Journal of Ceramic Processing Research. Vol. 8, No. 1, pp. 82~86 (2007)

J O U R N A L O F
Ceramic Processing Research

Development of recycling technology from waste aggregate and dust from waste concrete

Goo-Dae Kim* **and Tae-Bong Kim**
Nano-Material Research Center, Korea Institute of Science and Technology, Seoul 136-791, Korea

Much construction waste is produced during demolishing old buildings. We have considerable interest in recycling part of the construction waste because it is a cause of environmental pollution. So, research and development concerning recycling technology from waste aggregate and dust from waste concrete is constantly increasing. In this study, we manufactured a modified sulfur concrete (MSC) that has superior physical properties such as compressive strength above 78.4 MPa and degree of absorption below 0.5%. MSC is a mixture of modified sulfur, waste aggregate and dust from waste concrete. The modified sulfur is prepared by reacting for 4 hours in a chamber at 140 °C after mixing dicyclopentadiene (DCPD), oligomer and low-grade sulfur. As a result of a chemical resistance test for 3 months of the synthetic MSC using recycled aggregate/dust and Portland concrete, a general concrete was seriously corroded and destroyed but the MSC was almost unchanged in weight and exterior appearance. The MSC will, therefore, be utilized as a concrete material for repair/reinforcement work because it has superior chemical resistance and a fast hardening ability.

Key words: Waste Aggregate, Modified Sulfur, Recycling Technology, Modified Concrete.

Introduction

Recycled concrete aggregates, sometimes referred to as crushed concrete, come from the demolition of Portland cement concrete elements of buildings, roads, and other infrastructures. Due to the preservation of natural resources, prevention of environmental pollution, and cost-saving considerations of construction projects, the recycled concrete aggregates have been widely used for making different construction concretes and producing high-strength/high performance concretes [1-3]. The use of inorganic industrial residual products in making concrete will lead to sustainable concrete design and a greener environment. The need to develop concrete with non-conventional aggregates is urgent for environmental as well as economic reasons. However, waste aggregates and the dust from waste concretes must be washed before using them because carbonated mortar dust in the waste concrete decreases the strength of product. This washing process gives a problem with the high cost of the facilities needed.

Meanwhile, the impregnation of Portland cement concrete with organic monomers and subsequent polymerization of the monomers by radiation or by thermal catalytic techniques is a well known method for improving the properties of concrete. Compared with untreated concrete, an increase in compressive strength is easily achieved [4, 5]. Also, sulfur-impregnated concrete can be prepared without the washing step and various investigations of modified sulfur concrete are in progress. Over recent years a major drawback to the use of sulfur concrete in construction has been highlighted by many researchers [6, 7].

The main objectives of this study are to obtain high strength recycled aggregate and to utilize dust from waste concrete without the washing processing.

Experimental

Low-grade sulfur, a residual product of the domestic petrochemical industry, reagent dicyclopentadiene (DCPD) and oligomer were used as starting materials for sulfur modification synthesis. The procedure for sample preparation is described as follows. As in Fig. 1, sulfur, DCPD and oligomer were mixed in various ratios. The reactants were completely melted in a glass reactor with a built in refluxing system on a hot plate. In our experiments, we changed the mixture ratios of DCPD and oligomer. Also, we varied the conditions in the range from 120 to 180 °C and from 2 to 40 hour to study the effects of reaction temperature and time.

The amount of modified sulfur added, dust from waste and fly ash versus recycled aggregates, and amount and length of fiber added were used as variable factors in these experiments. The modified sulfur concrete was prepared by mixing modified sulfur, waste aggregate, dust from waste concrete, fly ash and fiber. The MSC was prepared at 140 °C to maintain the melting range of sulfur and on a vibrating plate for dense

*Corresponding author:
Tel : +82-2-958-5545
Fax: +82-2-958-5529
E-mail: gdkim@kist.re.kr

Fig. 1. Reactor for sulfur modification (6000 ml).

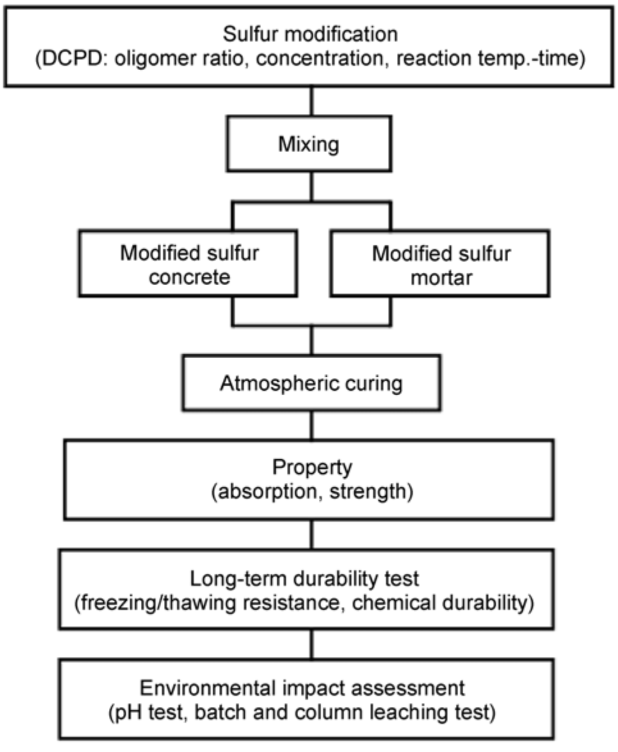

Fig. 2. Overall experimental flow chart.

packing when molding. These procedures are out lined in the flow chart of Fig. 2. The mechanical properties of MSC were determined as per KS F 2403, 2405, 2423, 2407 and ASTM E 900. Also, absorption was measured by the Archimedean method. The various stability tests of MSC were investigated by long-term durability tests and environmental impact assessments.

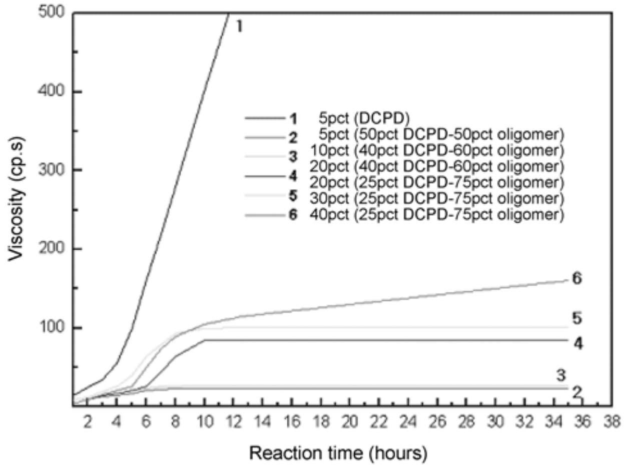

Fig. 3. Effect of reaction time on viscosity with various mixture ratios of DCPD and oligomer.

Results and Discussion

The effect of reaction time on the viscosity with various mixture ratios of DCPD and oligomer is shown Fig. 3. The viscosity of the mixture used only 5 vol.% DCPD as sulfur modifier suddenly increased after 6 hours due to the polymerization of the activated polymer [8]. The viscosity of the modified sulfur was decreased below 30 cP.s in the mixture ratio of DCPD: oligomer=1:1 as an additive of 5% of total volume. When the modifier was added above 20%, liquefied modified sulfur could not be handled. The optimal reaction temperature and time for useful viscosity of the modified sulfur were 4 hours at 140 ^{o}C.

The effect of drying time on compressive strength with various mixture ratios of the aggregate is shown in Fig. 4. The MSC, product in this study, had a higher compressive strength than Portland cement with added additives to increase its strength. We could confirm that as the amount of fine aggregates added was increased, so the compressive strength was decreased. The initial compressive strength of MSC in a mixture ratio of coarse aggregates:fine aggregates=1:1.5 was more than 58.8 MPa, and the final compressive strength after 28 days was very high about 78.4 MPa. In comparison with Portland concrete, MSC using only modified sulfur without other additives could achieve a much higher compressive strength [9]. Figure 5 shows the strength changes of Portland concrete and MSC with various types of added fibers. The bending and tensile strengths of MSC with added fibers and Portland concrete were increased by more than 25-30% in comparison with samples without fibers. The strength change with the amount added and length of steel fiber used as reinforcing material is shown in Fig. 6. In Fig. 6(A), as the amount of steel fiber was increased, the more the tensile and bending strength were increased. However, the compressive strength was the highest value when 1

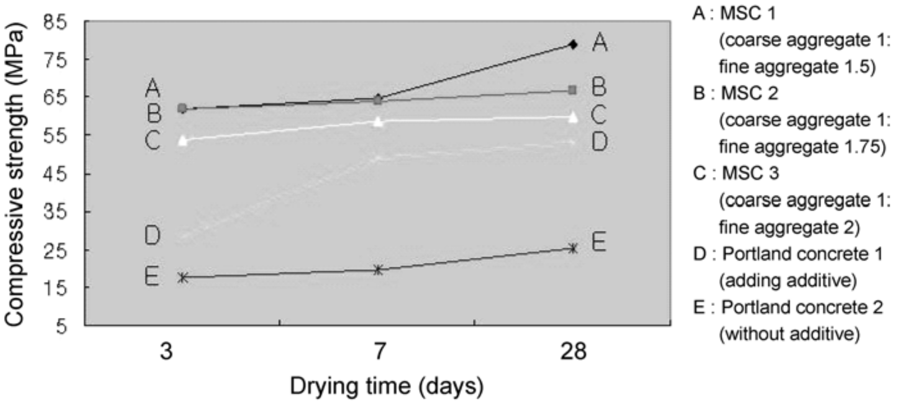

Fig. 4. Effect of drying time on compressive strength with various mixture ratios of aggregate.

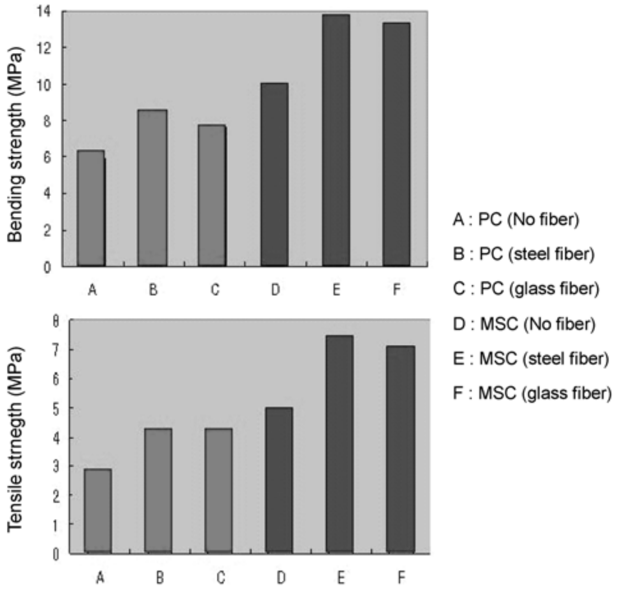

Fig. 5. Strength of Portland concrete (PT) and modified sulfur concrete (MSC) with various added fibers; Bending strength and Tensile strength.

% steel fiber was. In Fig. 6(B), the greater the length of steel fiber up to 60 mm, the more bending strength was increased but the compressive and tensile strengths

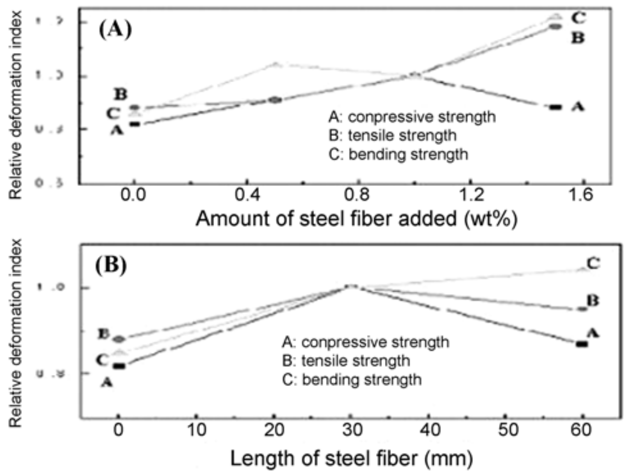

Fig. 6. Change of compressive, tensile and bending strength with amount added (A) and length of steel fiber (B).

were highest when the length of steel fiber was 30 mm. In view of the results so far achieved, the optimal amount added and length of fiber additive were 1 wt% and 30 mm.

The freezing/thawing resistance test of MSC was investigated by KS F 2456 (ASTM C666). The fly ash added to MSC gave a superior property, as shown in Fig. 7. The chemical durability test was investigated

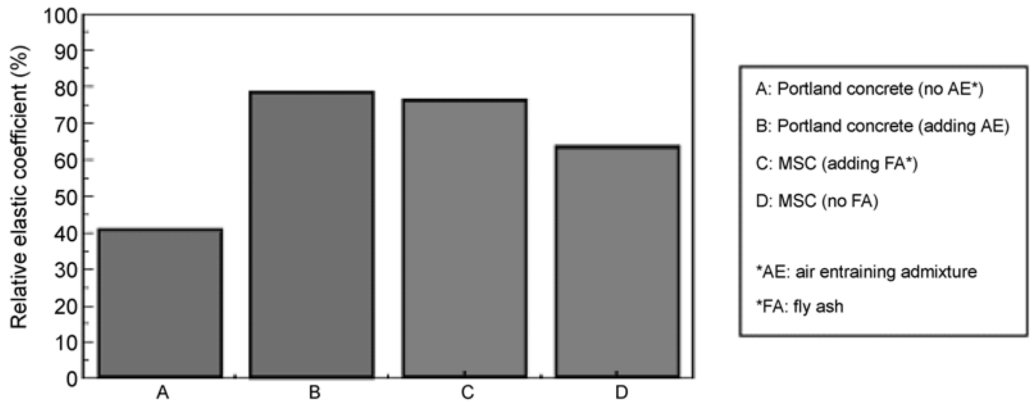

Fig. 7. Comparison of relative elastic coefficient after freezing/thawing resistance tests with various materials.

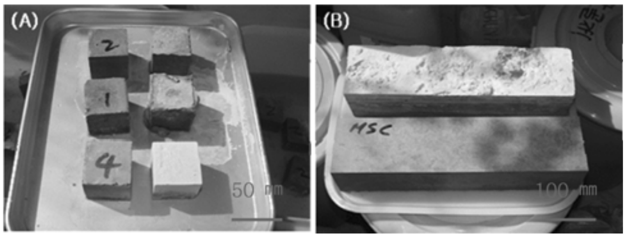

Fig. 8. Photographs of modified sulfur concrete mortar (left, bottom) and Portland concrete mortar (right, top) samples after soaking for 3 months in various solutions; (A) top - 5% $CaCl_2$, middle - 5% Na_2SO_4, bottom - artificial seawater, (B) 5% HCl.

through observations and measurements of weight loss after soaking for 3 months in various solutions of 5% $CaCl_2$, 5% Na_2SO_4, artificial seawater and 5% HCl, etc. The MSC was free from faults in all solutions and the weight loss was small, as shown in Fig. 8 and 9. On the other hand, Portland concrete was corroded and detached and weight loss increased to 65% after 3 months. The results of the leaching tests of waste concrete and MSC are summarized in Table 1 [10]. In the case of MSC, the heavy metal content was below the tolerance limit of Korean standards in the column leaching tests as well as the batch leaching tests.

Conclusions

Stable modified sulfur can be prepared from low-grade sulfur, formed from a residual product at an oil refinery, with the reaction conditions of 140 °C and 4 hours.

We manufactured modified sulfur concrete (MSC) without a washing processing. The MSC has superior physical properties such as compressive strength 78.4 MPa and a degree of absorption below 0.5%. It hardened rapidly and had an initial compressive strength over 49 MPa after curing for only 1 hour. Also, MSC was far superior in terms of chemical resistance and in freezing - thawing resistance tests.

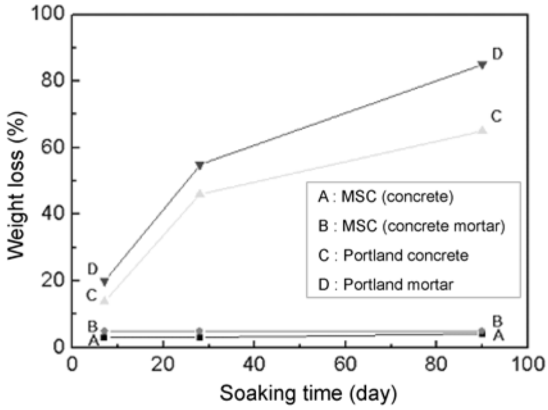

Fig. 9. Weight loss of modified sulfur concrete and Portland concrete with soaking time in a 5% HCl solution.

All results from the long-term endurance tests and

Table 1. Results for Batch leaching and Column leaching test (unit : mg/l)

Division	Cu	Cd	Pb	Hg	As	Cr	Cr^{6+}	CN^{-}
TLKS *1	≤3.0	≤0.3	≤3.0	≤0.005	≤1.5	–	≤1.5	≤1.0
				Batch leaching test				
MSC	<0.05	<0.05	<0.2	<0.001	<0.005	<0.05	<0.01	<0.001
Analysis*2	AAS	AAS	AAS	AAS	ICP	ICP	SP	SP
				Column leaching test				
30 minute	0.007	≤0.001	≤0.001	≤0.005	≤0.002	≤0.005	≤0.008	
A after 10 day	≤0.005	≤0.001	≤0.001	≤0.005	≤0.002	≤0.005	≤0.008	
B after 10 day	0.01	≤0.001	≤0.001	≤0.005	≤0.002	≤0.005	≤0.008	
C after 10 day	0.005	≤0.001	≤0.001	≤0.005	≤0.002	≤0.005	≤0.008	
Analysis*2	ICP/MS			AAS	ICP/MS		AA	
A after 1 month	≤0.05	≤0.02	≤0.2	≤0.005	≤0.05	≤0.05	≤0.008	
B after 1 month	≤0.05	≤0.02	≤0.2	≤0.005	≤0.05	≤0.05	≤0.008	
C after1 month	≤0.05	≤0.02	≤0.2	≤0.005	≤0.05	≤0.05	≤0.008	
Analysis*2	AAS				ICP		AA	
A after 2 month	≤0.05	≤0.02	≤0.2	≤0.005	≤0.01	≤0.05		≤0.001
B after 2 month	≤0.05	≤0.02	≤0.2	≤0.005	≤0.01	≤0.05		≤0.001
C after 2 month	≤0.05	≤0.02	≤0.2	≤0.005	≤0.01	≤0.05		≤0.001
Analysis*2	AAS				ICP			AA

*1 Tolerance limit of Korean Standards
*2 Analysis method used at advanced analysis center in Korea Institute of Science and Technology (KIST)

environmental impact assessments of materials showed the superiority of MSC.

The MSC will, therefore, be suitable for quick construction of harbors or dams.

References

1. C.S. Poon, S.C. Kou, and L. Lam, Constr. Build. Mater. 15[5] (2002) 281-289.
2. A. Ajdukiewicz, Cem. Concr. Compos. 24[2] (2002) 269-279.
3. R.M. Senthamarai and P.D. Manoharan, Cem. Concr. Compos. 27 (2005) 910-913.
4. M.S. Alam and R.S. Juruf, Cem. Concr. Res. 13 (1983) 161.
5. D.G. Manning and B.B. Hope, Cem. Concr. Res. 1[6] (1971) 631-644.
6. K.S. Crentsil, Cem. Concr. Res. 31[5] (2001) 707-712.
7. J.S. Ryu, Mag. Concr. Res. 54[1] (2002) 7-12.
8. W.G. Kim and J.Y. Lee, Polymer 43 (2002) 5713-5722.
9. S.S. Pickard, Concrete International, 3[10] (1981) 57-67.
10. Y.S. Choi, S.H. Cho, and Y.Y. Kim, J. Korean Society of Environmental Engineers 18 (1996) 211-221.