Assessment of Mechanical and Non Destructive Properties of Heavy Density Concrete Subjected to Acid Attack

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Abstract

Heavy-density concrete plays a pivotal role in providing structural integrity and radiation shielding in critical infrastructure. However, exposure to acidic environments poses a significant challenge, potentially compromising the material's durability and mechanical properties. This research examines the mechanical and non-destructive properties of heavy-density concrete produced by integrating grit iron scale aggregates as coarse aggregate in concrete and the utilization of silica fume as a supplementary cementitious material. The experiments involve preparing samples using 25% and 50% Heavy Weight Grit Iron Scale (HWGS) Aggregate along with 15% silica fume. Concrete specimens were tested for slump, compressive strength and rebound hammer after 28 days of curing. The water-cured specimens were exposed to 10% of sulfuric acid (H_2SO_4). The findings indicated that concrete containing 25% HWGS exhibited superior acid resistance in comparison to the other concrete mixes while achieving maximum compressive strength.

Keywords: Acid Attack, Grit Iron Scale, Heavy Density, Silica Fume

1. Introduction

Concrete is a readily available and cost-effective material that can be used to create complex structures. It consists of various light and heavy-weight aggregates that possess excellent properties for absorbing and slowing down photons and neutrons emitted from a radiation source [1]. A concrete is classified as HWC if its density exceeds 2600 kg/m3. Hence, heavy-weight aggregates are characterized by a specific gravity exceeding 3000 kg/m3 [2]. Nevertheless, concrete is frequently exposed to harsh environments, which can be naturally occurring (such as saltwater), man-made (such as compound wastewater from industries), or a result of waste foundation squander water. These elements have an impact on the long-term performance of concrete [3]. When sulfur dioxide from the atmosphere or sewage water comes into contact with concrete, sulphuric acid can attack the material. Because the sulfate ion participates in sulfate attack, sulphuric acid is especially corrosive [4]. Sulphuric acid (H2SO4), which can be extremely harmful to concrete nuclear power plant components as well as conventional concrete structures, is found in groundwater, industrial wastes, and sewage [5].

The heavy-weight concrete containing 0% and 15% silica fume incorporated barite and ilmenite as coarse and fine aggregates. SF-enhanced concrete displayed enhanced resistance against sulfate attack while RHA-infused concrete demonstrated commendable durability [6]. The silica fume content in the cementitious material studied in the sulphuric and acetic acid attack was 5%, 10%, and 15% by mass. The incorporation of silica fume enhanced the concrete's resistance to sulphuric acid attack [7].

In this experimental study, heavy-density grit iron scale aggregates and silica fume are utilized in concrete to assess its physical and mechanical properties. Several tests were conducted, including slump, compressive strength and rebound hammer tests before and after the acid attack up to 28 days. This study will help to provide valuable insights into the durability and service life of heavy-density concrete in corrosive environments.

2. Materials and Methods

In this investigation, ASTM Type-1 Ordinary Portland Cement (OPC) has been employed. Fine aggregate collected from a local vendor (Lawrancepur origin) with Fineness modules 2.6 was used. Normal weight Coarse Aggregate (NCA) from Margalla has been collected and utilized The Heavyweight Grit Iron Scale (HWGS) density of 3943 kg/m^3 was obtained from the foundry section of the Heavy Mechanical Complex (HMC) located in Taxila, Pakistan. The physical and chemical properties of NCA and HWGS are given in Table 1.

Table 1. Chemical Composition and Physical Properties of NWA and HWGS

Chemical composition	NWA Value%	HWGS Value%	Physical properties	NWA Value%	HWGS Value%
Fe	0.44	95	Specific gravity	2.4	6.63
Si	43.21	1.67	Bulk density(gcm^{-3})	1.44	3.94
Mn	0.03	1.20	Hardness	7	9
C	-	1.20	Melting point °C	-	1430
Cu	0.04	<0.2	Color	Light grey	grey
Ni	0.06	<0.15	Shape	Angular	Angular
Mg	4.69	-	Water absorption %	1.20	0.9
Ca	8.67		water	-	1.3

For the compressive strength test, cubical molds of the control mix (having no Heavy Weight Grit Iron Scale (HWGS) aggregates and Heavy-density Concrete were cast under controlled laboratory conditions. The Normal weight Coarse Aggregate (NCA) was replaced with 25% and 50% HWGS designated as HDC1 and HDC2, respectively and as a supplementary cementitious material,15% silica fume was utilized.

The concrete cubic specimens of dimensions 152×152×152 mm were cast in the laboratory. Slump values were used to evaluate the workability of fresh concrete following the guidelines outlined in ASTM C 143/C 143M – 03. Then, the specimens were kept at 25 ±1 °C for 24 hours. After demolding, the concrete samples were allowed to be cured for 28 days at room temperature in tap water and then immersed in sulphuric acid (10% of H_2SO_4) for 28 days. At 28 days of immersion, the specimens underwent compressive testing as per specifications laid by ASTM C 39/C 39M – 03, and non-destructive properties like rebound hammer to the reference samples after curing in tap water for up to 28 days. The experimental program is shown in Figure 1. Chemrite SP303 superplasticizers were used to control the workability. Using the volume method, HWGS was substituted for NCA in the HDC mixes, consistently upholding a water-to-cement ratio of 0.5. Moreover, for non-destructive evaluation, Rebound Hammer tests according to the specifications of ASTM C805-02 were also carried out on concrete cubes.

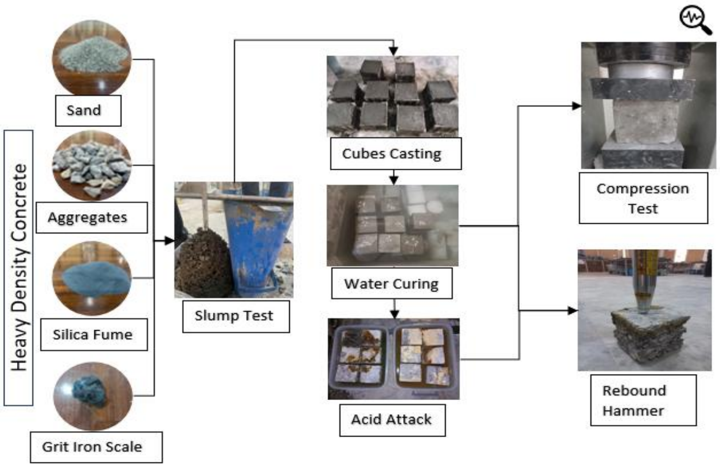

Figure 1. Experimental Program

3. Results

3.1. Slump

The variations of slump value concerning grit scale content are shown in Figure 2. The slump value for the normal concrete was 50.8 mm, whereas HDCI and HDC2 showed a slump of 54.4 mm and 64 mm, respectively. The slump is increasing by increasing the content of HWGS.The observed variations in slump can be ascribed to the increased density of the HWGS particles incorporated into the HDC mix. These particles possess a higher specific gravity, leading to their preferential settlement. The use of silica fume tended to reduce workability which is why a superplasticizer was used which increased the flow ability of the mix without affecting its strength [8].

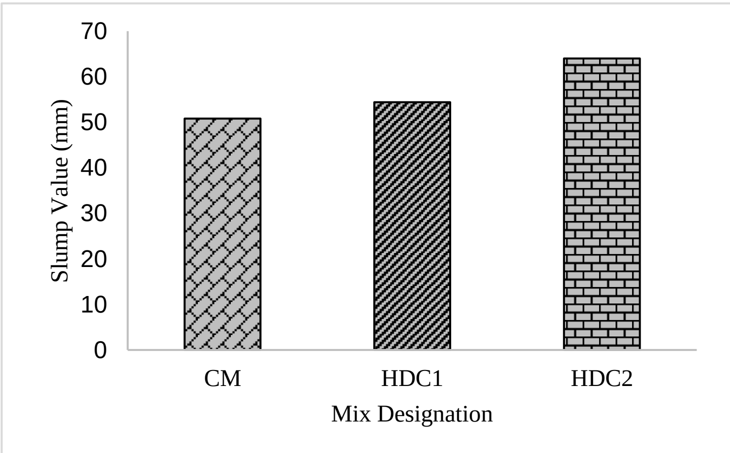

Figure 2. Slump Values

3.2. Compressive Strength

The relationship between the compressive strength and the concentration of HWGS is illustrated in Figure 3. The compressive strength observed before acid attack for CM, HDC1 and HDC2 was 18, 20 and 19 MPa, respectively. Whereas, after the acid attack, the compressive strength observed for CM, HDC1 and HDC2 was 10.68, 11.15 and 8.25 MPa, respectively. The results show that up to 25% replacement of NCA with HWGS, the maximum strength was achieved and proved to be more durable in a corrosive environment. The grit scale aggregate tends to make stronger bonds due to its irregular and angular texture [9].

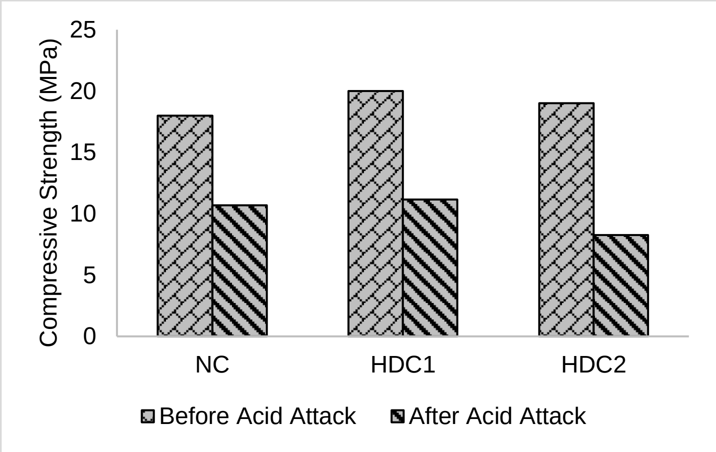

Figure 3. Compressive Strength

3.3. Rebound Number

The rebound hammer results before the acid attack indicate that the maximum value at the centre for NC was found to be 34 and lies in the "Good Layer" of the concrete quality. The lowest was noted for HDC2, which was found to be 24 and lies in the “Fair Concrete” category. The rebound hammer result is shown in Figure 4. Whereas, after the acid attack, a significant effect on the corners was examined tending to reduce the rebound hammer resulting in lying in the “Poor Concrete” category. The maximum rebound number for the centre was obtained for NC to be 27 and the minimum value of 20 was found at HDC1. Moreover, the maximum rebound number for the corner was obtained for HDC2 to be 14 and the minimum was found at NC to be 11.

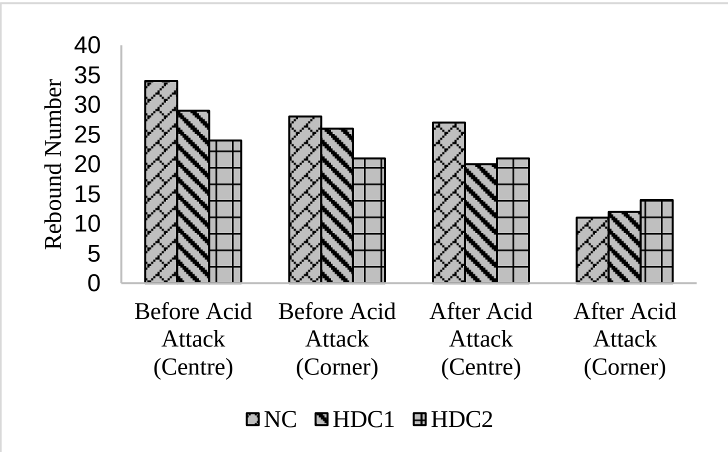

Figure 4. Rebound Number

4. Discussion

This investigation utilized heavyweight grit iron aggregates to evaluate concrete's mechanical and durability properties. The following conclusions were made:

1. Control samples, concrete incorporated with 25% and 50% grit scale showed slump values of 50.8mm, 54.4mm and 64mm, respectively. The slump increases as the HWGS content increases.
2. Concrete mix containing 25% replacement of grit scale showed a maximum compressive strength of 20 MPa and 11.15 MPa before and after the acid attack, respectively. This is because an excellent interlocking effect was observed in the grit scale, and the incorporation of silica fume exhibited superior resistance against acid corrosion.
3. Maximum rebound number before the acid attack at the center and corner was observed to be 34 and 28, respectively for the control sample. Whereas, after the acid attack, a maximum number

at the center and corner was observed for the control sample and concrete mix containing 50% replacement of grit scale, respectively. Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

Acknowledgments: The HoD foundry section, HMC, Taxila, Pakistan, and the concrete lab team are greatly appreciated by the authors. We are grateful for the anonymous reviewers' thorough examination and helpful recommendations.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

HWGS	Heavy Weight Grit Iron Scale
H_2SO_4	Sulfuric Acid
NCA	Normal weight Coarse Aggregate
OPC	Ordinary Portland Cement
HDC1	25% Replacement of HWGS
HDC2	50% Replacement of HWGS

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