Study on Engineering Properties of Concrete by using Terminalia Chebula Powder as Natural Admixture

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Abstract

In the recent past, attempts are vigorously made to enhance the fresh state and hardened properties of concrete. Hence to get high strength concrete with good rheology, natural admixtures are progressively used to the concrete during mixing stage. In this study, the influence of natural admixture Kadukkkai (Terminalia Chebula) on the engineering properties of high strength concrete has been investigated. Compressive strength, workability pore size and porosity distribution were assessed in order to enumerate the effect of Herbocrete (Kadukkkai) on the concrete. The results show that it has considerable effect on the workability of concrete. Pore size and porosity were decreased with the addition of the Herbocrete in the range of < 20 nm. The strength of the concrete has been increased with addition of plant extract at constant slump and hence hardened concrete properties are improved by the use of kadukkai extract.

Keywords: *Herbocrete, Kadukkai extract, Strength, Workability, Porosity, Pore size distribution.*

I. INTRODUCTION

The basic elements for human life are food, clothes and shelter. Among these, shelter is considered as a costlier one in the modern life. People around the world are dreaming to construct their dream house in their life time. But the constructions of buildings are very expensive in the present situation. Construction industry is the second largest in India. In recent past, attempts are being made to enhance the fresh state and hardened properties by addition of chemical admixtures in concrete. This use of chemicals in construction leads to different types and different levels of pollution and while producing of these chemicals emits toxic gases like CO_2 to the environment which significantly contributes to global warming. The chemicals are also patented products which are imported into developing countries and sold at exorbitant prices. To prevent this, natural admixtures such as Broiler hen egg, natural rubber latex, gram-flour, ghee and triphala have been employed in the concrete ([1]-[3]). Keeping the above argument in mind this study is carried out to prove that natural organic plant extract can also be use as alternative to chemical admixture.

More over the latest technologies and innovations are out into the modern world and researchers are working on cement and concrete in different aspects. Usually, cement is manufacture from the factory with specific chemical properties namely in market we can see ordinary cement, Portland cement and Portland Pozolonic cement. The main differences of these products are, during the powdering of clinkers gypsum is added to enhance the setting of cement like these products are called as Additives. Similarly, admixtures are also the products added to concrete which are other than ingredients of concrete such as cement, coarse aggregate and water which exhibit a specific property.

The use of natural admixtures as part of binders for concrete has been increasing throughout the world, particularly in the production of high strength and high performance concrete. This is due to the potential ability of these natural materials to enhance the properties and performance of concrete through their filler effect, as well as pozzolanic reaction. The inclusion of different natural admixtures normally alters the properties of concrete to a certain degree both in the fresh and hardened states. For example, the use of fly ash and metakaolin could retard the setting times of strength of concrete with constant dose of super-plasticiser and similar water/binder ratio [4]. In general, the use of low-cost materials in concrete has been associated with the refinement of the concrete pore structure. This in turn could affect the properties of concrete in the fresh and hardened states, including strength, deformation and durability performance ([5]-[9]).

Our research group aim to studying the possibilities of using KADDUKKAI (Terminalia chebula) as admixture in concrete in order to ensure an eco-friendly greener construction with sufficiently high strength, enhanced durability at reasonably low cost. Concrete is a mixture of Cement, Sand, Coarse aggregate and water. Concrete is one of the versatile building materials used in building technology and that can fit any structural shape as required. A good characteristic of concrete depends on the quality of the constituent material and the mix proportions of each constituent used. To obtain high workable concrete, normally much water is used than the required to hydrate the cement. The amount of water used is indirectly related to the strength of concrete. This research work was undertaken to determine the suitability of plant extract as an eco-friendly and economical admixture for concrete.

II. EXPERIMENTAL METHODS

A. Materials

The Kadukkai powder was used as a natural admixture in the concrete. The natural quartzite gravel with 10 mm size and natural river sand were used as the aggregates. The similar water/binder ratio of 0.28 was employed for the concrete mixtures with same quantity of super-plasticiser consequently that the workability changes due to the effect of the natural admixture. The control mix was directed using ordinary Portland cement (OPC) while the other mixture was prepared by replacing a few part of the cement with the natural admixtures at three different replacement levels on mass-for-mass basis. Without using admixture, the control mixtures of normal strength (325/1) and high strength (450/1) were casted. The weight by cement of 2.5% natural admixture was added to both 325 and 450 ordinary Portland cement and the same has been repeated while decreasing the water quantity. The mix proportions for concrete containing natural admixtures are present in Table 1.

Table 1. Mix proportions for concrete containing mineral admixtures

S. No	Materials	OPC	HERBOCRETE
1	Cement (kgm^3)	450	405
2	Admixture (kgm^3)	--	45
3	Sand (kgm^3)	605	605
4	Gravel (kgm^3)	1100	1100
5	Water (kg/m^3)	120	120
6	SP (kgm^3)	15	15
7	Slump (mm)	100	220

B. Compressive strength

Compressive strength test determines the behaviour of the materials under compressive loads i.e., the specimen is compressed and the maximum sustained load is recorded. Three specimens were tested in this study and the compressive strength test was performed on 100 mm cube specimens at the age of 1, 3, 7, 14, 28, 90 and 180. Using a 3000 kN capacity concrete compression machine, the specimens were tested for compressive strength and in accordance to BS EN 12390-3 the compressive strength was determined [10].

C. Workability

The workability of the fresh concrete was measured by means of the slump test in accordance to BS EN 12350-2 in the present study [11]. As per the ACI Committee 116 workability describes as ‘‘that possessions of freshly mixed concrete or mortar that concludes the ease with which it can be consolidated, placed, mixed, and finished to a homogenous mass’’. There is no single test method measure all aspects of workability and hence sufficient workability is essential so that the concrete can be placed and compacted to maximum density.

D. Porosity and pore size distribution

Mortar samples acquired by wet sieving of fresh concrete were used for the measurement of porosity and pore size distribution. By employing the Mercury Intrusion Porosimetry (MIP) apparatus, the porosity and pore size distribution of the high strength mortars were measured. The samples were tested at the age of 28 days. The cylindrical cores of 10-mm diameter were extracted from 25-mm thick mortar slabs at the time of testing. The two ends of the cored samples were cut and discarded to ensure homogeneity of samples and the remaining piece was cut to about 10 mm long. The samples were dried in a hot air oven at 105^{o}C for 24 h before testing to remove the volatile materials such as adsorbed water to achieve the desired vacuum reading prior to mercury intrusion.

III. RESULTS AND DISCUSSIONS

A. Influence of mix properties on concrete

The influence of the plant extract on the normal and high-strength concrete is shown in Table 2. From these results, it can be seen that the effect of adding 2.5 % Herbocrete to mix OPC325/2, and adding 5.0% of Herbocrete mix to OPC 325/3 while reducing equal volume of water, is to increase setting times by 9% and 6%, respectively. Mix OPC325/2 showed a slightly higher increase compared to mix OPC325/3. This can be attributed to the higher (water + Herbocrete)/cement ratio. With the same cement content and aggregate grading, the setting times of concrete are governed by the water/cement ratio; the lower the water/ cement ratio the shorter the setting times. In addition, the effect of the plant extract in reducing the surface tension of water could reduce the inter-particles force of attraction of the flocculated binder phase and retard the setting times.

The Herbocrete was used in combination with super-plasticiser; the increase in setting time was more significant and consistent, even when the water was reduced. The latter reasoning could also be used to explain the smaller increase of 6% in setting times exhibited by mix OPC325/3 for the high-strength concrete mixes. When a comparison is made between the setting times of mix OPC325/1 and mix OPC450/1, there seems to be a significant difference. Although the OPC325/1 mix has a much higher water/cement ratio than the OPC450/1, its setting times are much lower. Thus, the effect of super-plasticiser could have offset the influence of water/cement ratio and retarded the setting times. In general the results obtained in this study on the effect of the Herbocrete are in agreement with those reported by the manufacturer [12].

Table 2. Mix proportions for concrete containing the Herbocrete

S. No	Concrete mix	OPC (kg/m^3)	Sand (kg/m^3)	Gravel (kg/m^3)	Water (kg/m^3)	SP (kg/m^3)	Herbocrete (kg/m^3)	Slump (mm)
1	OPC325/1	325	757	1138	179	--	--	60
2	OPC325/2	325	757	1138	179	--	6.5	120
3	OPC325/3	325	757	1138	172	--	6.5	75
4	OPC450/1	450	675	1125	126	14	--	85
5	OPC450/2	450	675	1125	126	14	9	95
6	OPC450/3	450	675	1125	116	14	9	105

B. Influence of Herbocrete on compressive strength of concrete

The results reveal that the addition of the Herbocrete influences the compressive strength of the concrete mixes, as given in Table 3 and shown in Figs. 1. The 28-day cube compressive strength was found as 93.5 MPa and 114.7 MPa for OPC and Herbocrete respectively as presented in Table 3. The effect of replacing part of the cement with Herbocrete is a reduction in the early strength, as well as low early strength development of the concrete. At day 1, due to a dilution effect, there is a significant reduction in relative strength, with a greater and consistent reduction at higher replacement levels. However, this strength reduction effect decreases with curing time. After 28 days of moist curing, the relative strength of the 2.5% and 5.0% concrete was 97%, and 95%, respectively. Therefore, the Herbocrete concrete develops early strength at a slower rate than the OPC concrete. This can be attributed to the slower rate of pozzolanic reaction between Herbocrete and lime generated by the OPC hydration. The results obtained here are generally in agreement with the established effect of Herbocrete on the strength of lower- strength concrete mixes. At later ages, the Herbocrete concrete mixes exhibit greater strength development than the OPC concrete as the relative strength continues to increase with curing times (Fig. 1). After 90 days of curing all Herbocrete concrete mixes show higher strength than the control concrete. Thus, the optimum level of Herbocrete replacement to produce maximum long-term strength was found to be 35.0%.

Table 3. Compressive strength of concrete mixes at different testing ages (n/mm^2)

S. No	Testing age	OPC	Herbocrete
1	1-day	49.8	55.4
2	3-day	68.4	74.3
3	7-day	81.2	95.6
4	28-day	93.5	114.7
5	90-day	121.1	130.2

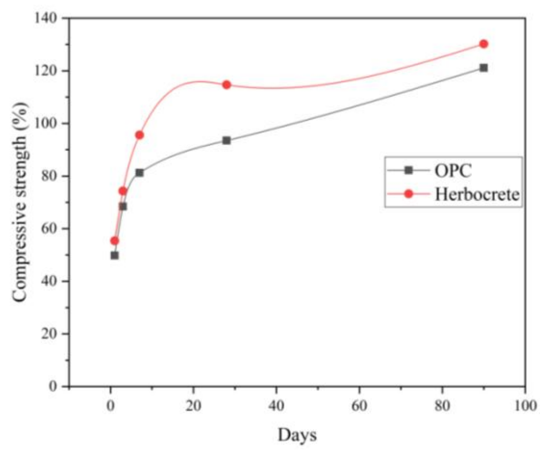

Fig.1 Effect of Herbocrete on relative compressive strenath of concrete

C. Influence of Herbocrete on workability of concrete

The results of the slump test are given in Table 2. From the results, it is clear that the Herbocrete used in the concrete mixes influence the workability of concrete. The effect of replacing part of the cement with 5% and 10% Herbocrete is that the workability of concrete improves; however, there is a decreasing effect as replacement levels of Herbocrete increase from 5% to 10%. On the other hand, at a higher replacement level of 15%, there is a marginal reduction in workability compared to the OPC concrete. The improvement in workability at lower contents of Herbocrete could be explained as due to the combined effect of super-plasticiser as well as the particle characteristic of Herbocrete. The super-plasticiser improved workability by dispersing the cement and Herbocrete particles through its adsorption and electrostatic repulsion mechanisms. At the same time, the Herbocrete which is known for its extreme fineness and having spherical shape could provide additional water reduction through its potential ball-bearing effect [13].

D. Effect of Herbocrete on porosity and pore size

The summary of the MIP test results, i.e. values of porosity, median pore diameter, average pore diameter, and total intrusion volume is tabulated in Table 4, the pore size of the mortars is divided into several ranges of size from <20 nm to greater than 50 nm to assess the influence of the Herbocrete on pore size distribution. The effect of the Herbocrete on the porosity, pore size and pore size distribution of high strength mortar is thoroughly investigated.

Table 4. Summary of test results for pore structure of mortar

S. No	Properties	OPC	Herbocrete
1	Porosity (%)	15.04	14.47
2	Relative reduction (%)	-	15.0
3	Median pore diameter (nm)	41.1	33.8
4	Relative redoction (%)	-	17.4
5	Averge pore diameter (nm)	37.1	24.8
6	Relative reducion (%)	-	41.1
7	Total intrusion volume (ml/gm)	0.0591	0.0521

From the Fig.2 and Table 4, it is evident that the effect of the Herbocrete is that they reduce the porosity of the high strength mortars. In comparison to the OPC mortar, the mortars containing Herbocrete exhibited a reduction in porosity almost 15.0%. Table 4 gives the value of total intrusion volume for both OPC and Herbocrete mortar samples. The total intrusion volume is independent of the shape and size of the pores; it is the cumulative volume of all pores in the mortar sample intruded by mercury, which may give an indication of the porosity of the sample. In term of pore size, the general effect of the Herbocrete is that they significantly reduce the mean pore size and average pore size of the high strength mortars. The overall observations that the use of Herbocrete generally reduces the pore size are in agreement with previous findings of others ([14], [15]).

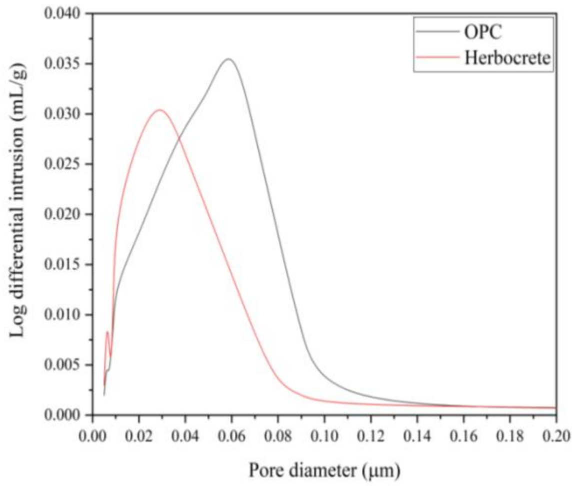

Fig.2. Pore size distribution of OPC and Herbocrete

IV. CONCLUSIONS

The following conclusions can be made from the results presented above in this paper.

- The addition of the plant extract significantly influences the compressive strength of the concrete mixtures. The strength of the concrete has been increased with addition of plant extract at constant slump and hence hardened concrete properties are improved by the use of kadukkai extract. The effect of hebocrete was enhanced the compressive strength of the concretes at all ages, particularly between the ages of 28 and 90 days.
- The plant extract increased the workability of concrete at constant liquid to cement ratio and hence fresh concrete properties are improved by the use of kadkkai extract. By comparing test results, the slump value has been increased up to 40% for Herbocrete than plain concrete. Greater effects were observed at higher replacement levels.
- The effect of plant extract is to reduce the porosity of mortar measured using the MIP apparatus, while the mean and average pore sizes are significantly reduced for all mortars containing Herbocrete. Water absorption percent has been decreased in it when compared to plain concrete. From the results, there is an average decrease of 15.0% in porosity for Herbocrete when compared to plain concrete.
- The effect of the plant extract is to increase the volume of mesopores in the ranges of <20 nm and 15–30 nm, but to significantly reduce the percentage of macropores. The mortars containing Herbocrete show significant increase in the percentage of mesopores in the range of < 20 nm.

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