Experimental Investigation of Roller Compacted Concrete with Industrial Wastes

K Hemantha Raja, Satish Sajja, K Shyam Prakash

Abstract: In this experimental study, different mixtures of Roller Compacted Concrete (RCC) were prepared in which fine aggregate was partially replaced by industrial waste materials like quarry dust (QD), glass powder (GP) with varying percentages. The main objective of this study was to investigate the effect of (QD) and (GP) on the mechanical properties of RCC. Flexural and compressive strength were conducted for the ages of 7 days, 28 days and 90 days of curing. The compressive strength values of RCC specimens were increased gradually up to 30% replacement of quarry dust at the age of 7 days and 28 days, beyond 30% replacement there is no considerable increment but up to 40% replacement can also be considered due to higher strength compared to conventional concrete. There are no higher increments in compressive strength when fine aggregate is replaced with glass powder still 30% glass powder can be used as the strength is nearly equal to normal RCC and flexural strength strengths are more than the target.

Index Terms: Roller compacted concrete, quarry dust, glass powder, mechanical properties.

I. INTRODUCTION

Roller-compacted concrete (RCC) is used for rapid construction of pavements with less labour and equipment than conventional concrete pavements [1] [2], [6],[7],[8]. It is a stiff mixture of aggregates, cementitious materials, and water. It is placed by pavers and compacted by vibratory rollers without forms, finishing, or surface texturing [2]. Because of the low water content and low water-cement ratio, it produces higher strengths or even greater than conventional concrete [2], [3],[4], [5]. It does not require joints, dowels, reinforcing steel, or formwork [10], [5], [7], [8], [27]. It produces stronger and durable pavement than conventional flexible pavement. It will bare heavy axle loads and will not slide during braking operations or during turnings. It will not brittle or soften even at high temperatures. It can resist degradation from materials such as diesel fuel [9]. 15 to 25 percent savings can be expected, if it is chosen as an alternative even for heavy loads. [7]. A considerable increase in strength is observed by replacing fine aggregate with glass powder when compared to traditional concrete. [11]. Similar to conventional concrete the intensity of the roller concrete is inversely proportional to the W/B ratio [12]. Quarry dust can be utilized in concrete as a replacement for natural river sand with higher strengths [13]. Minimum of 98% modified Proctor dry density ratio is required to attain maximum strength and admixtures can be used for extending the working time without compromising strength [14]. Vebe consistency time of RCC decreases with increase in crumb rubber and superplasticizer contents [15]. Incorporating quarry dust in concrete improves its flexural strength [16]. Due to improper curing conditions there won’t be any changes in compressive strength, but it would affect the surface exposed layer [17]. Mine tailings can be used as alternative to sand in roller compacted concrete [18]. Stumpy consumption of cement, less shrinkage, high strength, speedy construction and other advantages lead to study on RCC more since 1980 [19]. At higher percentages of replacement of quarry dust with cement increases coefficient of permeability and water absorption where as replacing with fine aggregate produces quality concrete with higher strengths and elastic modulus. [20] [21] [22]. Inferior aggregates, waste products, and other deleterious materials which do not meet standards and specification can be used in the manufacturing of Roller compacted concrete [23]. Using silica fume and fine cement will reduce the coefficient of permeability. [24]. Cold reuse technique can be used for RAP in manufacturing roller compacted concrete (RCC) which is an innovative technique for sustainable pavements [25]. Due to low water content, the problem of segregation of RCC is high. To minimize segregation the maximum aggregate size is limited to approximately 20 mm and by increasing fine aggregate [1], [2], [4], [6], [10]. Glass powder can be used as fine aggregate for low volume roads [26].

II. MATERIALS

The basic materials used for RCC are water, OPC 53 grade cement, fine and coarse aggregates. Cement used is tested as per IS 4031-1999 and shown in Table I. Natural river sand of Zone III available in Vijayawada is used confirmed to IS 383-1970 shown in Table II. Coarse aggregate used for the experiment is quarry rubble. The gradation requirements of combined aggregate are confirmed to ACI 211.3R-02 shown in Table III. The specific gravity of materials used in the study is tested and results are found to be 2.45, 2.37, 2.59 and 2.88 for glass powder, quarry dust, fine aggregate and coarse aggregate respectively.

Table I: Properties of cement

S.No.	Physical Property	Result
1	Fineness, m^2/kg	285

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K Hemantha Raja, Assistant professor, Civil Engineering Department, Koneru Lakshmaiah Education Foundation (Deemed to be University), Guntur, A. P., India.

Satish Sajja, Assistant Professor, V. R. Siddhartha Engineering College, Kanuru, Vijayawada, India.

K Shyam Prakash, Assistant professor, P. V. P. Siddhartha institute of Technology, Kanuru, Vijayawada, India.

2	% of Passing, 45 µm	88.5
3	Compressive strength	
	3days, N/mm^2	29
	7days, N/mm^2	40
	28 days, N/mm^2	58
4	Specific Gravity	3.15

Table II: Sieve analysis of fine aggregate

Sieve Size, mm	Percentage passing
9.5	100
4.75	99.84
2.36	99.25
1.18	94.67
0.6	69.13
0.3	5.4
0.15	0.73
0.075	0

Table III: Sieve Analysis of All in Aggregates

Sieve Size, mm	Percent Passing			
	Sand	Combined CA	Combined grading*	Desirable limits
19	100	100	100	82-100
12.5	100	88.8	93.28	72-93
9.5	100	65.94	79.56	66-85
4.75	99.8	33.78	60.2	51-69
2.36	99.2	14.76	48.56	38-56
1.18	94.6	7.02	42.08	28-46
0.6	69.1	4.86	30.57	18-36
0.3	5.4	2.62	3.73	Nov-27
0.15	0.73	0.98	0.88	Jun-18
0.075	0	0.12	0.07	02-Aug

***(60%CA: 40% Sand)**

III. MIX PROPORTIONING METHOD

Conventional RCC mix proportion was prepared as per ACI 211 3R-02. The Target flexural strength is 5 MPa. Various mixes are prepared by varying QD & GP percentages by replacing with fine aggregate.

A. Details of tests conducted and parameters studied

The present investigations are aimed to study the effect of partial replacement of recyclable industrial waste like quarry dust, glass powder with fine aggregate in RCC. Mechanical properties like Compressive strength and flexural strength parameter are studied with varying percentages.

IV. RESULTS AND DISCUSSIONS

A. Compressive strength

The standard cubes of (150mm X 150mm X 150 mm) are casted and tested for compressive strength as per IS 516-1959. The effect on compressive strength by partial replacement of quarry dust, glass powder, in varying percentages from 0% to 40% for varying ages of curing like 7days, 28days and 90 days are presented in Table IV.

Table IV: Compressive strength of RCC with varying Percentages of QD and GP

	normal mix	QD (20%)	QD (30%)	QD (40%)	GP (10%)	GP (20%)	GP (30%)
7 days	28.44	29.63	30.81	30.89	24.54	27.63	29.4
28 days	38.66	41.19	44.3	44.8	35.45	37.95	38.95
90 days	47.85	47.26	48	48.59	44.5	48.05	49.5

With the increase in age of concrete, the compressive strength of normal RCC increases. By varying QD percentages there is an increment 16% of compressive strength at 28days curing when compared to normal concrete. But when compare compressive strengths at 30% QD and 40% QD there is no significant growth in strength. Whereas when fine aggregate replaced with GP% there is a reduction in strength in initial replacements and achieved strength nearly equal to normal concrete at 30% GP.. As the age of curing goes on the strength of QD replaced concrete has an increment of 59.5%, 55.79%, and 57.3% of strengths for 20% QD, 30% QD and 40% QD. Similar trend was observed in GP replaced concrete also.

B. Flexural strength

The beams of (500mm X 100mm X 100 mm) are casted and tested for flexural strength as per IS 516-1959. The effect on flexural strength by partial replacement of quarry dust, glass powder, in varying percentages from 0% to 40% for varying ages of curing like 7days, 28days and 90 days are presented in Table V.

Table V: Flexural strength of RCC with varying Percentages of QD and GP

	Normal mix	QD (20%)	QD (30%)	QD (40%)	GP (10%)	GP (20%)	GP (30%)
7 days	4.64	4.95	5.3	5.25	4.7	5.15	5
28 days	5.52	6.25	6.65	6.48	5.65	5.9	5.8
90 days	7.4	8.1	8.35	8.2	7.42	7.65	7.5

The target flexural strength was achieved at 28 days curing for normal RCC. As the percentages of QD is increased the flexural strength increases by 13.22%, 20.47%, 17.39% with normal concrete at 28 days curing. Whereas the increase in flexural strength is very nominal for varying GP% i.e., 2.35%, 6.8% and 5.07% for 10%GP, 20%GP and 30%GP. As the curing age is increasing the flexural strength increased by 63.63%, 63.20%, 56.19% for

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10%QD, 20% QD and 30% QD.

V. CONCLUSIONS

There is a considerable increment in compressive strength and flexural strength while replacing fine aggregate with river sand. Glass powder didn't show the same effect in increment of strength but glass powder can also be used as fine aggregate as it acquires nearly equal strength as normal concrete which would help in savings of river sand. The results indicate that Quarry dust can be utilized as replacement to river sand up to 40%. whereas durability and long-term effects has to be studied. By utilizing the alternative industrial wastes the requirements of landfills can be reduced, natural resources can also be saved which leads to sustainable infrastructure development.

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AUTHORS PROFILE

Mr. K. Hemantha Raja working as Assistant Professor, K L University, Guntur District has more than 8 years of experience in teaching and research, has more than 15 technical papers in National, International Journals & Conferences.

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Mr. S. Satish working as Assistant Professor, V R Siddhartha Engineering College, Vijayawada has more than 5 years of experience in teaching and research, has more than 8 technical papers in National, International Journals & Conferences

Dr. K. Shyam Prakash working as Assistant Professor, PVP Siddhartha Institute of Technology, Vijayawada has more than 8 years of experience in teaching and research, has more than 10 technical papers in National, International Journals & Conferences

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