Study on Use of Recycled Concrete Aggregate and Ceramic Powder

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Abstract- **Recycled aggregate concrete utilizes demolition material from concrete and masonry construction. Reuse of demolition waste concrete avoids the problem of waste disposal and is also helpful in reducing the gap between the demand and supply of crushed natural aggregate. Though several studies have been made in the reuse of concrete waste but limited work has been made with respect to unknown strength of demolished old concrete as an aggregate. Ceramic waste powder is settled by sedimentation and then dumped away which results in environmental pollution, in addition to forming dust in summer and threatening both agriculture and public health. Therefore, utilization of the ceramic waste powder in various industrial sectors especially the construction, agriculture, glass and paper industries would help to protect the environment. It is most essential to develop eco-friendly concrete from ceramic waste. The purpose of this research was to study the combine behavior of RCA and Ceramic powder in Portland cement concrete. Firstly, standard aggregate tests will performed on RCA and natural aggregates. Laboratory testing of material (Aggregates) will be done which included the basic properties of aggregate which are Specific Gravity, Water Absorption Value, Abrasion Resistance, Impact Value, Crushing Value and Sieve Analysis. Secondly, several batches of concrete mixes will be prepared with different RCA to natural aggregates ratio and ceramic powder and the tests were carried out on concrete made using different proportion of RCA and ceramic powder. Viz. compression test, flexural strength, split tensile strength test for hardened concrete. There were numerous batches of concrete mixes, consist of recycle aggregate replacement from 0 to 50% such as 0%, 10%, 20%, 30% and 40%, 50% And also it consists ceramic powder with different percentage ranges from 0%, 5%, 10%, 15%, 20%, 25% as a replacement of Ceramic Powder.**

Index Terms- **Recycled Concrete Aggregate (RCA), Ceramic Powder (CP), Compression Test, Flexural Strength, Split Tensile Strength Test**

I. INTRODUCTION

Recycled aggregate concrete is simply a concrete obtained by using old demolished or broken concrete. Recycling is the act of processing the used material for use in creating new product. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. These materials are generally from buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes.

Indian ceramic production is 100 Million ton per year. In the ceramic industry, about 15%- 30% waste material generated from the total production. This waste is not recycled in any form at present. However, the ceramic waste is durable, hard and highly resistant to biological, chemical, and physical degradation forces. The Ceramic industries are dumping the powder in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of a vast area of land, especially after the powder dries up so it is necessary to dispose the Ceramic waste quickly and use in the Construction industry. As the ceramic waste is piling up every day, there is a pressure on ceramic industries to find a solution for its disposal. The advancement of concrete technology can reduce the consumption of natural resources. They have forced to focus on recovery, reuse of natural resources and find other alternatives. The use of the replacement materials offer cost reduction, energy savings, arguably superior products, and fewer hazards in the environment.

II. EXPRIMENTAL MATERIALS

A) CEMENT

The term cement is used to designate many different kinds of substances that are used as binder or adhesives. In the experimental study were used “BINANI Cement” OPC of 53 grades. It is locally available in the Dahod of Gujarat. Generally in our case OPC is used in all batch mixes. The cement was tested before use and the properties of cement were derived from the tests on cement at packing level in the cement factory. The cement bags were used only one at a time as and when required.

Table I: Physical Properties of Cement

Initial Setting Time	43 minute
Final Setting Time	315 minute
Soundness (Le-chat Expansion)	0.39mm

B) FINE AGGREGATES

The fractions from 4.75mm to 150mm are termed as aggregates. Fine aggregate (sand) were used for this entire study or investigation for concrete will be river sand confirming to zone-2 of IS: 383-1970.

C) CORASE AGGREGATES

The fractions from 20mm to 4.75mm are used as a coarse aggregates. In this investigation, two types of coarse aggregates were used for preparation of concrete, Natural coarse aggregate (NCA) and recycled coarse aggregate (RCA).

D) WATER

It is an important ingredient as it actively participates in the chemical reaction with cement to form cement gels having strength. The quantity and quality of the water added should be looked upon very carefully. For proper chemical action, the amount of water required is about 23% of the cement used, 15% of water is required to fill up gel pores and hence giving workability to the paste. Therefore 38% water is ideally required for complete chemical reaction. The water used for mixing or curing should be free from injurious amounts of oils, acids, salts, sugars, organic and other *Experimental Program* inorganic substances that may be harmful to the concrete. Therefore for experimental purpose clean potable tap water was used for mixing and curing.

E) RECYCLED CONCRETE AGGREGATES (RCA)

Recycled aggregates are derived from debris of roads. Vibratory Crusher was used at the location to derive the RCA. As we know recycled concrete aggregates were mostly collected from waste materials, recycled aggregates used in our experiment were obtained by crushing old concrete roads. The crushed aggregate then were filled and tagged, size wise in the cement bags. The crushed aggregate were sieved. The material sieved was pure, without impurities. It was tested for gradation purpose and physical properties like specific gravity and water absorption, Impact Value, Abrasion Value were also found out. The sieved aggregates were then stored in different compartments of aggregates. Single sized gradation has been used in our experimental study as shown in graph below:

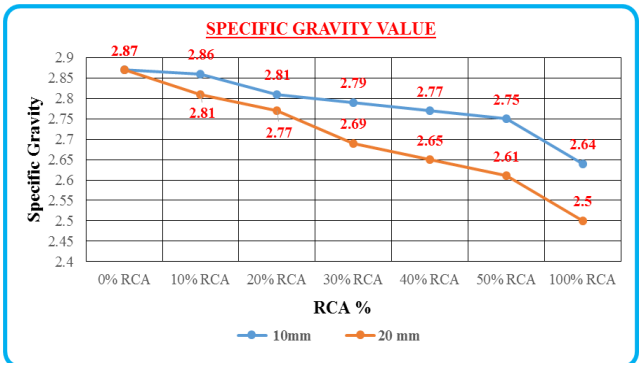

Fig 1. Specific Gravity Value

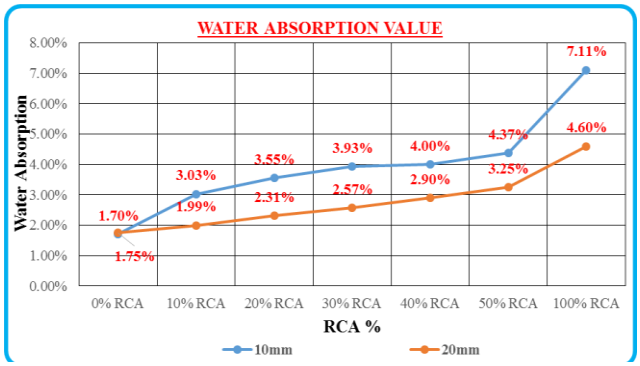

Fig 2. Water Absorption Value

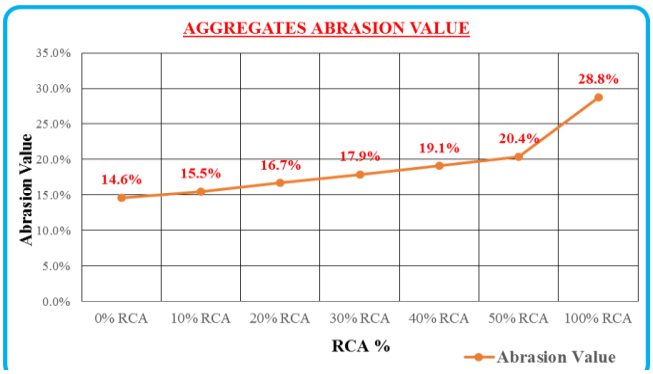

Fig 3. Aggregate Abrasion Value

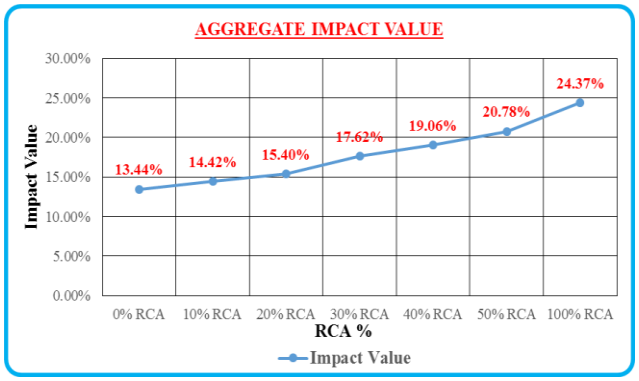

Fig 4. Aggregate Impact Value

F) Ceramic Powder

The principle waste coming into the ceramic industry is the ceramic powder, specifically in the powder forms. Ceramic wastes are generated as a waste during the process of dressing and polishing. It is estimated that 15 to 30% waste are produced of total raw material used, and although a portion of this waste may be utilized on-site, such as for excavation pit refill, The disposals of these waste materials acquire large land areas and remain scattered all around, spoiling the aesthetic of the entire region. It is difficult to find a use of ceramic waste produced. Ceramic waste can be used as a partial replacement of cement to achieve different properties of concrete. The ceramic powder was collected from Kohinoor tiles, Himmatnagar. Here are the chemical properties of Ceramic Powder.

Table II: Chemical Composition of Ceramic Powder

Materials	Ceramic Powder %
Silicon Dioxide(SiO2)%	75.30
Aluminium Oxide (Al2O3)%	18.29
Iron Oxide (Fe2O3)%	3.20
Calcium Oxide(CaO)%	1.210
Magnesium Oxide (MgO)%	1.545
Chloride (CL)%	0.45

III DESIGN MIX

A mix M25 grade was designed as per Indian Standard method (IS 10262-2009).

Table III: Concrete Mix Design for RCA Proportions

Mixes (%rca)	Vol (m^3)	Cement (kgs)	Water (Liters)	Sand (kgs)	Aggregates (Kgs)	
					NCA (kgs)	RCA (kgs)
0%	1	394	197	682.82	1197.53	0
10%	1	394	197	682.82	1055.25	117.25
20%	1	394	197	682.82	924.65	231.16
30%	1	394	197	682.82	785.71	336.72
40%	1	394	197	682.82	663.44	442.29
50%	1	394	197	682.82	544.52	544.52

Table IV: Concrete Mix Design for CP Proportions

Mixes (% cp)	Vol (m^3)	Cement (kgs)	Ceramic Powder (kgs)	Water (Liters)	Sand (kgs)	Aggregates (kgs)
0%	1	394	0	197	682.82	1197.5
5%	1	374.3	19.7	197	682.82	1197.5
10%	1	354.6	39.4	197	682.82	1197.5
15%	1	334.9	59.1	197	682.82	1197.5
20%	1	315.2	78.8	197	682.82	1197.5
25%	1	295.5	98.5	197	682.82	1197.5

IV EXPERIMENTAL SETUP

Table V: Concrete Mix Proportions (I)

Sr No.	RCA	CP	W/C Ratio
1	0%	0%	0.5
		5%	
		10%	
		15%	
		20%	
		25%	
2	10%	0%	0.5
		5%	
		10%	
		15%	
		20%	
		25%	
3	20%	0%	0.5
		5%	
		10%	
		15%	
		20%	
		25%	

Table VI: Concrete Mix Proportions (II)

Sr No.	RCA	CP	W/C Ratio
4	30%	0%	0.5
		5%	
		10%	
		15%	
		20%	
		25%	
5	40%	0%	0.5
		5%	
		10%	
		15%	
		20%	
		25%	
6	50%	0%	0.5
		5%	
		10%	
		15%	
		20%	
		25%	

The evaluation of recycled aggregates for use as a replacement of virgin aggregates and ceramic powder for use as a replacement of cement begins with the concrete testing. The recycled aggregates with proportions 0%, 10%, 20%, 30%, 40%, 50% replaced with the virgin aggregates. The ceramic powder with proportions 0%, 5%, 10%, 15%, 20%, 25% replaced with cement. The test is carried out on softened and hardened concrete. The slump test is carried out for softened concrete. The compression test, split tensile test and flexural test carried out on hardened concrete. The proportions of recycled aggregates and ceramic powder is given below in the table:

SLUMP TEST

Slump test is a common, convenient, and inexpensive test, but it may not be a good indicator of workability, of RCA. However, once it has been established that a particular RCA mixture has satisfactory handling and placing characteristics at a given slump. The slump test may be used as a quality control test to monitor the RCA consistency from batch to batch.

VII: Table Slump Value for Replacement of Ceramic Powder

RCA (%)	CP (%)	Workability (mm)
0%	0%	85
	5%	81
	10%	79
	15%	76
	20%	73
	25%	68

Table VIII: Table Slump Value for Replacement of Recycled Aggregates

CP (%)	RCA (%)	Workability (mm)
0%	0%	85
	10%	83
	20%	80
	30%	76
	40%	70
	50%	62

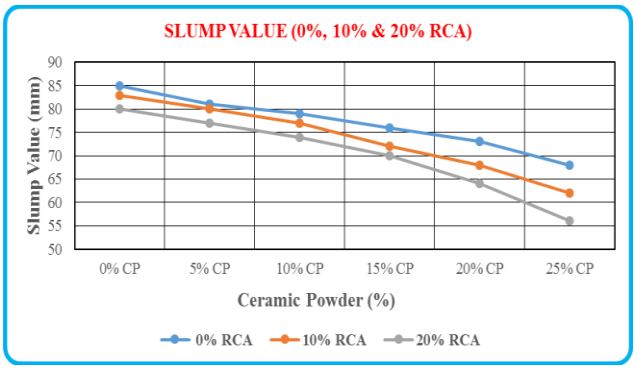

Fig. 5 Slump Value (0%, 10% & 20% RCA)

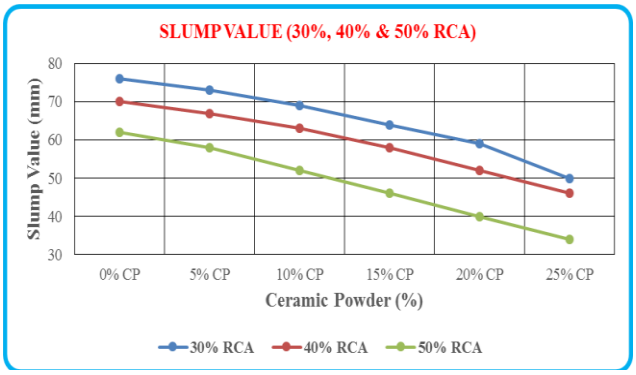

Fig. 6 Slump Value (30%, 40% & 50% RCA)

COMPRESSION TEST

Compressive Strength tests were performed on compression testing machine using cube samples. Three samples per batch were casted with average value reported in this paper. The size of a cubes are 150mm×150mm×150mm. The cubes were tested at 7 days and 28 days. The tables and graphs of the compressive strength shown below:

Table IX: Compressive Strength for Replacement of Ceramic Powder

RCA (%)	CP (%)	Compressive Strength (7 Days)	Compressive Strength (28 Days)
0%	0%	23.42	33.87
	5%	23.11	33.01
	10%	22.24	32.67
	15%	21.02	31.98
	20%	20.48	30.13
	25%	18.78	27.64

Table X: Compressive Strength for Replacement of Recycled Aggregates

CP (%)	RCA (%)	Compressive Strength (7 Days)	Compressive Strength (28 Days)
0%	0%	23.42	33.87
	10%	22.5	32.61
	20%	21.17	32.05
	30%	20.32	31.32
	40%	17.67	25.34
	50%	14.67	22.67

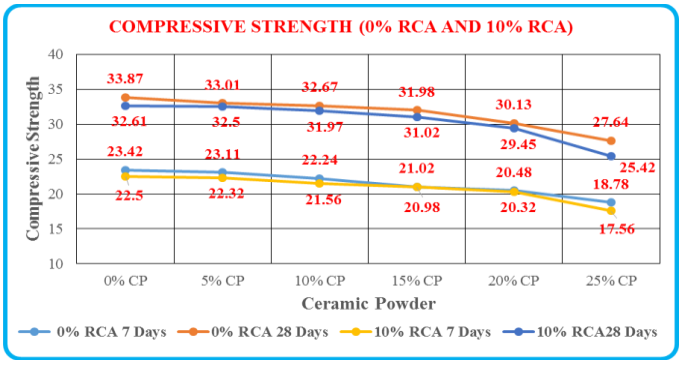

Fig.7 Compressive Strength (0% & 10% RCA)

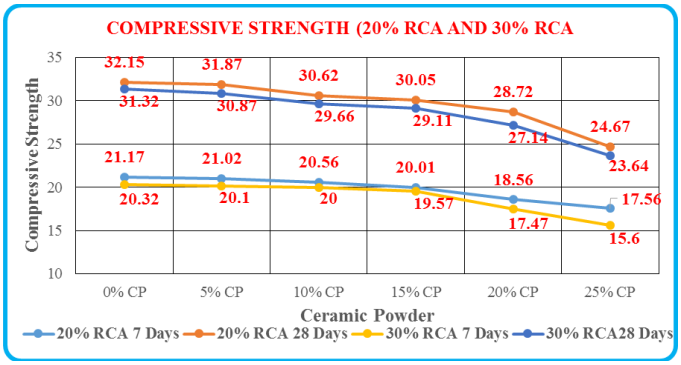

Fig.8 Compressive Strength (20% & 30% RCA)

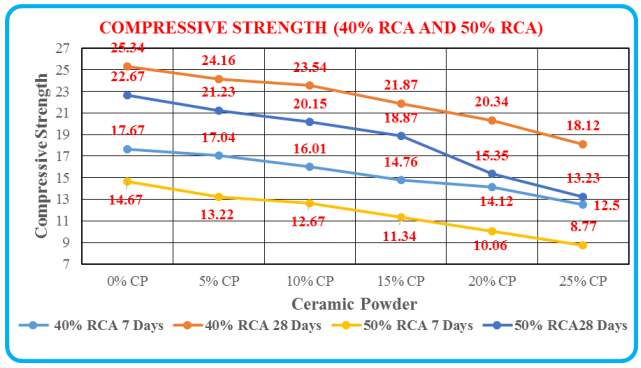

Fig.9 Compressive Strength (40% & 50% RCA)

SPLIT TENSILE TEST

The diameter of cylinder is 150mm and the height of the cylinder is 300mm. Three samples per batch were casted with average value reported in this paper. The cylinders were tested at 7 days and 28 days. The tables and graphs of the split tensile strength shown below:

Table XI: Split Tensile Strength for Replacement of Ceramic Powder

RCA (%)	CP (%)	Split Tensile Strength (7 Days)	Split Tensile Strength (28 Days)
0%	0%	2.89	4.13
	5%	2.8	4.01
	10%	2.67	3.85
	15%	2.47	3.63
	20%	2.3	3.34
	25%	2.05	3.12

Table XII: Split Tensile Strength for Replacement of Recycled Aggregates

CP (%)	RCA (%)	Split Tensile Strength (7 Days)	Split Tensile Strength (28 Days)
0%	0%	2.89	4.13
	10%	2.75	4
	20%	2.61	3.85
	30%	2.46	3.58

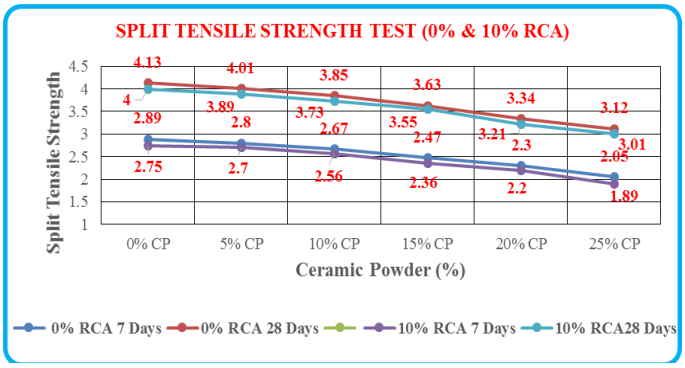

Fig.10 Split Tensile Strength (0% & 10% RCA)

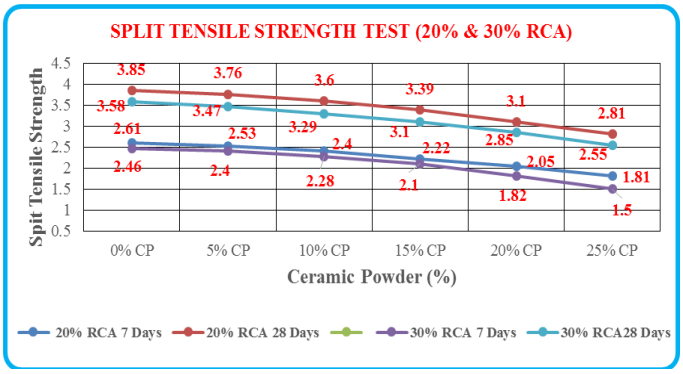

Fig.11 Split Tensile Strength (20% & 30% RCA)

FLEXURAL TEST

The size of the beam is 500mm×100mm×100mm. Three samples per batch were casted with average value reported in this paper. The beams were tested at 7 days and 28 days. The tables of flexural strength shown below:

Table XIII: Flexural Strength for Replacement of Ceramic Powder

RCA (%)	CP (%)	Flexural Strength (7 Days)	Flexural Strength (28 Days)
0%	0%	3.37	4.46
	5%	3.3	4.4
	10%	3.24	4.26
	15%	3.18	4.19
	20%	2.92	3.81
	25%	2.66	3.5

Table XIV: Flexural Strength for Replacement of Recycled Aggregates

CP (%)	RCA (%)	Flexural Strength (7 Days)	Flexural Strength (28 Days)
0%	0%	3.37	4.46
	10%	3.24	4.2
	20%	3.08	3.88
	30%	2.76	3.4

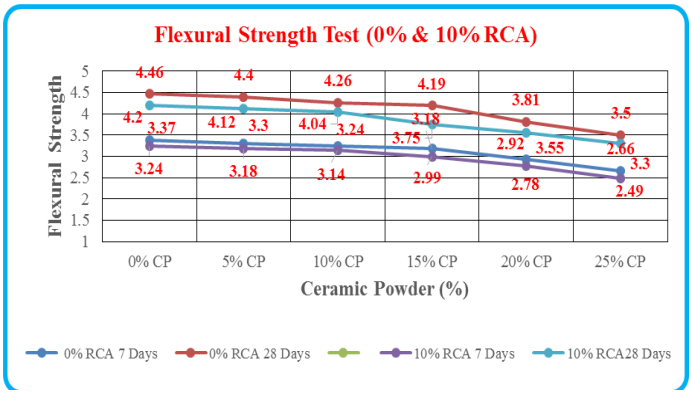

Fig.12 Flexural Strength (0% & 10% RCA)

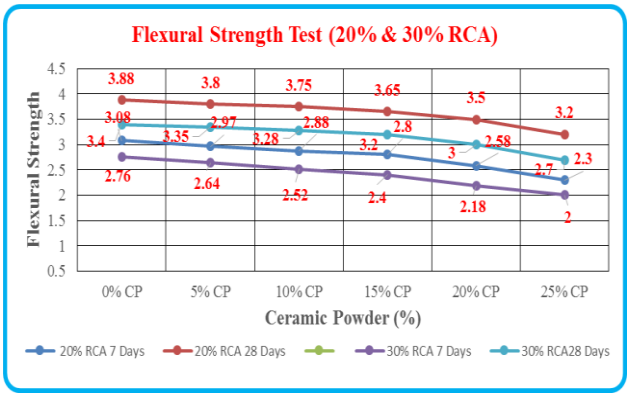

Fig.13 Flexural Strength (20% & 30% RCA)

V CONCLUSIONS

In this work mainly properties of Recycled Concrete was examined and liability of the recycled aggregates for use in the Concrete was studied. Recycled aggregates with different proportion was added with virgin aggregate and Ceramic Powder with different proportion was added with Cement in the normal strength concrete. From the experimental study following conclusions are drawn:

- The specific gravity of Recycled Concrete Aggregate is lower than that of natural aggregates. The specific gravity of natural aggregate and recycled aggregate is

2.87 and 2.64 respectively. So lesser the mortar adhering to Recycled Aggregates the higher is the Specific Gravity.

- The water absorption of natural coarse aggregate is 1.70% and the recycled coarse aggregate is 7.11%. So there is higher water absorption in recycled aggregates compare to natural aggregates. As the Mortar phase is present in the recycled aggregate, it is relatively porous as compare to the natural crushed aggregate.

- The values of percentage impact and abrasion gradually increase with higher RCA proportions with the virgin aggregates... Though the values are in the range of the all type building and road construction.

- The Slump Value decreased respectively 4.7% to 31.76 % with increase of 10% to 50% increase of RCA. This is because loose mortar sticks on the surface of the aggregates. That absorb the water. Due to this the flow cannot be achieved.

- The slump value decreased respectively 2.35% to 27.05 % with increase of 5% to 25% increase of Ceramic Powder.

- The compressive strength of the concrete decreases as the amount of coarse RCA increases, in our case it was found to decrease to a maximum at 33.06% at 28-days. This is due to less bonding between the Recycled aggregates and other materials due to presence of old mortar on the surface of the recycled aggregates.
- The compressive strength decreased respectively 3.72% to 33.06 % with increase of 10% to 50% increase of RCA.

- The compressive strength decreased respectively 2.53% to 18.39 % with increase of 5% to 25% increase of Ceramic Powder.

- The split tensile strength decreased respectively 5.08% to 24.45 % with increase of 5% to 25% increase of Ceramic Powder.

- The split tensile strength decreased respectively 3.14% to 13.31% with increase of 10% to 30% increase of Recycled Aggregates.

- The flexural strength decreased respectively 1.34% to 21.54% with increase of 5% to 25% increase of Ceramic Powder.

- The flexural strength decreased respectively 5.82% to 23.71 % with increase of 10% to 30% increase of Recycled Concrete Aggregate.

So from above conclusions we can say that the Recycled Aggregates up to 30% with replacement of virgin Aggregates and Ceramic Powder up to 20% with replacement of Cement can be used in Concrete because we can achieve target mean strength at these percentages.

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