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EXPERIMENTAL INVESTIGATIONS OF RECYCLED COARSE AGGREGATE CONCRETE

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Abstract:

In the current era, the present day world has witnessed a phenomenal rise in construction activities over decades. The demolition of existing old structures inevitably results in the generation of construction and demolition (C&D) waste, the disposal of which is a problem causing environmental hazards. However, the composition of this waste comprises concrete material, which has a potential to be used as aggregate in making the second generation concrete. The prime objective of the present work is the effective utilization of this material as recycled aggregate by replacing normal aggregate in defined proportions so that a durable M25 grade concrete is produced.In order to achieve this objective, the characteristics of recycled aggregates procured from ten different places from Western Maharashtra have been studied. It is observed that due to lower specific gravity and higher water absorption of recycled aggregates on account of adhered mortar, the concrete prepared with such recycled aggregates adversely affects compressive strength. Therefore, a simple and most practical method has been proposed in the present work toremove adhered mortar. Further, the mix proportions of recycled aggregate concrete are required to be selected depending on these typical properties of recycled aggregates.The replacement of 0, 50, 60 and 100 percent of normal aggregates by recycled aggregates have been studied by testing 186 specimens. Substitution of 60% of normal aggregate with recycled aggregate of 20 mm maximum size gives rise to desired compressive strength when mix design methodology as devised in the present work is adopted. Durability of 105 specimens of such recycled aggregate concrete has been examined by conducting typical tests, namely rapid chloride permeability, water permeability, drying shrinkage, modulus of elasticity and creep. The results of these tests inferred that recycled aggregates behave like normal aggregates when processed for removal of adhered mortar and also provide a durable M25 grade concrete, thus vindicating the objective in its entirety.

Keywords :Mix proportions, compressive strength, chloride permeability, shrinkage.

1.INTRODUCTION: Concrete is the most widely used construction material in the world with annual consumption estimated between 21 and 31 billion tonnes (Sabnis̄, 2012). Concrete is used more than any other man-made material (Lomborg, 2001) and is the second largest material consumed by mankind after food and water (Adegbola and Dada, 2012). Mehwish *et al*., 2013 have inferred that about7.5 billion cubic meters of concrete is produced each year, more than one cubic meter for every person on the Earth. Production of concrete requires a host of material resources in terms of cement, sand and aggregates. Most of these materials used in concrete are naturally occurring and due to their extensive use are becoming scarce.

River sand sources are fast depleting and the quantity of sand required is falling short of demand.To overcome this deficit, alternative material to river sand, namely manufactured stone crushed sand, is being used in the industry in making concrete. It is a well known fact that even aggregates are depleting and an alternative resource needs to be recognized and tried. The Countries who have faced issues pertaining to shortage of supply of raw materials have already switched on to recycling for meeting their requirement. As a large proportion of this requirement can be supplemented by using the demolished material, nevertheless this secondary material needs to be assessed before being used in making second generation concrete. This work tests such demolished material as an alternative material to be used in concrete by recycling thus saving onto the natural resources and also satisfying the social and environmental objective.

Construction aggregate (coarse aggregate), or simply "*aggregate*", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are the most mined materials in the world. Aggregates are a component of composite materials such as concrete and asphaltconcrete; the aggregate serves as reinforcement to add strength to the overall composite material. Due to the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in drainage applications such as foundation and French drains, septic drain fields, retaining wall drains, and road side edge drains. Aggregates are also used as base material under foundations, roads, and railroads. In other words, aggregates are used as a stable foundation or road/rail base with predictable, uniform properties (e.g. to help prevent differential settling underthe road or building), or as a low- cost extender that binds with more expensive cement or asphalt to form concrete.

2.OBJECTIVE:

The objective of this work is to analyze and propose technical guidelines on compressive strength, performance criteria and behavior of concrete made with recycled aggregates. Forstudy of their material properties and analyze how these properties in turn affect the quality ofthe second-generation concrete.There is already very rich experience in some European countries, Japan and in the USA on quality control standards of recycled aggregates and guidance on using them in construction. Japan and other developed countries have even laid down specifications for use of recycled aggregate in concrete. Therefore it is necessary to prepare specifications for the use of this material in construction having regards to local conditions in India.Recycled aggregates are obtained from the demolished waste crushed concrete. From a quality point of view, these aggregates are heterogeneous in composition being derived from different minerals and adhered mortar. The properties of these aggregates must be determined if they are to be used in concrete, therefore an attempt is made to study the aggregate characteristics to be employed in concrete mixes.

Thus the objective of present work is;

1.To characterize the recycled aggregates in terms of physical and chemical properties and also to study the properties of concrete made with recycled aggregates, to study the durability properties and lay standard guidelines for using recycled aggregate in concrete.

2.To analyze the structural behavior of concrete made with different percentages of recycled coarse aggregates.

3.To analyze the option for the use of recycled aggregate in concrete in mainstream construction rather than using it as an infill material.

4.To ameliorate the reservations if any, for the use of recycled aggregates in

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concrete and make the industry aware of the option available on recycling and reuse.

3.MATERIALS USED METHODOLOGY:

Flow Of Work

- Identify and select the area of study.
- The materials used in the experimental investigation are locally available cement, sand, coarse aggregate, mineral and chemical admixtures. The chemicals used in the present investigation are of commercial grade.

Experimental Study

In order to study the interaction of Steel fibers (hooked end) with concrete under compression, flexure, split tension and impact, 16 cubes, 16 beams and 16 cylinders were casted respectively. The experimental program was divided into four groups.Each group consists of cubes, cylinders and beams, of 15x15x15cm, 15x30cm and 15x15x70cm respectively.

The first group is the control (Plain) concrete with 25% waste aggregate

The second group consisted of 30% waste aggregate

The third group consisted of 35% of waste aggregate

The fourth group consisted of 45% of waste aggregate

Ordinary Portland cement of 53 grade [IS: 12269-1987, Specifications for 53 Grade Ordinary Portland cement] has been used in the study. It was procured from a single source and stored as per IS: 4032-1977. Care has been taken to ensure that the cement of the same company and same grade is used throughout the investigation. The cement thus procured was tested for physical properties in accordance with the IS: 12269 – 1987.One of the most significant advantages of cement is its durability. It can withstand extreme temperatures, high pressure, and harsh weather conditions. Cement structures can last for decades, and they require minimal maintenance, making them a cost-effective option for long- term projects. Cement also provides excellent thermal insulation, which helps regulate indoor temperatures, reduces energy consumption, and improves indoor air quality. Additionally, cement is a non-combustible material, which makes it a safe option for construction in fire-prone areas.Locally available Ordinary Portland Cement of 53 grade of ULTRATECH Cement brand confirming to ISI standards has been procured and following tests have been carried out according to (22) shown in table 3.1

Table .1 Physical properties of OPC 53 grade ultra tech brand cement

S.No	Property	Test Value	Requirements as per IS: 12269 - 1987
1	Fineness of cement	4.52	10% (should not be more th
2	Specific gravity	2.99	3.15
3	Normal consistency	33%	-
4	Setting time Initial setting time Final setting time	40 minutes 6 hours	30 minutes (should not be l than) 600 minutes (should no greater than)
5	Compressive strength at 3 days 7 days 28 days	34 N/mm² 44.5 N/mm² 59 N/mm²	27 N/mm² (min) 37 N/mm² (min) 53 N/mm² (min)

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Table 3. Sieve analysis

S.No	I.S Sieve designation	Weight Retained	% of Weight retained	Cumulative % of weight Retained	% Pass
1	4.75mm	15	1.50	1.50	98.5
2	2.36mm	16	1.60	3.10	96.9
3	1.18mm	59	5.90	9.00	91.0
4	600µ	78	7.8	16.8	83.2
5	300 µ	375	37.50	54.30	45.7
6	150 µ	392	39.2	93.50	6.50
7	75 µ	60	6.0	99.50	0.50

Fineness modulus=2.78 Total =277.80

4.MIXING AND CASTING:

For each mix, the required quantities of the constituents were batched by weight and collected materials are shown in Fig. 4.1. Concrete was mixed in a 50 kg capacity drum type mixer in the laboratory. Before starting mixer machine, the mixer drum was fully washed and allowed for few minutes to dry the drum. Coarse aggregate were first placed and mixed with 40% of the calculated water for one minute. Then the fine aggregate and 30% of the water is added along with the super plasticiser. The mixing was continued for two minutes. Finally the cement, waste aggregateand the remaining water were added and mixing as continued until the fresh concrete become homogeneous. The mixing of materials is shown in Fig. 4.2.During assembling of the mould for use, the joints between the sections of mould were thinly coated with crude oil and a similar coating of crude oil was applied between the contact surfaces of the bottom of the mould and the base plate in order to ensure that no water escapes during the filling of concrete. The interior surfaces of the assembled mould also are thinly coated with crude oil to prevent adhesion of the concrete The prepared empty moulds are shown in Fig. 4.3.Test specimens were made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive latitude. Compaction was done by means of an electric vibrating table. After the top layer has been compacted, the surface of the concrete was finished level with the top of the mould, using a trowel, and covered with plastic sheets for 24 hours to prevent the evaporation of water from the concrete. The casted specimens are shown in Fig. 4.5. They were demoulded after 24 hours and cured in water at the room temperature of 25 - 28^{0}C until testing.Mixing and curing are two critical processes in concrete construction that determine the strength, durability, and performance of concrete structures. Here are a few points about mixing and curing in concrete:Mixing: Proper mixing of concrete is essential in ensuring that the mix is consistent and uniform.The mixing

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process involves blending cement, sand, water, and aggregates in specific proportions to create a workable mix. The mix should be thoroughly mixed until all ingredients are evenly distributed, and there are no lumps or clumps.Curing: Curing is the process of maintaining moisture in the concrete mix for a specific period to ensure that the mix reaches its maximum strength and durability. The curing process should start as soon as possible after the concrete is placed, and it should continue for at least seven days or longer, depending on the mix design and environmental conditions Importance of water in mixing and curing: Water is a critical component in both mixing and curing of concrete. It is needed to create a workable mix and to hydrate the cement in the mix, which creates the strength and durability of the final product. During curing, water is required to maintain the moisture content in the mix to ensure proper hydration and curing.

Fig.1 Casting cubes.

The test specimens were stored in a place, free from vibration, and at a room temperature for 24 hours from the time of addition of water to the dry ingredients. After this period, the specimens were in clean, fresh water and kept there until taken out just prior to the testing. The water in which the specimens were submerged was renewed every seven days and the specimens were not allowed to become dry at any time until they have been tested. The curing of all specimens shown in Fig. 4.6.

Fig.2 Curing of specimen

Fig. 3 Casting Cylinders.

Casting cylinders for concrete is an essential process in the construction industry for testing the strength of concrete. The process involves creating cylindrical molds using materials such as plastic, steel or cardboard, and filling them with fresh concrete.After the concrete has been poured, it is left to cure for a specified period, usually 28 days, and then subjected to a compressive force test. This test is conducted to determine the strength of the concrete, which is critical for assessing its suitability for construction purposes.

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5.RESULTS :

Table7: Compressive strength test

% Granules added	Weight (kg)			Peak load (kN)			Compressive Strength (MPa)		
	7th day	14th day	28th day	7th day	14th day	28th day	7th day	14th day	28th day
0 %	8.20	8.27	8.29	418.50	505.12	708.57	18.60	22.45	31.27
	8.10	8.17	8.22	402.75	501.07	723.37	17.90	22.27	32.15
10 %	7.96	7.99	8.00	371.5	391.90	562.20	16.50	20.40	27.90
	8.06	7.91	7.80	321.2	502.90	612.50	16.20	22.30	27.20
20 %	7.83	7.91	7.66	309	455.20	655.50	15.70	20.10	25.20
	7.60	7.76	7.75	331.6	438.00	621.50	14.80	19.40	26.60
30 %	7.83	7.75	7.80	373.9	416.30	739.40	15.40	18.50	22.80
	7.37	7.56	7.87	387.6	380.70	712.20	15.20	16.90	23.20

Fig 4: Compression test using UTM

Direct measurement of tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of the "pull" applied to the concrete. While a number of investigations involving the direct measurement of tensile strength have been made, beam tests are found to be dependable to measure flexural strength property of concrete. The value of modulus of rupture(extreme fibre stress in bending) depends on the dimension of the beam and manner of loading. The systems of loading used in finding out the flexural tension are central point loading and third point loading. in the central point loading, maximum fibre stress will come below the point of loading where the bending moment is maximum. In case of symmetrical two point loading, the critical crack may appear at any section, not strong enough to resist the stress with in the middle third, where the bending moment is maximum. It can be expected that the two point loading will yield a lower value of the modulus of rupture than the centre point loading. Since the largest nominal size of the aggregate does not exceed 20 mm, the standard sizes of the specimens used are 100 × 100 × 500 mm.Test specimens are stored in water till the time of testing. They are tested immediately on removal from the water whilst they are still in a wet condition. No preparations of surfaces have been made and the dimensions of the specimen were noted before testing. The bed of the testing machine is provided with two steel rollers, 38 mm in diameter, on which the specimen was supported, and these rollers are adjusted in such a way that the distance from the center to center is equal to.

6.CONCLUSION:

Based on the test results of the present investigation, the following conclusions are drawn. Recycled aggregate concrete (RCA) has compressive strength comparable to the natural coarse aggregate concrete compressive strength for all grades of concrete at 3, 7, 28 and 90 days. This can be attributed to the cement mortar coat of RCA participates in the hydration process and contributes additional strength. Along with strength, concrete should also be durable. The durability property of concrete is determined using RCPT on the concrete specimens prepared with natural coarse aggregate and recycled coarse aggregate. It is observed that as per ASTM C1202, the chloride penetration rate is “high” for RCA concrete and “moderate” for NCA concrete for all grades of concrete. Based on the test results, it can be recommended for the full replacement of NCA concrete with RCA concrete in structural concrete. RCA concrete can be effectively used to meet the objective of disposal of waste and also to meet the replacement for the depleting natural coarse aggregate.It has been observed that the recycled coarse aggregate is used as normal aggregate. The workability of the concrete is increased by using RCA. Maximum properties of Recycled coarse aggregate have shown good with a little variation. Recycled aggregate materials produce harsh mixes with lower workability than Natural aggregates. New standards should be introduced for recycled aggregates so that these materials can be used successfully in future.

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