Sixth International Conference on Sustainable Construction Materials and Technologies. https://www.scmt-conferences.com/proceedings

SUGGESTION FOR ENVIRONMENTALLY FRIENDLY TSC WITH OPTIMIZED GROUTING MATERIALS

Noguchi Yurika[1], Iyoda Takeshi[2]

[1] *3-7-5, Toyosu, Koto-ku, Tokyo, Japan, mh23027@shibaura-it.ac.jp, Shibaura Institute of Technology*
[2] *3-7-5, Toyosu, Koto-ku, Tokyo, Japan, iyoda@shibaura-it.ac.jp, Shibaura Institute of Technology*

ABSTRACT

Various types of concrete have been developed to adapt to manufacturing methods, construction environments, and various performance requirements. Two Stage Concrete is one of them which is made by spreading coarse aggregate on the formwork and them fill the spaces between the coarse aggregate with grout material prepared with pre-mixed mortar and become concrete. This study first examined the preparation of grouting materials using materials which is environmentally friendly. As a result, that the compressive strength of the grout material itself had no significant effect on the compressive strength of the TSC. On the other hand, when is the fresh performance of the grout material, we confirmed that the use of the supernatant water of sludge in the mixing water ensured optimal performance of the grout material with 70% replacement of GGBS. Finally, it is considered necessary to consider further strength assurance to realize TSCs aimed at reducing environmental impact.

Keywords

Two Stage Concrete (TSC), Grouting material, Ground granulated blast-furnace slag (GGBS), Recycled aggregate for roadbeds (RC-40)

INTRODUCTION

There are various types of concrete to adapt to the performance requirements of manufacturing methods and constructions. One of these is Two Stage Concrete (TSC), a special construction method in which coarse aggregate is spread on the formwork in advance and grout is filled in between the aggregates to form concrete. In this method of construction, the splitting tensile strength can be conservatively estimated using the American concrete institute (ACI) equation for conventional concrete. Using TSC, concrete that meets the required performance can be produced in locations where it is difficult to transport concrete due to the ease of material transport and local procurement of coarse aggregate using pre-mix grouting materials. On the other hand, due to the properties of TSC, the interface between the aggregate and the grout materials is expected to be fragile, and there are concerns about its strength and durability. Previous studies have shown that TSC has lower compressive strength than conventional concrete and increased porosity due to the continuity of interfacial transition zone and voids between aggregates, but the compressive strength of TSC is independent of the type of coarse aggregate and addition of expansion material to the grouting material results in improved strength and durability. On the other hand, the growing seriousness of global environmental problems has led to a focus on decarbonation, and in the concrete sector, attention is being paid to the use of recycled aggregate produced from dismantled concrete masses and ground granulated furnace slag (GGBS). Therefore, it was considered that TSC using recycled coarse aggregate and GGBS as grout material for filling could contribute to environmental impact. This study aims to develop grouting materials with reduced environmental impact for environmentally friendly TSC.

PHYSICAL PROPERTIES OF GROUT MATERIALS

For the development of grouting materials, the environment friendly materials, GGBS and supernatant water were used. Various admixture materials were also used to meet the performance requirements. Table-1 shows the mixed materials of grout materials. The use of GGBS was 0~70% of cement. Also set the W/C as 45%~70% and S/C was 0.2~1.0. In addition, powder thickener, high quality submersible admixture for underwater concrete (ASK) was added at 0.0~1.0(%) for material separation resistance, a high performance water reducer(SP) was added at 0.0~0.2(C×%) to improve flowability, a Calcium Sulfoaluminate-based bulking agent (CSA) at 0.0~20(kg/cm^3) to densify the voids at the aggregate interface. To improve the filling of the grout material, the fine aggregate used was passed through a 1.2mm sieve.

Table-1. Mixed materials of grout material

water	water or supernatant water
W/C (%)	45,50,70
S/C	0.2,1.0
GGBS (%)	0,50,70
ASK(Cement×%)	0,0.25,0.5,0.75,1.0
SP(Cement×%)	0,0.5,0.75,1.0,2.0
CSA (kg/m^3)	0,10,20

Outline of the Experiments

As it is difficult to check the grouting status of the grout material at the time of placing the TSC, there is concern about poor filling, it is necessary to select an appropriate grout material. Therefore, the required performance of the grout material, such as flowability and viscosity, was checked.

Slump Flow Test

The slump flow value of the grout material (hereafter flow value) and the time taken to reach the maximum flow value were measured in accordance with JIS A 1171.

JP Funnel Test

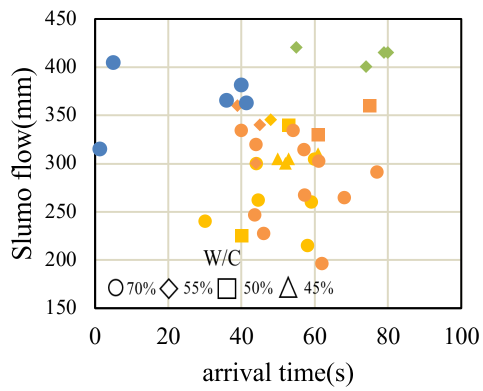
Viscosity and flowability cannot be adequately assessed only by slump flow test. Therefore, the JP funnel test was conducted according to JSCE-F 531-2018.

Expansion Rate Test

This test is conducted to ascertain the effect of the expansion agent added to the grout material. Tests were conducted in accordance with JSCE-F 522-2018 “Bleeding rate and expansion rate test method for injected mortar in prepacked concrete (Polyethylene bag method)”

Results of the experiments

Figure-1 shows the results of the slump flow and JP funnel test for all mix proportion. If bleeding of the materials was visually observed 5mins after the end of the slump flow test, we considered that the mix proportion of the grout material is not suitable for TSC. From Figure-1**,** even with similar flow values, there were differences in the arrival time of the maximum flow values. Therefore, a JP funnel test was conducted to select the appropriate mix proportion. Most of the grout materials were found to have residual grout material in the funnel and were therefore considered unsuitable. On the other hand, the grout materials which are considered suitable were 4 mix proportions. Their mix proportions are shown in Table-2, and the results of slump flow and JP funnel test for the 4 mix proportions are shown in Figure-2. Based on these results, grout materials need to be both fluidity and viscosity. Therefore, the acceptable limits for the grout materials must have a flow value of at least, 400mm. and an arrival time of at least 80 seconds.



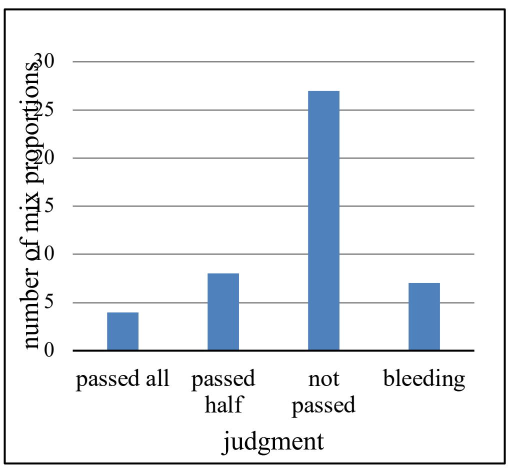


Figure 1. Results of slump flow and JP funnel of test (left: slump flow, right: JP funnel)

Table-2. Mix proportions of grout material suitable for TSC

No.	water	W/C (%)	S/C	GGBS (%)	ASK (C×%)	SP (C×%)	CSA (kg/m^3)
N	water	55	1	0	0.25	1	20
BB				50			
BC-1				70			
BC-2	supernatant water						

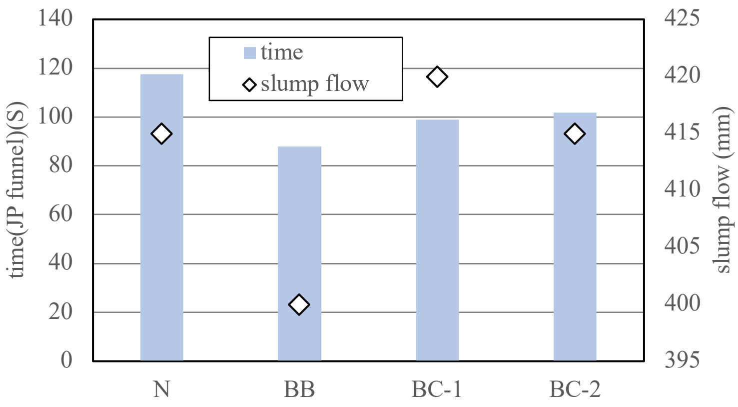


Figure-2. The results of the tests for suitable mix proportions

Figure-3 shows the results of expansion rate test. It was thought that the addition of an expander could improve the porosity of the aggregate interface, but no expansion was observed in the BC-2 mix proportion. The effect of adding an expander is unclear, so the effect of using expanders and supernatant water should be studied

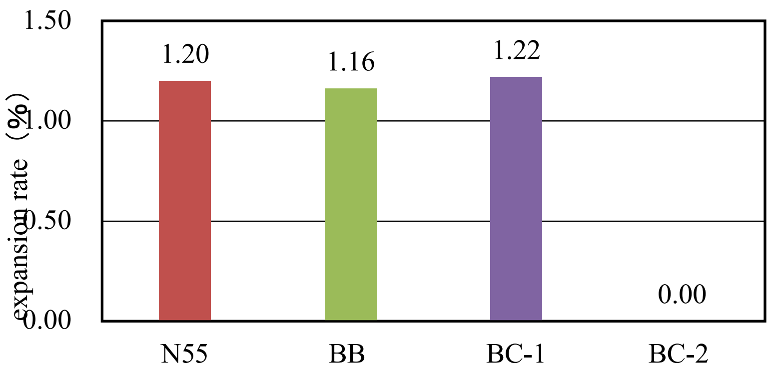


Figure-3. The results of expansion rate test

from the porosity of the grout material and the hydrates produced. As shown in the table, the supernatant water has approximately 20 times higher calcium concentration than tap water. It is thought that the higher than usual calcium content eliminates the effect of the expander.

Table-3. Ca^{2+} concentration of mixing water

Mixing water	Ca^{2+} concentration (ppm)
Tap water	41.5
Supernatant water	870

EVALUATION OF GROUTING MATERIALS IN TERMS OF STRENGTH AND DURABILITY OF TSCS

Using mix proportions showed in Table-2, 450 × 200 × 300mm squire TSC specimens were made. Reducing environmental effect, recycled coarse aggregates were used. Figure-4 shows the summary of the specimens. Cylinder cores were taken from the square TSCs, and compressive strength test and porosity test were conducted.

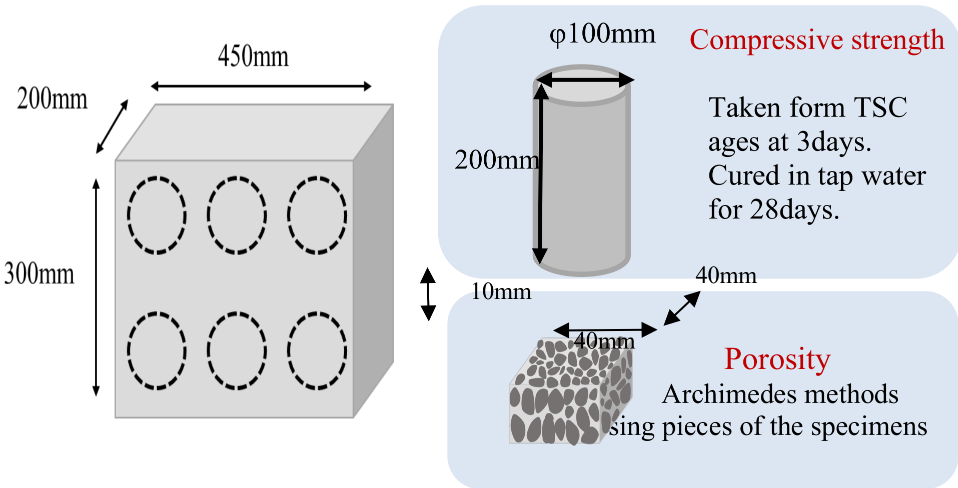


Figure-4. Summary of the specimens

Compressive Strength of TSCs using Grout Materials and Grout Materials

Outline of the Experiment

TSC

Figure-4 shows the summary of the specimens. Cylindrical cores were taken from the TSC, which ages at 3 days. After the cores were taken, they moved into tap water and cured for 28days. The test was conducted at the age, according to JIS A 1108.As a specimens, some pieces of about 40×40×10mm were taken from TSCs and the porosity was calculated using Archimedes methods.

Grout Materials

The mortars were made with the grout materials using the mix proportions shown in Table-2 were made into cylindrical specimens. The specimens were cured in tap water for 28days. After the age comes, compressive strength tests were conducted.

Results of the Experiment

The result of compressive strength test of mortar and TSCs are shown in Figure-5. Comparing the results of specimens made with BC-1 and BC-2, the compressive strength is decreases a little when using the supernatant water. On the other hand, comparing compressive strength of N, BC-1, and BC-2, they showed no significant differences. This suggests that the compressive strength of the grout material is independent of the compressive strength of TSCs.

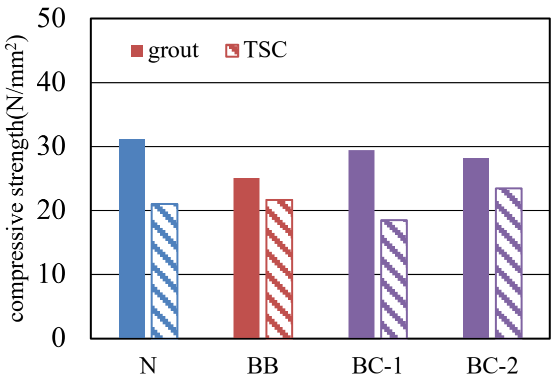


Figure 5. Compressive strength of the grout and TSC

Compressive Strength and Porosity of the TSCs

Outline of Experiment

Figure-4 shows the summary of the specimens for porosity test. Some pieces of about 40×40×10mm were taken from TSCs and the porosity was calculated using Archimedes methods.

Results of the Experiments

The results of compressive strength test and porosity test are shown in the right side of Figure-6. Comparing the results of specimens made with BC-1 and BC-2, the compressive strength is decreases a little when using the supernatant water. On the other hand, comparing the results of N, BC-1, and BC-2, the compressive strength showed no significant differences. The right side of Figure-6 shows the result of the porosity test. Figure-7 shows the relationship between compresive strength and porosity has weak correlation, the lower the porosity, the higher the compressive strength. Especially between BC-1 and BC-2, their only differences between the two was the mixing water, the results showed significant differences in compressive strength and porosity among the four mix proportions. The specimen surfaces of BC-1 and BC-2 are shown in Figure-8. BC-1 has higher porosity than BC-2, and Figure-7 shows that some air bubbles stay in the grout material. Theses bubbles may have become weak areas within the TSCs, leading to a reduction in compessive strength.

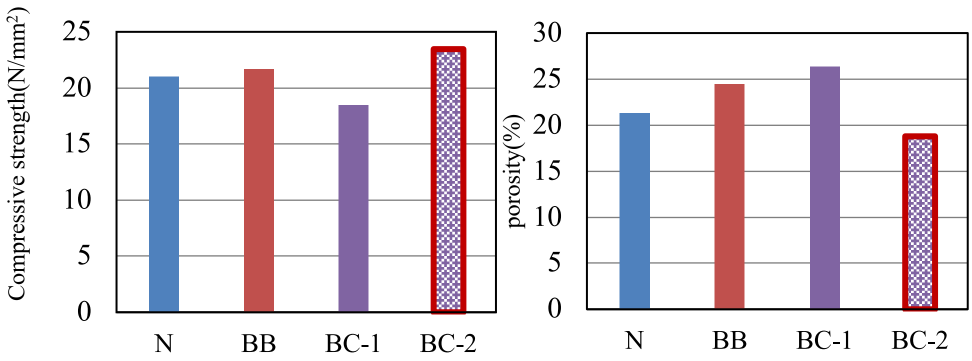


Figure 6. Compressive strength and porosity of TSCs

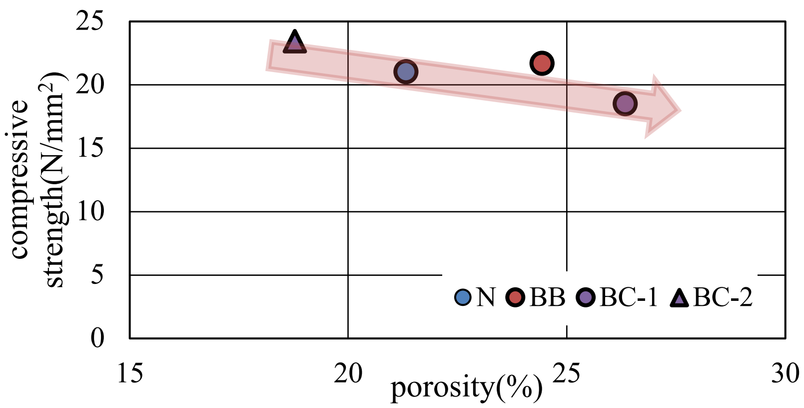


Figure 7. Relationships between compressive strength and porosity

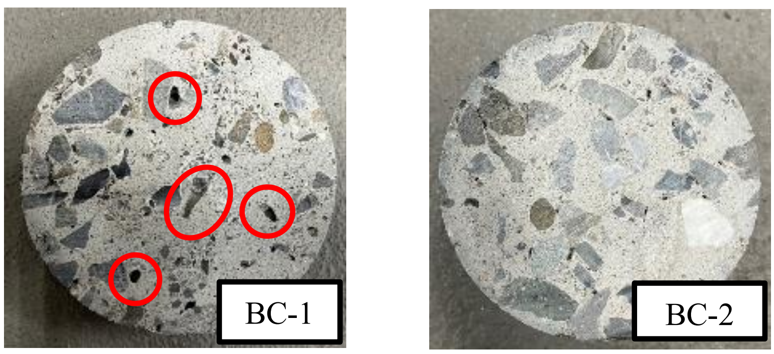


Figure-8. Surface of the specimens

The fracture of TSCs made with ordinary aggregate(left) and recycled aggregate(right) are shown in Figure-8. The specimen which was made with recycled aggregate was also added the expander. The specimen which was made with ordinary aggregate has fractured along the coarse aggregate and the aggregates were exposed. On the other hand, the specimen was made with recycled aggregate fractured both grout material and coarse aggregate. Only coarse aggregate was not exposed. As mentioned in section 3.1.2, no expansion of the grout was observed in BC-2, despite the addition of expander. However, the porosity of BC-2 was lowest. It is thought that the compressive strength of mortar has a large effect on the compressive strength of the TSCs.

CONCLUSIONS

(1) The slump flow test and the JP funnel test can be used to select the grout material, and a slump flow value of at least 400mm is required.

(2) Even though differences in the compressive strength of the grout material were identified, the compressive strength of the TSCs was similar. Therefore, TSC grouting materials do not need to have high compressive strength. This is because the compressive strength of TSC is presumably dependent on porosity.

(3) No correlation was found between the porosity of TSC and the JP funnel sulphurisation time, while a correlation was found between the porosity of TSC and slump flow value. Therefore, grout materials adapted for TSC require a certain high slump flow value to be ensure.

(4) It was thought that the addition of an expander could improve the porosity of the aggregate interface, but no expansion was observed in the BC-2 mix proportion. The effect of adding an expander is unclear, so the effect of using expanders and supernatant water should be studied from the porosity of the grout material and the hydrates produced.

REFERENCES

Shibuya, A., and Iyoda, T (2019). " A REVIEW OF PREPLACED-AGGREGATE CONCRETE USING RECYCLED AGGREGATE AND RAILWAY WASTED BALLAST." 16th East Asia-Pacific Conference on Structural Engineering & Construction (EASEC16), Australia, December 3-6.,

Nagoya, T., and Iyoda, T. (2021) “A study to achieve Two-Stage-Concrete with the same level of strength and durability as conventional concrete.” Proceedings of the Japan Concrete Institute 41 No.1 pp.1493-1498

Torichigai.T., Mori.T., Kojima.M.,(2023) “Development of Innovative Carbon-Negative Concrete Materials, Construction Technology, and Quality Evaluation Technology ,CUCO Carbon Utilized Concrete”:Concrete Journal, Vol.61, No.6

Iwanaga,T(2010) “Utilization of Sludge Water and Consideration to the Environment”: Concrete Jourbal, Vol.48, No.9

Fukazawa,Y., Sugiyama,T.,Iyoda,T.,(2019) “Mechanism of Pore Modification in Concrete by C-S-H Based Curing Accelerators” 73rd The Annual Meeting of Cement and Concrete Engineering