EXPERIMENTAL STUDY ON THE EFFECT OF SUPER PLASTICIZER ON MECHANICAL PROPERTIES OF RECYCLED AGGREGATE CONCRETE

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***ABSTRACT**: Strengthening of concrete specimen in compression by changing the type of the concrete ingredients has been investigated in this research study. 18 cubes of size 6"x 6"x 6"and 18 cylinders of size 12"x6"dia were prepared and cured properly in curing tank and tested for compressive strength after 28 days. For this purpose ordinary Portland cement, coarse aggregate, recycled concrete aggregate, super plasticizer and sand were used. The cement used was ordinary Portland cement, the coarse aggregates used were pull 111 crush, and the sand used was local Chenab sand. These specimens were designed by ACI mix design method using assumed minimum strength of 15 MPa for M15 and 13 MPa . Three combinations were made and compared in compressive strength after 28 days with containing locally available materials. The mix designed ratio is established on the basis of the properties of respective materials. These combinations were tested in compressive testing machine by applying loading rate of 200 Kpa/s. Comparative studies between concrete cubes and cylinders was carried out in terms of compressive strength. The findings of this experimental study show that how to use proper material for construction in order to gain maximum strength using economical materials. Future research studies are recommended to be carried out to investigate the durability of these concrete cubes and cylinders.*

Keywords: Super Plasticizer; RCA; Compressive strength; Debonding;

1. INTRODUCTION

The use of super plasticizer in the concrete improves the workability and the compressive strength of concrete also increases due to lower water cement ratio. It is commonly stated that the compressive strength of concrete is more at low w/c ratio. The placing of concrete at low w/c ratio is not possible so we have to use such material (admixture) which enhances the workability of concrete. The use of recycled concrete aggregate will decrease the cost of the civil work.

In detail one of the major factors affecting the properties of RAC is the source concrete from which recycled aggregates are prepared. **S N R Shah, Muhammad Aslam, S A Shah, Raja Oad** [1] investigated the influence of parent concrete on properties of RAC. They concluded that the water absorption of recycled aggregates increases with an increase in strength of parent concrete of recycled aggregate, while it decreases with an increase in maximum size of aggregate. The ratio of mortar pieces in recycled aggregate significantly affects the properties of RAC and it has an inverse relation with the achieved strength.

A mix of high performance concrete was described by **M. Saidi, F. Ait-Medjber, B. Safi, M. Samar**[2] which is defined as a concrete with high filling capacity.

William C. Eckert and Ramon L. Carrasquillo[3] suggested the term High Performance-Concrete (HPC) for concrete mixtures that possess the following three properties: high workability, high-strength, and high durability. Durability rather than high strength appears to be the principal characteristic for high-performance concrete mixtures being developed for use in hostile environments such as seafloor tunnels, offshore and coastal marine structures, and confinement for solid and liquid wastes containing hazardous materials. Strength, dimensional stability, impermeability, and high workability are usually the principal characteristics required of high-performance concrete.

Saeed Ahmad [4] determined the mechanical properties of RAC under uniaxial loading and indicated a reduction in compressive strength, elastic modulus and ductility while an increase in peak strain of RAC with increasing the replacement level of recycled aggregates.

The properties of concrete made with recycled aggregates and super plasticizer from partially hydrated old concrete, **Amnon Katz (2003)**[5] reported a significant difference between properties of RAC and Super plasticizer made concrete of different particle size groups while the crushing age had almost no effect.

Franklin[6] stated that, super plasticizers are organic polyelectrolytes, which belong to the category of polymeric dispersants. The performance of super plasticizers in cementations system is known to depend on cement fineness, cement composition mode of introduction to the mixture etc., as well as on the chemical composition of super plasticizers.

For many years, it was not possible to reduce water/cement ratio of concrete below 0.40 till the advent of super plasticizers. The super plasticizers were first used in concrete in 1960s and their introduction occurred simultaneously in Germany and Japan **Glanville, W.H., Collins, A>R and Mathews**[7] At first, the super plasticizers were used as fluidizers than water reducing agents. By using large enough super plasticizer, it was found possible to lower the water/binder ratio of concrete down to 0.30 and still get an initial slump of 200mm. Reducing the water/binder ratio below 0.30 was a taboo until Bache reported that using a very high dosage of super plasticizers and silica fume, water binder ratio can be reduced to 0.16 to reach a compressive strength of 280MPa **(Bache, 1981). Aitcin et al. (1991)**[8] reported, that by choosing carefully, the combination of Portland cement and super plasticizer, it was possible to make a 0.17 water/binder ratio concrete with 230mm slump after an hour of mixing which gave a compressive strength of 73.1MPa at 24 hours but failed to increase more than 125MPa after long term wet curing.

During 1980s, by increasing the dosage of super plasticizers little by little over the range specified by the manufacturers, it is realized that super plasticizers can be used as high range water reducers **(Ronneberg and Sandvik, 1990)**[9].

Jorge de Brito[10] the production of concrete with recycled aggregates (RAC) is treated in normative standards of different countries, as well as its response to the need for a sustainable development. Based on existing norms and specifications that allow the use of recycled aggregates in the production of concrete a comparison is made of the parameters involved, such as density, water absorption and contaminants ratio within the recycled aggregates and maximum strength allowed for the RAC, among others.

Nisreen Muhammad and Maaz Hussain[11] Use of Recycled Coarse Aggregate (RCA) in concrete can be described in terms of environmental protection and economy. This paper deals with the mechanical properties of concrete compressive strength, splitting tensile strength, modulus of elasticity, and modulus of rupture.

Research conducted of use of Recycle Concrete Aggregate & Super Plasticizer in the concrete shows that the use of super plasticizer improves the workability of the concrete and as well as compressive strength. In our research we found different types of super plasticizer (water reducer) and we select most favorable water reducer for our testing procedure. We also did research on the properties and behavior of recycle concrete aggregate which will be used in concrete testing.

2. EXPERIMENTAL PROGRAM

2.1. Preparation of Test Specimens

Concrete mix prepared from the material chosen with respect to combination by the ratio derived from the ACI mix design and cast in the laboratory as shown in Fig.1. First of all concrete mix of local materials like Ordinary Portland cement, pull 111 crush and Chenab sand were mixed with the ratio designed 1:2:4, 1:4:8 and water added according to the mix design (W/C = 0.64 & 0.44).The designed strength of the concrete cube and cylinder is to achieve a minimum of 15 MPa for cubes and 13Mpa for cylinders. Oiled the mold of size 6”x6”x6” , 12”x6”dia and poured the materials in 3 layers compacting each by 25 strokes of tempering rod as shown in Fig 2.(Due to unavailability of compacting machine).

Fig.1: Preparation of concrete mix

Fig.2: Preparing of sample

Other cubes and cylinders were also casted by repeating the same procedure as described above. The ingredients of all these combinations are shown in the Table 1.

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Table 1: Combinations

Sr.	TEST FOR	CEMENT	AGGREGATE	SAND
1	SP CONCRETE (M15)	Ordinary Portland	Karyana Crush	Chenab
2	RCA CONCRETE (M15)	Ordinary Portland	Karyana Crush	Chenab
3	SP+RCA CONCRETE (M15)	Ordinary Portland	Karyana Crush	Chenab
4	SP CONCRETE (M7.5)	Ordinary Portland	Margala	Chenab
5	RCA CONCRETE (M7.5)	Ordinary Portland	Karyana Crush	Chenab
6	SP+RCA CONCRETE (M7.5)	Ordinary Portland	Karyana Crush	Chenab

2.2. Test Performed

After 24 hours of casting of cubes and cylinders, samples were removed from molds and properly cured for 28 days in curing tank. On the 28th day of curing the specimens were dragged out of the curing tank and allowed to dry for 24 hours to make them ready for testing. After that, the specimens were tested in the compressive testing machine (Fig 3) of 3000 kN Capacity. The machine was manually set to apply the load at the rate of 200 Kpa/s while the area of the cube was 23230 mm^2 as shown in the Fig 4. The compressive strength of the specimens was found to be nearly equal to the designed because the specimens were tested after 28 days and gain maximum strength.

Fig.3: Compression Testing Machine

Fig.4: Setting loading rate and area of specimen

3. RESULTS AND DISCUSSION

3.1 Experimental observations

Recorded data in terms of loads was used to plot bar chart to represent the values of compressive strength which is shown in Fig.6, where it is obvious that the maximum load in compression carried by the concrete specimens was 361.7 kN. Moreover, the behavior of concrete specimens up to failure was noticed to be almost linear. As well as the failure mode of concrete specimens is concerned, it was due to de-bonding of the cement mortar and aggregate as shown in Fig.5 which resulted in the brittle failure of the concrete specimens.

(a)cylinder **(b) cube**

Fig.5: failure pattern of cylinder and cube

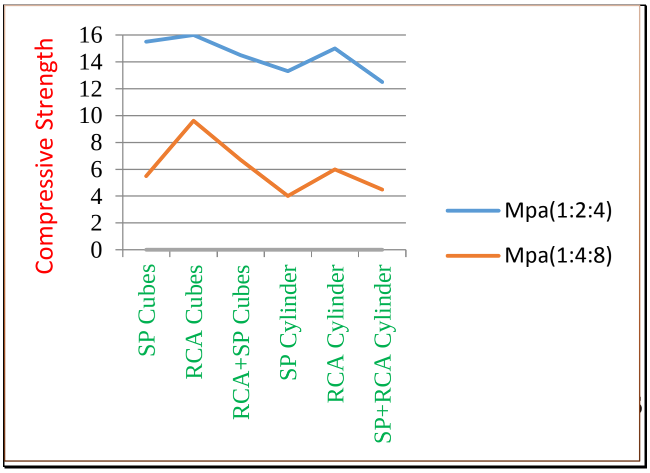

Fig.6: Bar chart between strength of concrete cubes and cylinder

Analytical procedure to calculate compressive strength

3.2 Design of concrete specimens

The concrete specimens are designed using ACI mix design method. In which first of all we performed tests to find the properties of the cement, aggregate and sand.

3.3 Finding properties

Properties and characteristics of materials determined using different cement sand and aggregate tests.

1. 1. fineness of cement
2. 2. the consistency of cement
3. 3.initial and final setting time of cement
4. 4. Compressive test of hydraulic cement mortar
5. 5. sieve analysis of coarse aggregate
6. 6. Aggregate impact value
7. 7. Bulk density

8. Relative density

After calculating these properties carefully used them in ACI mix design to find the ratio of specific strength of 15MPa

3.4 Establishing Ratio

Using ACI mix design the ratio of materials and w/c ratio is calculated. This involves following steps:

3.4.1 Required material information

The properties like sieve analyses of both fine and coarse aggregates, unit weight, specific gravities, and absorption capacities of aggregates were determined.

3.4.2 Choice of slump

The value of slump is assumed for the purpose of designing concrete mix. In our case, the value of slump is 4-5 in (100-125mm) for SP's concrete and 00mm for RCA's concrete..

3.4.3 Maximum aggregate size

The maximum aggregate size that confirms the limitations given in the ACI

- 1/5 the minimum dimension of structural members,
- 1/3 the thickness of a slab, or
- 3/4 the clearance between reinforcing rods and forms. These restrictions limit maximum aggregate size to 1.5 inches, except in mass applications.

In our case that is 0.9 inch that fulfills the conditions as well.

3.4.4 Estimation of mixing water and air content

A table is given in ACI mix design to calculate the water content in air entrained and non-air entrained concrete for the slump value assumed and maximum aggregate size. For mild exposer that is 2.50%

3.4.5 Water to cement ratio

It is calculated keeping in view the strength we are going to design. For 15 MPa (2175 PSI) that is 0.6 and 0.45

3.4.6 Calculation of Cement content

When the water content or the w/c ratio is determined, the amount of cement per unit volume of the concrete is found by dividing the estimated water content by the w/c ratio.

3.4.7 Estimation of coarse aggregate content

The percentage of coarse aggregate to concrete for a given maximum size and fineness modulus of aggregate is given in the Table in ACI mix design. In this case finess of 2.5

and maximum aggregate size 0.9 the corresponding value is 0.466.

3.5 Estimation of Fine aggregate content

The volume of fine aggregates is found by subtracting the volume of cement, coarse aggregate, water and air from the total concrete volume.

3.6 Adjustment for moisture in the aggregate

To adjust water amount just decrease the amount of water by surface moisture and increase the amount of aggregate equal to the surface moisture by weight.

3.7 Dosage of Super plasticizer:

Super plasticizer is used 1 to 3% of the weight of Portland cement.

3.8 Comparison with Experimental Results

The maximum strength of the concrete cube obtained experimentally is 15.5Mpa and the designed value was 15 Mpa are closed because 15Mpa is the strength designed to be obtained after 28 days and the experimentally obtained value 15.5 was also actually gained by concrete cube after 28 days. It can be noticed that the experimental compressive strength of concrete cube is close to analytically obtained value. Based on this observation, it may be concluded that the casting and testing are done well.

3.9 Comparison of the strength each cube and cylinder

As early described that we casted 6 cubes and 6 cylinders so our aim is to compare their strength in order to find the behavior of every individual material in the concrete cube sample so now start one by one.

3.9.1 Cube and cylinder 1 (1:2:4) using SP

In the first specimens, the combination of a material selected was Ordinary Portland cement, Chenab sand (locally available) pull 11 crush (local) and super plasticizer chemerite 520BA. The compressive strength gained after 28 days was found to be 15.5 Mpa (361.7kN) for cube and 13.3 Mpa for cylinder.

3.9.2 Cube and cylinder 2 (1:2:4) Using RCA

In this specimens, the aggregate was replaced by recycled concrete aggregate (50%) is also locally available but our purpose was to check whether the compressive strength increases or decreases while working with white cement. So our experimental results show that the compressive strength increases because it gained more strength in 14 days than that of Ordinary Portland cement but usually its strength is less than the natural aggragte concrete due to less percentage of impact value. The compressive strength gained after 28 days was found to be 16 Mpa and 15 Mpa.

3.9.3 Cube and cylinder 3 (1:2:4) Using SP+RCA

In this combination, the the aggregate was replaced by recycled concrete aggregate (50%) and super plasticizer(3% of cement weight) is also used So our goal is to compare its compressive strength with Super plasticizer specimens and RCA used specimens strength. The compressive strength gained after 28 days was found to be 14.5 Mpa (313kN) and 12.5 Mpa.

3.9.4 Cube and cylinder 4 (1:4:8) Using SP

In this combination, the ratio of cement aggregate and sand is kept 1:4:8. Chemerite 520BA super plasticizer is used to improve the workability of concrete using natural aggregate. The compressive strength gained after 28 days was found to be 5.5 Mpa (111kN) and 4 Mpa. Which is less than the designed strength because of less use of cement due to M10 mix ratio.

3.8.1 3.9.5 Cube and cylinder 5 (1:4:8) Using RCA

In this combination, the Coarse Aggregate is replaced by 50 % of recycled concrete aggregate using ratio of 1:4:8. The compressive strength gained after 28 days was found to be 9.6 Mpa (223.8kN) and 6 Mpa(109.6 KN). It is less than the strength of M15 mix design using RCA combination. It is observed that the strength of cube is more than the strength of cylinder in every combination of concrete.

3.8.2 3.9.6 Cube and cylinder 6 (1:4:8) using SP+RCA

In this combination, coarse aggregate is replaced by 50% of recycled concrete aggregate and also use chemerite 520BA super plasticizer to improve the workability of concrete. The use of super plasticizer is very effective in the case of recycled concrete aggregate because the water absorption of recycled aggregate is very high so the super plasticizer improve the workability of the concrete without increasing w/c ratio of the concrete. The compressive strength gained after 28 days was found to be 3.76.7 Mpa (197.6kN) and 4.5 Mpa.

3.10 Cost Comparison

After designing of Concrete cubes and cylinder, the cost comparison between the materials used for same application was carried out. While comparing the cost, not only cost of the materials was taken into consideration but also the carriage cost the material to the construction site is also considered. The comparison in Pakistani rupees is given in Table 2.

In the cements, only the actual cost is taken into account due to locally availability and other materials the cost of per 100cft is taken which includes material and carriage cost both

Table 2:Cost comparison of SP, RCA and SP+RCA Concrete

Material	SP Concrete	RCA Concrete	SP+RCA Concrete
Ordinary Portland cement	590 Rs/50kg bag	590 Rs/ 50 kg	590 Rs/ 50 kg
Sand	1100Rs/100cft	1100 Rs/100 cft	1100 Rs/100 cft
Natural Aggregate	3500Rs/100cft	3500/2 (50%)	1750
Recycled concrete aggregate	-	1500/2(50%)	750
Super plasticizer	3000Rs/liter	-	3000 Rs/ liter
Total	**8190**	**4190**	**7190**

4.1 CONCLUSIONS AND RECOMMENDATION FOR FUTURE WORK

Based on the findings of the experimental study reported in the paper, following conclusions are drawn:

- Our main concept in this research was ‘‘low w/c ratio, more compressive strength”
- Since there is very less compressive strength difference between the Super plasticizer concrete, recycled aggregate concrete and both used concrete. It allows us to choose as per requirement of the site situation to use the super plasticizer type, dosage and percentage of recycled concrete aggregate to decrease the cost of project without affecting the compressive strength.
- The slump value of Super Plasticizer’s concrete show that the workability of such concrete at low w/c ratio is very high so in warmer areas we can use high water reducer (WHR) such as super plasticizers in concrete to improve workability of concrete without increasing w/c ratio of concrete.
- The recycled aggregate concrete gives compressive strength nearly equal to the natural coarse aggregate’s concrete which allows engineers to use the recycled concrete aggregate instead of natural aggregate to decrease the cost of wok.
- When we used recycled concrete aggregate, the water absorption of aggregates was very high and it was difficult to place the concrete because of less workability so we used super plasticizer in recycled aggregate concrete to increase the work ability of concrete.
- It is clearly observed that the strength of M15 concrete is more than the M7.5 mix design concrete which tell us how to use the proper mix design for different purposes.
- For future work it is recommended to select some different materials like mobile oil which can use as a super plasticizer and less expansive to check its compressive strength which may be give more or equal strength compared with SP’s concrete and least cost than other water reducing materials.
- In Pakistan, the use of recycled concrete aggregate is very rare, so we can use at least 30-40 % of recycled aggregate instead of 50%(which is used in our experimental work) to minimize the cost of our civil work.

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