete. The natural graded gravel with green cement can meet the strength and freeze-thaw resistance standard requirements for concrete pavement and the volume stability is also in the range of standard.

3. Green concrete shows a more homogeneous microstructure with less pores than that of ordinary concrete. It explains the higher strength and better freeze-thaw resistance which green concrete has shown to us. The green cement should be further researched and spread widely for its convenience and low construction cost. It is also a environmental-friendly material by using natural graded gravel.

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