An Experimental Study on the Effect of Fresh & Sea Water on Recycled Coarse Aggregate Cement Concrete

Nazish Farooqui[1] Rahul Sharma[2] Akash Jaiswal[3]
[1]M.Tech. Student [2,3]Professor
[1,2,3]Department of Civil Engineering
[1,2,3]Prashanti Institute of Technology & Science, India

Abstract— Environmental issues such as climate alteration and related global warming, reduction of natural resource and biodiversity, water and soil pollution, creation of vast quantity of waste materials and their disposal are some of great challenges faced by present day civilization. Recycling of materials and salvage of the material is very important. Recycled concrete aggregates are used in concrete in replacement of nominal concrete aggregates, replacement of various percentages like 10, 20 & 50% have been done. Cubes are curing in sea water solution. After the duration of 7 & 28 days cubes have been tested. This study also enhance the performance of the fresh and hardened properties of a proposed green concrete mixed using construction and demolition waste as a recycled aggregate curing with fresh and sea water. Fresh and hardened properties of the concretes, including workability, strength gain, drying shrinkage, permeability, and microstructure, were characterized and studied. The study reveals that the use of seawater and RCA together has substantial effects on concrete performance. These strategies, however, somewhat reduce the green aspect of the proposed seawater-mixed concrete with RCA.

Keywords: Concrete, Recycled Coarse Aggregate, Construction & Demolition Waste, Sea Water, Compressive Strength, Tensile Strength, Curing

I. Introduction

Concrete is the most widely used man made construction material in the world. Concrete is a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregate. In hydraulic-cement concrete, the binder is formed from a mixture of hydraulic cement and water (Mehta & Montario). Concrete in the broadest sense, is any product or mass made by the use of a cementing medium. Generally, this medium is the product of reaction between hydraulic cement and water. But, these days, even such a definition would cover a wide range of products; concrete is made with several types of cement and also contains pozzolana, fly ash, blast-furnace slag, micro silica, additives, recycled concrete aggregate, admixtures, polymers, fibres, and so on, and these concretes can be heated, steam-cured, autoclaved, vacuum-treated, hydraulically pressured, shock-vibrated, extruded, and sprayed. The mixture when placed hardens into rock like mass known as concrete. The hardening is the result of the chemical reaction between cement and water which continues along with time; as a result concrete hardens with ages. The matrix of concrete is very simple; the larger aggregates called as coarse aggregate (size range between 40mm to 4.75mm) have voids which are filled by sand or fine aggregate (size range between 4.75mm to 75µ). The voids of fine aggregates are filled by cement and water paste. In addition to filling the voids, the cement water paste also coats the surfaces of fine and coarse aggregates and binds them together in the compacted solid mass.

India is a developing country and the need of infrastructure demand is increasing at a larger extent. This demand to be fulfilled requires a large quantity of resources as aggregate, sand, cement etc. As these materials which were at abundance at some time, are going to be finished in near future due to increase in the intervention of mankind.

At the same time, scope exists for the development of new or improved technologies for construction using alternate materials. The mineral aggregates, associated binders and modifiers used in the industry at present, occur in sufficient quantities to satisfy the current demands. Alternative materials are unlikely to be found in sufficient quantities for building construction to replace existing materials and the objective of these new or improved technologies should therefore, be focused on utilizing the currently available materials in a more efficient and cost-effective manner. In addition, consideration of the environment through sustainable development of buildings is of paramount importance. This is applicable to both new construction and rehabilitation works, with the latter placing emphasis on recycling as focal point in future technologies.

Indiscriminate mining of sand and other minor minerals has caused extensive damage to the environment, scarred rivers, made many areas susceptible to floods, and destroyed the crucial recharge zones. In 2012, the Supreme Court had asked state governments to amend the rules to regulate mining of minor minerals and ensure environmental management. On August 5, 2013, the National Green Tribunal (NGT) declared sand mining without environmental clearance as illegal. However, the concern for a deteriorating environment is being seen in the context of a growing shortage of these materials. The Union ministry of housing and urban poverty alleviation had told the Rajya Sabha in 2012 about the shortage of building material, especially for aggregates and concrete owing to mining bans/restrictions on environmental grounds. The shortage has been so severe that several civic projects in India are facing delays. This is aggravating the housing crisis and affecting the construction of roads, bridges, canals, etc. If sand mining and other naturally sourced materials have to be restricted and regulated, other strategies must be put in place to reduce demand.

II. Objective

The following are the objectives of the research work:

– To study about the properties of recyclable aggregates.
– To study the effect of sea water on the strength of concrete mixes.
– To save natural aggregates for future needs.

III. MATERIALS USED

A. Cement

Ordinary Portland Cement (OPC) of 43 grade is taken for this project, as per IS: 8112-1989.

B. Sand

The sand taken for this project was tested for water absorption, specific gravity, bulk density and particle size grading as per IS: 2386 (I & III). Sand in each test was taken after sampling it as per IS: 2430-1969.

C. Coarse Aggregates

The available coarse aggregate is of two types: a) on basis of size as 20mm and 10mm, b) on basis of source as natural and C & D waste. These two aggregates are tested to know various physical properties such as size, toughness, hardness etc. These aggregates were tested as per Indian Specifications to ensure the quality of the aggregate. The test performed are water absorption (as per IS: 2386 part III-1963), specific gravity (as per IS: 2386 part IV-1963), flakiness and elongation value test, impact test (as per IS: 2386 part IV-1963), crushing value (as per IS: 2386 part IV-1963) and Los Angles abrasion value (as per IS: 2386 part IV-1963).

D. Water

Water used in concrete mix is potable water conforming the specification of IS 456:2000. Water used for mixing is free from injurious amount of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete.

E. Salt Water/ Sea Water

The salt water prepared in laboratory with mixing common salt in the fresh water. The amount of NaCl was fixed as 35gm/litre to make 'artificial' sea water.

IV. DESIGN MIX

Mix Design of Concrete and Material Requirement for Mix (Based on IS 10262 and IRC 44). The mix used for study was M40 grade and the ingredients are as follows:

Stipulations for proportioning

Grade Designation	M40
Type of Cement	OPC 43
Maximum nominal size of aggregate	20 mm
Minimum cement content	325 kg/m^3
Maximum water cement ratio	0.5
Workability	20 mm
Degree of supervision	Good
Type of aggregate	Crushed angular aggregates
Maximum cement content	425 kg/m^3
Chemical admixture type	Superplasticizer

– Test data for materials

A. Specific gravity

Cement	3.16
Coarse aggregate 20mm	2.72
Coarse aggregate 10mm	2.70
Fine aggregate	2.63

B. Water Absorption

Coarse aggregate 20mm	0.54
Coarse aggregate 10mm	0.71
Fine aggregate (Zone-3)	1.21

C. Free surface moisture

Coarse aggregate 20mm	nil
Coarse aggregate 10mm	nil
Fine Aggregate	nil

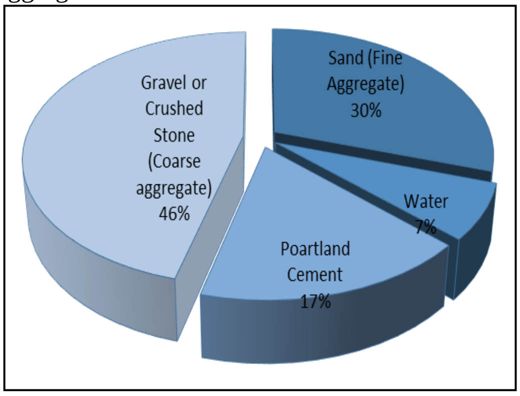

Fig. 1: Percentage constituents of Concrete as per Design

Contents	Quantity
W/C	0.38
Cement (kg)	400
Sand (kg)	728.6
20mm Aggregates (kg)	682.73
10mm Aggregates (kg)	454.4
Water (kg)	167.8
Super Plasticizer (l)	3.2
Theoretical Fresh density (kg/m^3)	2433.53
Temperature of Air (^{0}C)	20
Temperature of Concrete (^{0}C)	21

Ingredients of Concrete in 1 m^3

V. EXPERIMENTAL STUDY & RESULTS

This includes testing of different materials of concrete individually for checking its suitability for the mix. The properties of mix fairly depends on the property of material; so to get proper mix of expected strength, the material of mix should also be as per standards. Testing of concrete viz. various strength and durability criteria and their significance are discussed further.

A. Compressive Strength Test Results

Compressive strength is the most common and widely used test in concrete to measure its strength. For concrete, the cube specimens of 150*150*150 mm size are prepared. Maximum size of aggregates is restricted to 20mm. The general practice is to test the sample at 7 days and 28 days when concrete develops approximately 75% and 100% strength respectively. Ages of 13 weeks and one year are recommended if tests at greater ages are required. The concrete was tested immediately after removing it from water, wiping the surface and carefully removing any dirt, sand or other such material to have smooth even surface and rest of the specification are followed as per IS:516-1959. The strength is calculated as follows:

$f_c = P_c/A_c$
Where,
f_c= Compressive Strength of concrete
P_c = Load Sustained by cube in tonnes
A_c = Area of Concrete Exposed to loading

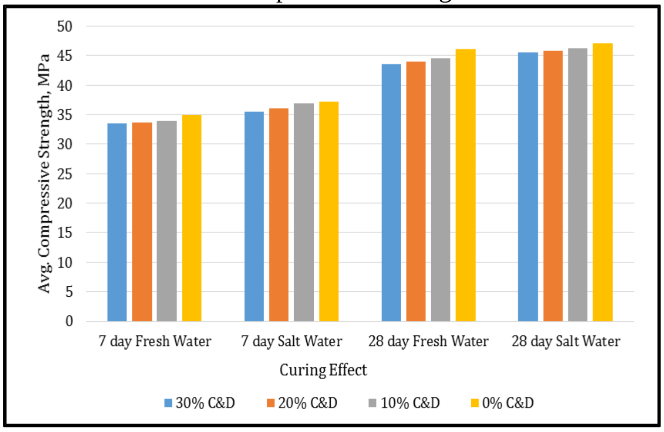

Fig. 2: Compressive Strength of Concrete

B. Tensile Strength Test Results

Concrete is known for its compressive strength and weak tensile strength but it's important to know the tensile strength as tensile stress are likely to develop in concrete due to drying shrinkage, rusting of reinforcement, temperature gradient and many such reasons, so it's important to have knowledge of tensile strength of concrete. In case of concrete slab the tensile stress are developed by two principle sources, load and volume change in concrete. Loads may cause high tensile stresses due to bending when inadequate support is there. Volume changes are due to changes in moisture and temperature generally called as warping stress.

Due to difficulty in applying uniaxial tension to a concrete specimen, the tensile strength of the concrete is determined by indirect test methods:
(1) Split Cylinder Test (2) Flexure Test.

C. Flexure Strength Test Results

For this beams are prepared of 500 mm length and 100*100 mm cross section is used. Test immediately on removal from the water while they are still in a wet condition. Concrete is wiped to remove loose material from its surface and placed in machine such that the upper face during casting is on the upper side.

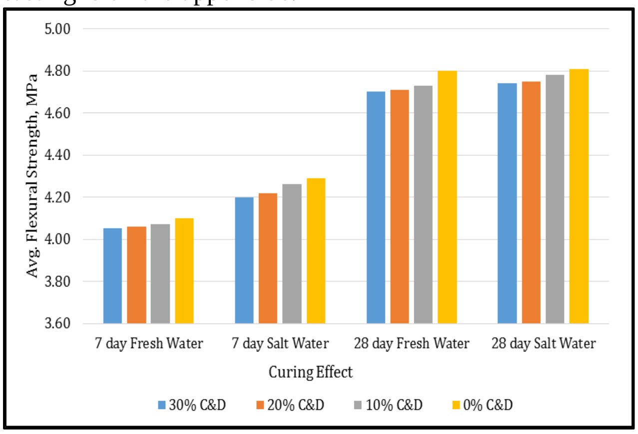

Fig. 3: Flexural Strength of Concrete

D. Split Cylinder Test Results

It is the standard test, to determine the tensile strength of concrete in an indirect way. This test could be performed in accordance with IS: 5816-1970.

A standard test cylinder of concrete specimen (300 mm X 150mm diameter) is placed horizontally between the loading surfaces of Compression Testing Machine (Fig-4). The compression load is applied diametrically and uniformly along the length of cylinder until the failure of the cylinder along the vertical diameter. To allow the uniform distribution of this applied load and to reduce the magnitude of the high compressive stresses near the points of application of this load, strips of plywood are placed between the specimen and loading platens of the testing machine. Concrete cylinders split into two halves along this vertical plane due to indirect tensile stress generated by poisson's effect.

Due to this compressive loading, an element lying along the vertical diameter of the cylinder is subjected to a vertical compressive stress and a horizontal stress (Fig-4). The loading condition produces a high compressive stress immediately below the loading points. But the larger portion of cylinder, corresponding to its depth is subjected to uniform tensile stress acting horizontally. It is estimated that the compressive stress is acting for about 1/6 depth and the remaining 5/6 depth is subjected to tension due to poisson's effect. Assuming concrete specimen behaves as an elastic body, a uniform lateral tensile stress of f_t acting along the vertical plane causes the failure of the specimen, which can be calculated from the formula as,

$$f_t = 2P/\pi DL$$

where,
f_t = Lateral Tensile Stress,
P= Compressive Load at failure
D= Diameter of Cylinder
L= Length of Cylinder

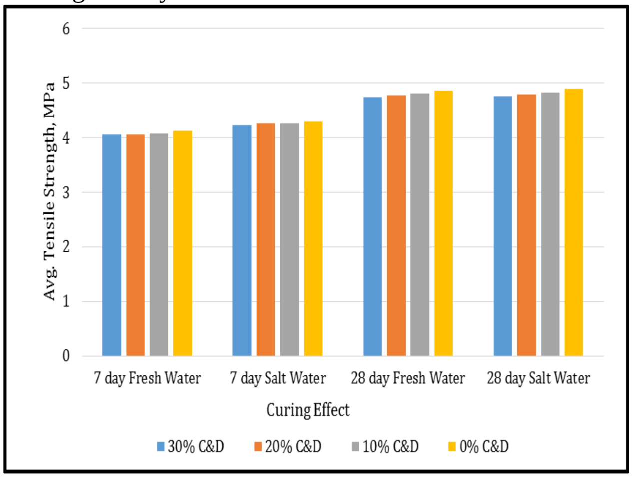

Fig. 4: Tensile Strength of Concrete

VI. CONCLUSIONS

Based on the study, the following conclusions are drawn:
– Physical properties of the C & D waste aggregates in combination with the natural aggregates show the suitability of these aggregates for construction and maintenance purposes.

- Compressive strength of concrete when cured in salt water was found to be more than that of concrete cured in fresh water.
- Flexural strength also increases in the saline water.
- Water absorption and percentage voids increase and density decreases with increase in recyclable waste material in concrete.
- The overall result states that on replacing coarse aggregate with 30% of recyclable C & D waste aggregate, the properties of concrete are enhanced; so it can be used as additive to enhance the property of concrete.

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