DURABILITY OF CONCRETE IN WHICH FINE AGGREGATE IS SOIL

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ABSTRACT

In this experimental investigation concrete was produced using soil as fine aggregate instead of river sand. Concrete with a nominal mix of 1:1:2 and strength of 25 MPa was adopted. Standard test specimens were cast and tested to determine the durability properties such as resistance to acid and alkali attack, elevated temperature, abrasion, and impact, and porosity characteristics, and observed to possess better sustainability under the action of these agents. It was observed that the percentage loss of mass in respect of soil concrete against acid attack was 1.28 and that of sand concrete was 1.82 which is about 29 per cent over that of soil concrete. Corresponding values against alkaline attack were 0.775 for sand specimen and 0.795 for soil specimen, respectively. The mass loss in respect of soil specimen against alkaline attack was 2.6 per cent higher than that of sand specimen. Nonetheless the loss of mass for both soil and sand against chemical attack was meager and the values were almost the same for all practical purposes. The residual compressive strength of soil concrete after exposure to elevated temperature of 300°C was 33.75 N/mm^2 for soil specimen and 34.5 N/mm^2 for sand concrete which is 2.2 per cent higher than that of soil specimen. Overall it was concluded that durability of concrete containing soil as fine aggregate was on par with that of sand as fine aggregate and hence soil can be used successfully in the preparation of concrete.

Keywords: Concrete, Fine aggregate, Soil, Testing, Durability Properties

1. INTRODUCTION

The construction industry in India accounts for about 11 per cent of its Gross Domestic Product (GDP) [1]. It contributes significantly to the national economy and provides employment to large number of people. In the construction activity, concrete plays an important role and at present a large quantum of concrete is being utilized. River sand is one of the major constituents used in the production of conventional concrete [2]. The substantial use of concrete increases the consumption of large quantities of the river sand too. However, river sand is the only material acquired naturally and used without any modification or process. So, sand has become a preferred material in making concrete resulting in its exploitation. The continuous consumption of river sand leads to its scarcity. Also, it affects the living organisms of river severely because its surface goes downwards along with river bed. As a consequence of this, storing capacity of river is reduced leading to severe water scarcity during lean season. Considering all these factors the National Green Tribunal of India has banned mining of river sand [3].

For conserving the natural resources and preservation of environment, there is an imperative need to develop alternative materials for replacing natural sand. Many alternative materials such as flyash, bottom ash, granite powder, copper slag, wood waste, etc., are available to replace river sand but their availability at all places in adequate quantity is in doubt. So, use of soil as fine aggregate is explored in this investigation because it is omnipresent and available in abundance.

The basic properties of both soil and sand concrete were determined by conducting various tests. Using the soil hundred per cent as fine aggregate, concrete of 25 MPa with mix proportion of 1:1:2 and w/c ratio of 0.45 was prepared in casting the control specimens like cubes, cylinders and prisms. After 28 days of water curing the specimens were tested to evaluate the strength. First, ultrasonic pulse velocity (UPV) was conducted on the cube specimens to ascertain the quality. The compressive strength, split strength, and flexural strength of concrete made of soil and sand were determined by appropriate testing. Complete details of the determination of different strength properties of concrete prepared with soil as fine aggregate have been published elsewhere by Thandavamoorthy [4].

Durability is an important engineering property of concrete, which determines the service life of concrete structures significantly. Due to the interaction of concrete with external agents, the mechanical and physical properties of concrete may be endangered. The factors endangering the life of the concrete structures are freezing and thawing, abrasion, corrosion of steel, chemical attack, etc. [5]. The objective of the present investigation is to investigate the durability properties of soil concrete. The paper presents the results pertaining to the durability aspect of concrete containing soil as fine aggregate as well as the conclusions drawn therefrom.

2. REVIEW OF LITERATURE

Natural aggregates are becoming scarce and continued use of these aggregates in the production of concrete is degrading the environment. Thus, it is becoming inevitable to use alternative materials for aggregates in concrete which include recycled aggregates, fly ash, manufactured sand, crushed rock powder, etc. The use of such materials not only results in conservation of natural resources but also helps in maintaining good environmental conditions. The investigation carried out by Nagabhushana and Sharada Bai [6] studied the properties of mortar and concrete in which Crushed Rock Powder (CRP) was used as a partial and full replacement for natural sand. For mortar, CRP was replaced at percentages of 20, 40, 60, 80 and 100. The basic strength properties of concrete were investigated by replacing natural sand by CRP at replacement levels of 20, 30 and 40 per cents.

The suitability of crushed granite fine (CGF) to replace river sand in concrete production for use in rigid pavement was investigated by Manasseh [7]. Slump, compressive and indirect tensile strength tests were performed on fresh and hardened concrete. The 28 days compressive and indirect tensile strength values of 40.70 N/mm^2 and 2.30 N/mm^2, respectively, were obtained with the partial replacement of river sand with 20 per cent CGF, as against values of 35.00 N/mm^2 and 1.75 N/mm^2, respectively, obtained with the use of river sand as fine aggregate. Based on economic analysis and results of tests, river sand replaced with 20 per cent CGF is recommended for use in the production of concrete for use in rigid pavement. Conservation of river sand in addition to better ways of disposing wastes from the quarry sites are some of the merits of using CGF.

Aggarwal et al. [8] have carried out experimental investigations to study the effect of use of bottom ash (the coarser material, which falls into furnace bottom in modern large thermal power plants and constitute about 20 per cent of total ash content of the coal fed in the boilers) as a replacement of fine aggregates. Different strength properties studied consisted of compressive strength, flexural strength and splitting tensile strength. The strength development for various percentages of 0 - 50 replacement of fine aggregates with bottom ash was easily equated to the strength development of normal concrete at various ages.

Research about the use of residues from industrial processes and waste incinerators in concrete production is a positive advance in sustainable development by saving natural resources and decreasing waste volume stored at landfills. Today, modern solid waste incinerator plants produce bottom ashes, which are used in building industry. To evaluate the effect of bottom ash on concrete, concrete specimens were produced with ordinary Portland cement CEM I 32.5 R and aggregates according to the grading curve of B32, whereby the aggregates from 2 to 32 mm particle size were replaced by the treated bottom ashes. Their engineering properties, such as workability, compressive strength, dynamic modulus of elasticity, frost resistance and ASR stability were studied. The results showed that the additional treatments improved the quality of the concrete. Thus, according to Rübner et al., [9] concretes with a compressive strength of C20/25 can easily be produced.

Siddique [10] presented the results of an experimental investigation carried out to evaluate the mechanical properties of concrete mixtures in which fine aggregate i.e., sand was partially replaced with Class F fly ash. Sand was replaced in five percentages. i.e., 10, 20, 30, 40 and 50 of Class F fly ash by weight. Tests were performed for properties of fresh concrete. Compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity were determined at 7, 14, 28, 56, 91 and 365 days. Test results indicated significant improvement in the strength properties of plain concrete by the inclusion of fly ash as partial replacement of fine aggregate (sand), and could be effectively used in structural concrete.

Seif [11] reported that the fine aggregates of Egyptian dunes were considered as an important natural source of fine aggregate making them a major component in concrete and mortar mixes. The dune sands in Kharga Oasis were composed mainly of quartz, feldspars and trace amounts of other minerals. The silt and clay contents were negligible. Using the USCS-classification, the studied dune sands were poorly graded sand. Texturally, these dune sands were consisting of rounded spherical grains with less abundant angular components. Based on the grain-size, textural, mineralogical and chemical results obtained in this study, it was recommended that dune sands in Kharga Oasis could be used as fine aggregates in cement mortar.

The objective of the paper by Hamza et al. [12] was to utilize marble and granite waste of different sizes in the manufacturing of concrete bricks, with full replacement of conventional coarse and fine aggregates with marble waste scrapes and slurry powder of content up to 40 per cent. The bricks produced were tested for physical and mechanical properties according to the requirements of the American Standards for Testing Materials (ASTM) and the Egyptian Code. The test results revealed that the recycled products had physical and mechanical properties that qualified them for use in the building sector, where all cement brick samples tested in this study complied with the Egyptian code requirement for structural bricks, with granite slurry having a positive effect on cement brick samples that reached its optimum at 10 per cent slurry incorporation.

Acid attack is a topic of increasing significance, owing to the spread of damage to concrete structures in both urban and industrial areas. This generally occurs where the calcium hydroxide is attacked vigorously, although all the Portland cement compounds are susceptible to degradation. Acidic solutions of both mineral (such as sulphuric, hydrochloric, nitric, and phosphoric acids) and organic (such as lactic, acetic, formic, tannic, and other acids produced in decomposing silage) are about the most aggressive agents to concrete. Depending on the type of acid, the attack can be mainly an acid attack, or a combination of acid followed by a salt attack. It cannot cause deterioration in the interior of the specimen without the cement paste on the outer portion being completely destroyed. The rate of penetration is thus inversely proportional to the quantity of acid neutralizing material, such as the calcium hydroxide, C-S-H gel, and limestone aggregates. In practice, the degree of attack increases as acidity increases; attack occurs at values of pH below about 6.5, a pH of less than 4.5 leading to severe attack. The rate of attack also depends on the ability of hydrogen ions to be diffused through the cement gel (C-S-H) after calcium hydroxide Ca $(OH)_2$ has been dissolved and leached out [13].

Curing of concrete plays a major role in developing the microstructure and pore structure of concrete and therefore its durability and performance were improved. Due to its alkaline nature, concrete in general is susceptible to acid attack causing the components of the cement paste to decompose [14]. Reddy and Reddy [15] conducted experimental investigation to understand the behaviour of High Performance Concrete (HPC) subjected to attack by HCL, NaOH, and combined $MgSO_4$ and $NaSO_4$.

The addition of supplementary cementitious materials (SCM) reduces the heat of hydration of concrete and extends its service life in structures by improving its durability and strength. Some of the commonly used SCMs are flyash, silica fume and metakaoline which are used as partial replacement of cement.

The goal of study conducted by Siad et al. [16] was to compare the behaviour under hydrochloric and sulphuric acid attack of a SCC-containing Algerian natural pozzolan with SCC-containing fly ash and limestone filler additions. The changes in mass loss and compressive strength loss for each acid solution within the test period were recorded. After 28 days of curing, the samples were immersed in hydrochloric sulphuric acid solutions for a period of 12 weeks. The Scanning Electron Microscope (SEM) and XRD analysis were used to better understand the mechanism of deterioration of each type of concrete. In spite of their economical properties, the results confirmed that the use of Algerian natural pozzolan contributed to the improvement of resistance of SCC under sulphuric and hydrochloric acid attacks.

Türkel et al. [5] conducted study with the objective of comparing the acid resistance of a pozzolanic cement (CEM IV-A/32·5) with Portland cement (CEM I 32·5) that was made from the same clinker. For this purpose, 50 mm mortar cubes were prepared with two different kinds of cement according to TS EN 196-1. After 28 days of hardening, the samples were immersed into four different concentrations of hydrochloric, nitric and sulphuric acid solutions for a period of 120 days. The changes in mass loss and compressive strength values for each acid solution within the test period were recorded. The acid resistance of mortars made from Portland cement was better than the pozzolanic cement incorporated samples after 120 days of acid attack.

In the study conducted by Elsayed [17] effects of mineral admixtures on water permeability and compressive strength of concretes containing silica fume (SF), fly ash (FA) and super pozzolan (SP) were experimentally investigated. Permeability of concrete was determined through DIN 1048 (Part 5). The research variables included cement type, ordinary Portland cement (OPC) or high slag cement (HSC), and mineral admixtures content was used as a partial cement replacement. They were incorporated into concrete at the levels of 5, 10 and 15 per cents for silica fume and 10, 20 and 30 per cents for fly ash or super pozzolan by weight of cement. Water-cement ratio of 0.40 was used and tests were carried out at 28 days. From the tests, the lowest measured water permeability values were for the 10 per cent super pozzolan and 10 per cent silica fume or 20 per cent fly ash mixes. The highest compressive strength of concretes determined was for 10 per cent silica fume mix with ordinary Portland cement and was reduced with the increase in the replacement ratios for other mineral admixtures than ordinary Portland cement concrete.

Naganathan and Linda [18] conducted investigation to study the effect of fly ash fineness on the durability of cement mortar. The durability properties such as water absorption and sorption showed a decreasing trend with the increase of fly ash fineness; whereas the strength increased with the increase of fineness. It was concluded that increasing the fineness of fly ash increased the strength and reduced absorption by 15 per cent and hence was an effective method to improve its performance in cement mortar.

3. EXPERIMENTAL PROGRAMME

It was observed that various non-conventional materials had been used earlier as a substitute for river sand in making concrete. However, the availability of these waste materials all over the country was doubtful and some of them were also priced. Therefore only omnipresent material is soil and also available in abundance. Because of this consideration it was decided to make use of the soil in the production of concrete in place of river sand. Figure 1 shows the sample of soil and Fig. 2, the sand.

As discussed earlier soil is omnipresent and hence before selecting the soil as fine aggregate it was confirmed that the soil satisfied the properties of river sand for use in the manufacturing of concrete. The main property of the soil was that it should conform to the grading curve similar to that of sand since it indicated the particle size distribution of the sample. It was very important since all sizes of particles would fill the gaps and avoid porosity in concrete and densify it further thus giving a good strength.

It was proposed to make use of the excavated soil available at a construction site in the campus as a substitute for river sand because this would avoid dumping of this unused soil in low lying areas causing problem to the society. In this investigation soil was used as a replacement to sand to an extent of 100 per cent. First, gradation of the soil along with grain size was established by testing it. Figure 3 shows the gradation curve of soil and the same was compared with the river sand.

Fig. 1 Local Soil

Fig. 2 River Sand

4. DURABILITY OF SOIL CONCRETE

In concrete technology, durability refers to the resistance against degradation. The primary factor determining durability is a good-quality concrete with low porosity, i.e., low permeability. The other advantages of durable concrete include resistance to alkali-silica reaction and sulphates, increased corrosion protection, and reduced heat of hydration [19].

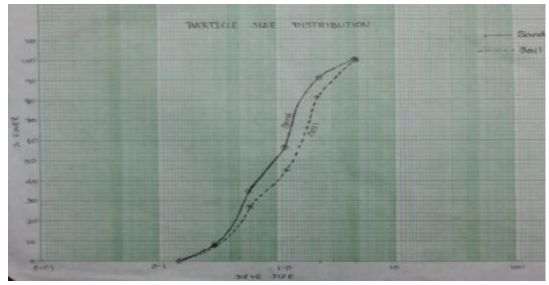

Fig. 3 Gradation curves of soil and sand

According to ACI Committee Report 201 [20] durability of Portland cement concrete is its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. A durable concrete will retain its original form, quality and serviceability when exposed to its environment. It has generally been observed that water is the primary agent of deterioration. It can be a cause of many physical processes of deterioration, or it can be a vehicle for transport of aggressive ions which cause chemical process of deterioration. The movement of water in concrete is controlled by the permeability of concrete. Permeability is the most important indicator of durability of concrete. Concrete is a basic material; therefore, acidic waters are more harmful to concrete. ACI Committee Report 201 [20] has classified chemical attacks into several types that include; acidic attack, alkali attack, carbonation, chloride attack, leaching and sulphate attack. It can be accepted as a general rule that acids are deleterious to concrete. In this investigation durability tests were planned to evaluate acid and alkali attack, porosity, fire resistant, abrasion and impact resistance characteristics.

4.1 Acid Test

In this test both soil and sand cubes after standard curing of 28 days were weighed and immersed in a 5 per cent HCl solution for 30 days (Fig. 4). Afterwards their weights were noted. From this weight loss of concrete was calculated.

Fig. 4 Cubes under Acid Attack

4.2 Alkaline Test

In this investigation after normal curing of 28 days both soil and sand cubes were taken out and weighed. For alkaline test, 5 per cent sodium hydroxide solution was prepared. Then cubes were immersed in the prepared sodium hydroxide solution for 30 days. Afterwards cubes were taken out and weighed (Fig. 5). From this the weight loss was calculated.

Fig 5 Cubes under Alkaline Attack

4.3 Porosity and Water absorption

The porosity, i.e., the volumetric proportion of voids, of concrete was used extensively for the prediction of the properties of concrete [21]. The objective of the investigation conducted by Claisse [22] was to compare three different measurements of porosity, to show how effective they were as predictors of durability performance related properties of concrete and to show how the predictive models were affected by the use of silica fume (SF) in the concrete. Porosity is one of the major parameters which influence the strength and durability of concrete. The porosity of a porous material, such as cement paste, mortar, concrete and other porous material could be determined by measuring any of two quantities; bulk volume, pore volume or solid volume. As stated by Khan [23] the porosity was the fraction of the bulk volume of the material occupied by voids.

Porosity test was conducted in this investigation using 100 mm cubes of both soil and sand concrete. Cubes were dried in oven for 24 hours at 100°C. Then the dry weight of cubes was noted. Afterwards, the cubes were immersed in water for 24 hours. The weight of the wet cubes was taken. Then differences in weight between dry and wet cubes were calculated. This yielded the weight of water absorbed. This water weight divided by its density resulted in the volume of voids which was considered as porosity.

The water absorption of concrete is the procedure that involves drying a specimen to a constant weight, taking its weight afterwards, immersing it in water for specified amount of time, and weighing it again. The increase in weight as a percentage of the original weight is expressed as its absorption in percent. According to Shah and Pitroda [24] the average absorption of the test samples shall not be greater than 5 per cent with no individual unit greater than 7 per cent.

4.4 Thermal Test

The thermal test was conducted to find out the fire resistance capacity of soil and sand concrete. The specimens were kept in oven after 28 days of curing at 300ºC for 6 hours (Fig. 6). During the test colour changes and cracks were observed for every hour. After the test, samples were cooled in the atmosphere. Then they were tested under compression.

Fig. 6 Cubes in Oven

4.5 Abrasion Test

This test was conducted to find out the resistance capacity of concrete against abrasion. The broken prism samples after completing the flexure test were collected for performing abrasion test. These samples were weighed before testing. Then 6 steel balls along with these samples were put in the Los Angles Abrasion testing machine and rotated for 15 min constantly. Afterwards the abraded sample was weighed (Fig. 7). The same procedure was followed for both soil and sand sample. The abrasion loss percentage was then calculated.

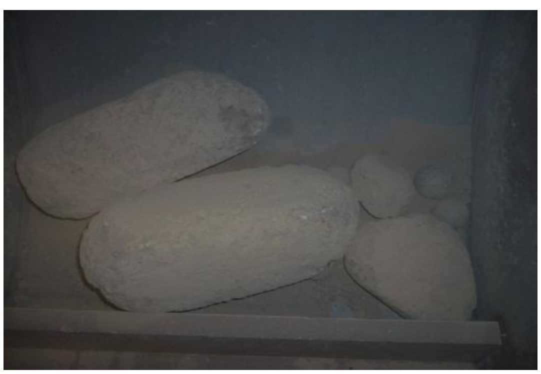

Fig. 7 Samples after Abrasion test

4.6 Impact test

Impact test was conducted to find out the impact resistance of the specimens. The broken soil specimens were taken for this test. The constant weight of 10 kg was impacted on the sample as free fall with height 75 cm. The number of blows was counted for every sample until the crack was formed (Fig. 8). The same procedure was repeated for sand sample also to compare the impact resistance of both sand and soil samples.

5. RESULTS AND DISCUSSION

The durability of concrete prepared using soil and sand were investigated and the properties obtained from different tests are presented in this section and discussed further. They have beenarranged in the sequence of acid test, alkali test, porosity, and fire resistance.

Fig. 8 Failure due to Impact test

5.1 Acid test

Acid test results are shown in Table 1. From the result it would be observed that the percent loss of mass of soil concrete was 1.28 per cent on an average and that of sand concrete was 1.82 per cent which was 29 per cent higher than that of the former. Reddy and Reddy [15] have reported a mass loss of about 1.8 percent in respect of conventional concrete of M60 grade after 90 days of immersion in acid. Chatveera and Lertwattanaruk [25] have reported a weight loss of 5 per cent in the case of concrete prepared from OPC and river sand after immersion in HCl solution for 30 days. According to Madhan Gopal and Naga Kiran [26], the weight loss of conventional concrete after immersion for 28 days in 1 per cent HCL solution was 3.76 per cent. However, overall the percentage loss of both soil and sand concretes was much lower and hence soil concrete with very low values was more durable and possessed strong resistance to acid attack.

Table 1 Test result of acid attack on concrete

S. No.	Type of Concrete	Avg. weight before immersion in acid	Avg. weight after immersion in acid	Loss (kg)	Loss (%)
1	Soil	2.602	2.57	0.032	1.23
		2.556	2.522	0.034	1.33
2	Sand	2.532	2.486	0.046	1.82
		2.530	2.484	0.046	1.82

5.2 Alkaline Test

Tests were carried out to obtain weight loss of soil concrete and sand concrete. Alkaline test results are shown in Table 2. From the result it would be observed that the weight loss in the case of sand concrete was 0.775 per cent and that of soil 0.795 per cent. Pitroda et al [27] have reported a loss of mass of 0.16 per cent in the case of normal concrete after immersion in 5 per cent NaOH solution for 56 days. Reddy and Reddy [15] have reported a mass loss of 1.6 per cent in the case of normal High Performance Concrete after immersion for 90 days in 5 per cent NaOH solution. Therefore the values obtained in the present investigation are comparable and hence justifiable.

5.3 Porosity

Porosity test were conducted using 100 mm cubes. The porosity values of soil concrete are shown in Table 3 and sand concrete in Table 4. The porosity for soil concrete on the average was 7.05×10^{-5} m^3. Corresponding value for sand concrete was 2.6×10^{-5} m^3. From the results it would be observed that porosity value was higher for soil concrete than sand concrete. It is because the fineness percentage, as is evident from grading curve, between 40 and 90 soil has more coarse particles than sand. As the porosity is higher for soil concrete the water absorption is also more with an average value of 2.82 per cent than the value of 1.01 per cent for sand concrete.

5.4 Thermal test

The specimens of both soil and sand concrete were tested for thermal resistance. During and after exposure to elevated temperature, there was no formation of crack or change in colour for all samples. The result of residual compressive strength of these specimens after thermal test is shown Table 5 for soil concrete and in Table 6 for sand concrete. The average weight loss of soil concrete was 6.4 per cent and the average residual compressive strength was 33.75 per cent. In the case of sand concrete weight loss was 2.54 and the residual compressive strength was 34.5 per cent. The weight loss of soil concrete was 152 per cent higher than that of sand concrete. As can be observed from Table 3 and Table 4 the water absorption of soil concrete was 179 per cent higher than that of sand concrete. When the concrete was subjected to elevated temperature higher quantity of impounded water got evaporated and hence weight was reduced. However, overall the weight loss of soil concrete was less than the general permissible value of 10 per cent. Not much significant change in the residual strengths of both concretes was noticed.

Table 2 Results of alkali attack on concrete

S. No.	Type of concrete	Avg. weight before immersion in alkaline solution	Avg. weight after immersion in alkaline solution	Loss (kg)	Loss (%)
1	Sand	2.586	2.584	0.02	0.77
		2.566	2.564	0.02	0.78
2	Soil	2.546	2.544	0.02	0.79
		2.504	2.502	0.02	0.80

Table 3 Porosity result of soil concrete

Sample	Dry weight after 24 hrs of 100°C heating (kg)	Wet weight after 24 hrs of immersion in water (kg)	Water absorption (%)	Porosity (m^3)
1	2.471	2.540	2.792	6.9×10^{-5}
2	2.524	2.596	2.852	7.2×10^{-5}

Table 4 Porosity result of sand concrete cube

Sample	Dry weight after 24 hrs of 100°C heating (kg)	Wet weight after 24 hrs immerse in water (kg)	Water absorption (%)	Porosity (m^3)
1	2.612	2.634	0.842	2.2×10^{-5}
2	2.548	2.578	1.18	3.0×10^{-5}

5.5 Abrasion test

The broken samples from flexural test were tested for abrasion. The results are shown in Table 7 for soil concrete and in Table 8 for sand concrete. Average loss of mass of soil concrete was 25.27 per cent and that of sand was 24.27 per cent. There is no significant change in mass loss of both concretes.

Table 5 Residual compression of soil concrete after elevated temperature

Sample	Initial Weight After 28 Days of Curing (kg)	Final Weight After 6 Hrs of 300°C Heating (kg)	Mass loss (%)	Compressive Strength (N/m^2)
1	2.645	2.478	6.31	29.5
2	2.547	2.382	6.48	38.0

Table 6 Residual compression of sand concrete after elevated temperature

Sample	Initial Weight After 28 Days of Curing (kg)	Final Weight After 6 Hrs of 300°C Heating (kg)	Mass loss (%)	Compressive Strength (N/mm^2)
1	2.650	2.568	3.09	26
2	2.612	2.560	1.99	43

5.6 Impact test

In impact test was conducted on broken samples obtained from flexural test on prisms. The numbers of blows are almost equal for both soil and sand sample. It is shown in Table 9.

Table 7 Test Result of Abrasion Test

Samples	Initial Weight (kg)	Final Weight (kg)	Mass Loss (%)
1	6.75	5.587	17.23
2	2.631	1.675	36.34
3	6.515	5.065	22.23

Table 8 Test Result of Abrasion Test

Sample	Initial Weight (kg)	Final Weight (kg)	Mass Loss (%)
1	9.96	6.6	33.73
2	7.489	5.987	20.05
3	8.04	6.39	20.52

Table 9 Results of impact test

Broken Sample	Weight (kg)	No. of blows
Soil	6.0	19
Sand	6.0	18

6. CONCLUSIONS

In this experimental investigation the durability properties of soil and sand concretes such as acid attack, alkaline attack, thermal resistance, porosity characteristics, abrasion resistance and impact resistance were determined. With regard to acid test, the mass loss after 30 days of 5 per cent HCl solution was 1.82 per cent for sand concrete and average of 1.28 per cent for soil concrete. Even though the mass losses in both concretes were very meager, it was quite obvious that resistance of soil concrete against acid attack was better than that of sand concrete. The mass loss under alkaline attack of sand concrete was 0.775 per cent whereas that of soil concrete was 0.785 per cent. Values of both concretes were obviously very negligible but the resistances of both concretes were almost the same. The average porosity of soil concrete was 7.05×10^{-5} m^3 and that of sand concrete was 2.6×10^{-5} m^3. The porosity of soil concrete was 2.71 times higher than that of sand concrete. Similarly, water absorption of soil concrete was 2.82 per cent as against 1.81 per cent for sand concrete. The reason for higher porosity and water absorption of soil concrete was that soil contained more coarse particles between 40 and 90 per cent when compared to sand.

Under elevated temperature the weight loss of soil concrete was higher by 152 per cent than sand concrete. The porosity of soil was 2.71 times greater than that sand. The reason for this was soil contained 179 per cent more impounded water than sand which on evaporation led to higher mass loss in the case of soil concrete. Average loss of mass of soil concrete under abrasion test was 25.27 per cent and that of sand was 24.27 per cent. There is no significant change in mass loss of both concretes. Under impact test the number of blows sustained by both concretes was almost the same. Therefore it was concluded from this investigation that the behaviour of soil concrete was similar to that of sand concrete in all aspects within that range of variability of parameters. Hence soil is a suitable material to be used as fine aggregate in the preparation of concrete. This would also give a relief to the construction industry when it is faced with scarcity of river sand.

REFERENCES

[1] Ashok Kumar, P., Iyyappan, M., Anandaraj, A., and Prakash, R.. "Strength and Durability Properties of Hollow Block using Concrete Containing Local Soil as Fine Aggegate." Project Report, Department of Civil Engineering, Adhiparasakthi Engineering College, Melmaruvathur, April. 2013, 50 pp.

[2] Neville, A.M. and Brooks, J.J., "Concrete Technology," Pearson Education India, New Delhi, 2008, 452 pp.

[3] Urmi Goswami, "Illegal Sand Mining: National Green Tribunal Bans Sand Mining across the Country," ET Bureau, The Economic Times, Mumbai, August 5. 2013, p. 5.

[4] Thandavamoorthy, T.S., "Feasibility of Making Concrete from Soil instead of River Sand," ICI Journal, Vol. 13, No. 3, April-June 2014, pp. 7-12.

[5] Türkel, S., Feleko ğ lu B, and Dulluç, S., "Influence of Various Acids on the Physico–Mechanical Properties of Pozzolanic Cement Mortars," Sādhanā, Vol. 32, No. 6, 2007, pp. 683–691.

[6] Nagabhushana, K. and Sharada Bai, H., "Use of Crushed Rock Powder as Replacement of Fine Aggregate in Mortar and Concrete," JSS Academy of Technical Education, Bangalore, India, 2011.

[7] Manasseh, S., "Use of Crushed Granite Fine as Replacement to River Sand in Concrete Production" JOEL, Civil Engineering Department University of Agriculture P.M.B. 2373, Makurdi, Benue State, Nigeria, 2010.

[8] Aggarwal, P., Aggarwal, Y., and Gupta, S.M., "Effect of Bottom Ash as Replacement of Fine Aggregates in Concrete," National Institute of Technology, Kurukshetra, India, 2007.

[9] Rübner, K., Haamkens, F., Linde, O., "Use of Municipal Solid Waste Incinerator Bottom Ash as Aggregate in Concrete," Geophysical Research Abstracts, Vol. 9, No. 03435, 2007, European Geosciences Union.

[10] Siddique, R., "Effect of Fine Aggregate Replacement With Class-F Fly Ash on the Mechanical Properties Of Concrete," Institute of Engineering and Technology, Deemed University, Patiala, India, 2002.

[11] Seif, E. S. A., "Performance of Cement Mortar Made with Fine Aggregates of Dune Sand, Kharga Oasis, Western Desert, Egypt: An Experimental Study." Jordan Journal of Civil Engineering, Vol. 7, No. 3, 2013. *Pp.* 270-284.

[12] Hamza, R. A., El-Haggar, S. and Khedr, S., "Marble and Granite Waste: Characterization and Utilization in Concrete Bricks," International Journal of Bioscience, Biochemistry and Bioinformatics, Vol. 1, No. 4, 2011, pp. 286-291.

[13] Nirmalkumar, K. and Sivakumar, V., "Acid Resistance Behavior of Concrete Made Using Untreated and Treated Tannery Effluent," Modern Applied Science Vol. 3, No. 1, January 2009, pp. 139-143.

[14] Boel, V. , Audenaert, K., De Schutter, G., " Chemical Attack of SCC: Immersion Tests and X-ray CT " In: Concrete Repair, Rehabilitation and Retrofitting II, Alexander et al (eds), Taylor & Francis Group, London, ISBN 978-0-415-46850-3, 2009, pp. 167-173.

[15] Reddy, M.V.S. and Reddy, I.V.R., "Studies on Durability Characteristics of High Performance Characteristics," International Journal of Advanced Scientific and Technical Research, Vol. 6, Issue 2, December 2012, pp. 226-234.

[16] Siad, H., Mesbah, H.A., Khelafi, H., Kamali Bernard S., and Mouli, M., "Influence of Natural Pozzolan on the Behavior of Self-Compacting Concrete under Sulphuric and Hydrochloric Acid Attacks, Comparative Study," The Arabian Journal for Science and Engineering, Vol. 35, No. 1B, April 2010, pp. 183-195.

[17] Elsayed, A. A., "Influence of Silica Fume, Fly Ash, Super Pozz and High Slag Cement on Water Permeability and Strength of Concrete," Jordan Journal of Civil Engineering, Vol. 5, No. 2, 2011, pp. 245-257.

[18] Naganathan, S. and Linda, T., "Effect of Fly Ash Fineness on the Performance of Cement Mortar." Jordan Journal of Civil Engineering, Vol. 7, No. 3, 2013, pp. 326-331.

[19] Ayub, T., Shafiq, N., Khan, S.U. "Durability of Concrete with Different Mineral Admixtures: A Review." International Journal of Civil, Architectural Science and Engineering, Vol. 7, No. 8, 2013. pp. 17-28.

[20] ACI Committee Report 201, "Guide to Durable Concrete." ACI Manual of Concrete Practice, American Concrete Institute, Detroit, 2001.

[21] Neville, A. M. "Properties of Concrete." 4th edn., Longman, London, 1995.

[22] Claisse, P. A., Cabrera, J. G. and Hunt, D. N. "Measurement of Porosity as a Predictor of the Durability Performance of Concrete with and without Condensed Silica Fume." Advances in Cement Research, Vol. 13, No. 4, 2001, pp. 165-174.

[23] Khan, M.I., "Novel Method for Measuring Porosity of High Strength Concrete." Proceedings of the 7th Saudi Engineering Conference, (sec7) 2004, pp. 1-10.

[24] Shah, D. S. and Pitroda J., "An Experimental Study on Durability and Water Absorption Properties of Pervious Concrete." International Journal of Research in Engineering and Technology (IJRET), Vol. 3, No. 3, 2014, pp. 439-444.

[25] Chatveera, B. and Lertwattanaruk, P., "Durability of Conventional Concretes Containing Black Rice Husk Ash," Journal of Environmental Management Vol. 92, 2011, pp. 59-66.

[26] Madhan Gopal, K. and Naga Kiran, B., "Investigation on Behaviour of Fly Ash Based Geopolymer Concrete in Acidic Environment," International Journal of Modern Engineering Research (IJMER), Vol. 3, Issue 1, January-February 2013, pp. 580-586.

[27} Pitroda, J., Zala, L.B., Umrigar, F.S., "Strength Assessment of Fly Ash Concrete with Water Containing Sodium Hydroxide," IOSR Journal of Engineering (IOSRJEN), Vol. 3, Issue 11, November, 2013, pp. 30-37.

BIOGRAPHY

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