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Abrasion of Concrete on Hydraulic Structures with Underwater Method

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ABSTRACT: Hydraulic structures are usually made of concrete. Structures such as dams, bridge piers, irrigation canals are generally preferred to concrete. Concrete is a durable material with a long service life. For this reason, it is preferred in many buildings. Abrasion problems can occur under the influence of water in water structures. In this study, the test method specified in ASTM C 1138 standard is applied to investigate the abrasion of concrete under water effect in hydraulic structures. Fly ash and blast furnace slag were used by weight in different ratios as 10%, 20%, 30% instead of cement. These specimens were compared with the reference concrete sample. As a result of the study, 10% blast furnace slag added concrete specimen was found to have the best abrasion resistance.

KEYWORDS: Abrasion resistance, Blast furnace slag, Concrete, Fly ash, Hydraulic structures.

I. INTRODUCTION

Concrete water structures suffer from abrasion damage over time as they are constantly subjected to dynamic and mechanical effects of water. In particular, water structures such as dams, bridges, etc. are exposed to very high water loads during floods. It is desirable that such structures are in features that can withstand the worst case scenario. Abrasion is one of the problems most exposed to concrete water structures.



Fig. 1 An abraded concrete surface by effect of water

In this study, which investigates the problem of abrasion in water structures, the effects of mineral admixtures on abrasion resistance in hydraulic structures were investigated. As a result of this study, it was expected that the use of mineral additive concrete in water structures would be proved to be more environmentally and economically possible.



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II. RELATED WORK

There are many studies in the literature which experimentally examine the abrasion resistance of concrete water structures.Liu, (2005) studied the abrasion tests of high performance concrete with waterborne sand flow apparatus. In this study, it was observed that strength and wear resistance of concrete is directly proportional [1].ACI Committee, (2003) and James, (1998) reported that the most influenced concrete structures against hydrodynamic erosion problems can be seen on the surface of the bridge piers, spillway or drainage conduits [2-3].Liu et al. (2006), developed a new test method which abrasion by impact sand-water jet to concrete surface [4]. It is stated that plastic deformation in the area of impact in the concrete causes tensile stresses in that region, causing lateral cracks as material loss occurs [5].Galvao et al. (2012) showed that the surface of the hydraulic concrete member will be destroyed and need to be repaired again at the end of harmful exposure [6].

Kumar and Sharma, (2014), investigated that different test methods being currently used to measure abrasion of concrete [7]. In the studies carried out, the test method described in ASTM C 1138 standard is used to simulate abrasion in concrete water structures.Kryzanowski et al. (2009), provided ans assessment of the suitability of the ASTM C 1138 laboratory method for the abrasion of concrete in hydraulic structures [8].Horszczaruk, (2009) investigated that abrasion resistance of high performance fiber-reinforced concrete by using underwater method [9]. Horszczaruk, (2012) reported that the evaluation of abrasion resistance of hydraulic concretes using Böhme is not possible, only the underwater method simulates the natural conditions of abrasion [10].

III.MATERIALS AND METHOD

A.Materials

In this study, CEM I 42.5 R type Portland cement was used as binder in accordance with the standard EN 197-1 [11]. The cement was obtained from Çimsa Cement Factory in Eskişehir, Turkey. Fly ash (FA) was obtained from Tunçbilek Thermal Power Plant in Kütahya, Turkey. The blast furnace slag (BFS) was obtained from Bolu Cement Factory in Bolu, Turkey. FA and BFS were replaced against by weight of cement at 10%, 20% and 30% replacement ratios. The aggregate was obtained from Çimsa ready-mixed concrete plant aggregate silos in Eskişehir, Turkey. Eskişehir tap water was used for the preparation of concrete composites. Polycar 150 type superplasticizer was obtained from Iksa Construction Chemicals Company in Ankara, Turkey.

B. Method

Concrete Design

In the study, first of all, the physical properties of the supplied aggregates were determined in order to be able to design concrete. Loose and compact unit weight, specific gravity, water absorption, Los Angeles wear experiments have been carried out to determine the physical properties of the aggregates. After the physical properties of the aggregates have been determined, sieve analysis has been carried out to determine the aggregate percentages to be used in the mixture. Fractions 0 - 4 mm, 4 - 16 and 16 - 32 mm were used in sieve analysis. Suitable grading distribution of aggregates obtained in the sieve analysis experiment leads to suitable workability and durability. After the appropriate aggregate percentages have been determined, the concrete mix design has been made.



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Type of Mix	Reference	FA10	FA20	FA30	BFS10	BFS20	BFS30
Cement (kg/m ³)	350	315	280	245	315	280	245
Water (kg/m ³)	158	158	158	158	158	158	158
Sand (0-4 mm) (kg/m ³)	468	468	468	468	468	468	468
Crushed Stone Aggregate (4-16 mm) (kg/m ³)	655	655	655	655	655	655	655
Crushed Stone Aggregate (16-32 mm) (kg/m ³)	749	749	749	749	749	749	749
Superplacticizer (kg/m ³)	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Fly Ash (kg/m ³)	-	35	70	105	-	-	-
Blast Furnace Slag (kg/m ³)	-	-	-	-	35	70	105
Water/Binder Ratio	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Slump (mm)	40	32	20	20	30	22	15
Compressive Strength (MPa)	64.6	65.0	62.6	56.3	70.9	63.2	60.5

Table 1 Mixture proportioning and properties of testing concrete

The concrete was produced 0.45 w/c ratios and the maximum coarse aggregate size (D_{max} = 32 mm) that are generally used in hydraulic structures. In the study, concrete with 7 different mixing ratios proportions were designed to compare the results with each other. The mixture proportioning and properties of testing concrete are shown in Table 1. Fly ash and blast furnace slag were used to replace 10, 20, 30 wt.% of the cementitious materials in the 6 different mixture designs.

Test Technique

The abrasion resistance of concrete was evaluated according the "underwater method" complies with American Standard ASTM C 1138 [12]. The underwater method simulates the natural conditions of abrasive concrete wear and can be used for the comparative analysis of the abrasive resistance of standard and high-strength concrete. In this test, the concrete sample was subjected to an abrasive charge consisting of 70 chrome steel balls circulating in water over the concrete surface. A paddle rotating at 1200 rpm was used to cause the circulation of this abrasive charge. The mass loss were measured for 72 h. 100 mm height and 300 mm diameter cylindrical concrete specimens were cast and used to evaluate the underwater abrasion resistance for each concrete. The testing machine in used for this method is shown in Fig. 2.



Fig. 2Underwater abrasion test apparatus



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D. Abrasion Test Results

The results are analyzed and discussed in detail in regard to relevant published research findings. For abrasion resistance measurements, tests were performed at concrete age of 90 days. The density of sand mix with water was maintained same which is 100 kg/m^3 . The abraded specimen is shown in Fig. 3.



Fig. 3 Abraded surface of the concrete specimen by water-sand jet

Two types of mineral additive materials (fly ash and blast furnace slag) were used to observe the effect of mineral additive materials on the abrasion resistance of concrete. Fig. 4 shows the weight loss of the concrete due to the abrasion.



Fig. 4 Weight loss of the concretes due to the abrasion test



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In general, it is observed that, for each type of concrete mixtures, abrasion loss decreases with the increasing age. According to the results of abrasion test, the weight loss of 90 days of reference concrete was 1.45%. According to the test results, the best abrasion resistance was found in BFS10 concrete samples. The BFS10 concrete mix decreased by 26.90% at 90 days of age as weight loss by Reference. FA10 concrete mixture exhibited wear loss at about the same value as the Reference concrete. BFS20 and BFS30 concrete showed better wear results than the other FA20 and FA30 concrete.

When the results of abrasion test are examined, it is seen that the abrasion resistance values are directly proportional to the compressive strength, and at the same time, BFS-added concretes have good results in visually observed abrasion resistance compared to FA-added concrete.



Fig. 5 Relationship of compressive strength and abrasion loss

When a concrete specimen is subjected to the abrasion test according to the method used in this study with the force exerted by the water jet, pressure, tensile and shear forces are generated on the sample surface. From literature, it has been already established that the strength of concrete has a profound impact on the abrasion resistance of concrete. Fig. 5 illustrate the relationship between abrasion loss and compressive strength. In a nutshell, the abrasion loss decreases when the concrete strength increases. Coefficients of determination (R^2) was used to correlate the concrete compressive strength with the abrasion loss. The figures clearly show that if compressive strength increase, the abrasion rate decrease which coincides with the previous research.

IV. CONCLUSION

The aim of the study was to evaluate the abrasion resistance of different concrete specimens due to the underwater method. The experimental study was helpful to understand the influence of mineral additive materials regarding the abrasion erosion problem in hydraulic structures and will help to achieve a viable engineering solution for this particular problem. The conclusions drawn from the results of this study can be summarized as follows:

- In this study, fly ash and blast furnace slag were used in the concrete mix designs by reducing the amount of cement in the evaluation of waste. In this way, concretes resistant to abrasion have been produced with an environmental and economic solution.
- Seven types of the concrete mixture were used in the study. Among all seven mixture, BFS10 exhibited better abrasion than others. FA10 comes after blast furnace slag mixture in terms of abrasion resistance. The worst abrasion resistance was exhibited by 30% added mineral additives concrete. Test results proved that the use of mineral additives in appropriate proportions can improve the abrasion resistance of concrete.



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Abrasion mass loss is strongly correlated to compressive strength in most cases. With the increment of compressive strength, abrasion loss decreases linearly. The higher the compressive strength of concrete, the better the abrasion resistance.

Mineral additive concrete mixtures were used for the study where the limitation was that the amount, percentage of fly ash and blast furnace slag were fixed. Experiments with different concentration of these materials would help to analyze more accurately on their contribution to abrasion resistance. Also, different concrete mixtures can be designed to investigate the effects of abrasion.

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REFERENCES

- Liu, Y. W., "Abrasion-Erosion Resistance of High Performance Concrete Used As Overlay Material of Hydraulic Structures", PhD 1. Dissertation, Department of Civil Engineering, University of Chung-Hsiung, Taiwan, 2005.
- 2. ACI Committee 210, "Erosion of Concrete in Hydraulic structure (ACI 210R-03)", ACI Manual Concrete Practice, Part 1, American Concrete Institute, Farmington Hill, MI, 2003.
- 3. James, R. G. C., "Erosion of Concrete in Hydraulic Structure", Reported by ACI Committee 210, ACI manual Practice, Part 1, 1998.
- Liu, Y. W., Yen, T., Hsu, T. H., "Abrasion Erosion of Concrete by Waterborne Sand", Cement and Concrete Research, Vol. 36, pp. 1814-4. 1820, 2006
- Henk, W., Miko, C. E., "A Closer Look at The Ductile-Brittle Transition in Solid Particle Erosion", Wear, Vol. 253, No. 9, pp. 1035-1043, 5. 2002
- Galvao, J. C. A.,"Abrasive Effects Observed in Concrete Hydraulic Surfaces of Dams and Application of Repair Materials", Abrasion 6. Resistance of Materials, Ed. By Marcin Adamiak, Published by Intech, Rijeka, Crotia, 2012.
- 7. Kumar, G. B., Sharma, U. K., "Standard Test Methods for Determination of Abrasion Resistance of Concrete", International Journal of Civil Engineering, Vol. 5, No. 2, pp. 155-162, 2014.
- Kryzanowski, A., Mikos, M., Susteric, J., Planinc, I., "Abrasion Resistance of Concrete in Hydraulic Structures", ACI Materials Journal, Vol. 8. 106, No. 4, pp. 349-356, 2009.
- 9. Horszczaruk, E. K., "Hydro-Abrasive Erosion of High Performance Fiber-Reinforced Concrete", Wear, Vol. 267, pp. 110-115, 2009.
- 10. Horszczaruk, E. K., "Abrasion Resistance of High-Performance Hydraulic Concrete with Polypropylene Fibers", Tribologia, pp 63-72, 2012.
- EN 197-1, "Cement-Part 1:Composition", Specifications and Conformity Criteria for Common Cements, CEN Brussels, Belgium, 1992.
 ASTM Designation C1138, "Standard Test Method for Abrasion Resistance of Concrete (Underwater Method)", American Society for Testing and Materials, Philadelphia, 1998.