International Journal of Engineering &Technology, 7 (3.12) (2018) 369-373

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Durability Characteristics of Ceramic Waste based Light Weight Concrete

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Abstract

Ceramic waste powder (CWP) is one waste material produced during cutting of ceramic tiles. CWP is rich in silica and alumina and is a fine material. Due to generation of more such waste it is mandatory to make use such material effectively in construction industry to minimize the disposal problem and also to reduce production of cement. Use of such material will minimize the carbon foot print in production stage of concrete. LECA is a light weight expanded clay aggregate could be used as substitute to natural coarse aggregate which is energy intensive. In this study, CWP is partially substituted for cement and LECA is partially substituted for natural coarse aggregate. CWP was used from 10 to 30% and LECA was used from 20 to 40%. All the mix combinations were subjected to durability studies namely sorptivity and porosity to study the effectiveness of enhancement on the performance of admixed light weight concrete. All the tests are performed as per ASTM standards. The durability performance of admixed concrete with ceramic waste and LECA aggregate are compared with results of conventional concrete.

Keywords: *Ceramic waste, LECA, sorptivity, porosity*

1. Introduction

Many research works were conducted on strength and durability performance of natural and artificial aggregates to produce concrete. It was inferred that cost reduction in production of concrete was found to be more when natural aggregate used instead of artificially produced aggregate [1-5]. Certain research works were performed recently on possibility of using volcanic ash and pumice as partial substitute to cement in the production concrete and recommended its use [6-9]. One of the important representations from construction and demolition waste is a Ceramic waste. Some researchers have used waste materials from the industries as partial substitute to cement and the results were successful. The wastes were tried in conventional concrete and also in high performance concrete. It was assessed that use of such ceramic wastes in concrete exhibited Pozzolanic reactions and formed new compounds and was responsible for enhancing the strength and durability of concrete [10-16]. One of authors of the present work has done extensive study by conducting experiments to explore the possibilities of using ultrafine mineral admixtures available from industrial wastes and its effect on concrete properties. They inferred that use of such ultrafine mineral admixtures in concrete enhanced the strength and durability characteristics [17-22].

Hence in the present work, it was decided to perform experimental investigations to assess the durability characteristics such as porosity and sorptivity of concrete with ceramic waste powder as partial substitute to cement in three different percentages and LECA as partial substitute to natural coarse aggregate in three different percentages. Investigations were also carried out by replacing these two materials in a combined manner.

2. Experimental Investigations

2.1 Material Properties

Cement used in the present research work was OPC 53 grade with a characteristic compressive strength of 53 MPa. Ceramic waste powder (CWP) obtained from ceramic industry near Pudhuchery. Light weight expanded clay aggregate (LECA) obtained from Chennai. Fine aggregate used in the present work was River sand and coarse aggregate was broken granite stone. Specific gravities of cement, ceramic waste powder, sand, coarse aggregate and LECA are 3.15, 2.8, 2.65, 2.8 and 1.1 respectively.

2.2 Methods

The grade of concrete for the present work was chosen as M60 with a characteristic compressive strength is 60 MPa. Proportioning of mix was done in accordance with ACI 211.1-91[23]. The mix ratio was arrived as 1:0.7:1.87 in the sequence of cement, fine aggregate and coarse aggregate respectively with constant water to binder ratio of 0.30. Originally the water binder ratio arrived for the mix was 0.33 without using super plasticizer and has modified to 0.30 by adding High range water reducer. This HRWR influenced the workability of concrete and made workable even for lesser water binder ratio. After arriving the desired workability of concrete, the specimens were cast for the respective durability tests and the following sequence of procedure was adopted for the same. The chemical admixture called high range water reducer of desired volume was added with water since it was used as an additive. It was mixed thoroughly to have homogeneity.

Subsequently a mixture of binders (cement and ceramic waste powder) was prepared. It was then mixed with fine aggregate and again with coarse aggregates (broken stone and LECA). This process of dry mixing of ingredients was done first. Then prepared water-HRWR liquid medium was added with dry mix and subjected to thorough mixing till to get homogeneous mix and specimens were cast. The durability tests namely porosity and sorptivity tests were performed in accordance with ASTM C642 and ASTM C1585 [24, 25]. Parameters such as permeable pore volume, density of concrete, water absorption were found out using porosity method. Specimens were subjected to heating to a higher temperature for certain period, immersed in water for normal condition, immersed in boiled water and corresponding mass of specimens were taken. These values were incorporated to calculate the magnitude of permeable pores and absorption of water in the respective concrete as per the guidelines given in ASTM C642.

The property of concrete exhibiting the resistance against capillary suction was found out by casting cylindrical prisms of standard size in accordance with ASTM C1585. These specimens were subjected to a constant temperature of 50°C for 72 hours in a hot air oven. After that the specimens were subjected to ambient temperature for a period of 15 days before testing. Then it was subjected sorptivity test for a period of 9 days to assess primary and secondary sorption. Primary sorption was assessed for the first six hours of duration of testing and secondary sorption from 6 hours to 9 days. Specimen's bottom portion only exposed to water during the testing procedure and the remaining surface were applied with epoxy resin to have realistic assessment of capillary suction. After the test, calculations were done and graphs were plotted to obtain sorption coefficient.

3. Results and Discussion

3.1 Volume of Voids and Water Absorption

Effect of Ceramic Waste Powder

The variation of volume of permeable pores and water absorption due to the replacement of cement with different percentages of ceramic waste powder (CW) is shown in Figure 1. From the results it was understood that the volume of voids and water absorption of control concrete was found to be 1.69% and 10.69%. Due to the replacement of cement with ceramic waste powder, both the values of water absorption and volume of voids were increased irrespective of percentage of substitution. For 10% replacement of cement with ceramic waste powder, water absorption and volume of voids were 3.31% and 15.24%. Further increase of ceramic waste powder to 20%, these values has come down to 2.44% and 11.46%. It was inferred that this percentage of replacement lead to densification of mix by properly filling voids and could have modified the microstructure of concrete. Increase of ceramic waste powder substitution to 30% has shown a reverse trend in the results. The water absorption and volume of voids were 2.88% and 13.66 %. It means that use of ceramic waste beyond 20% made the concrete little porous.

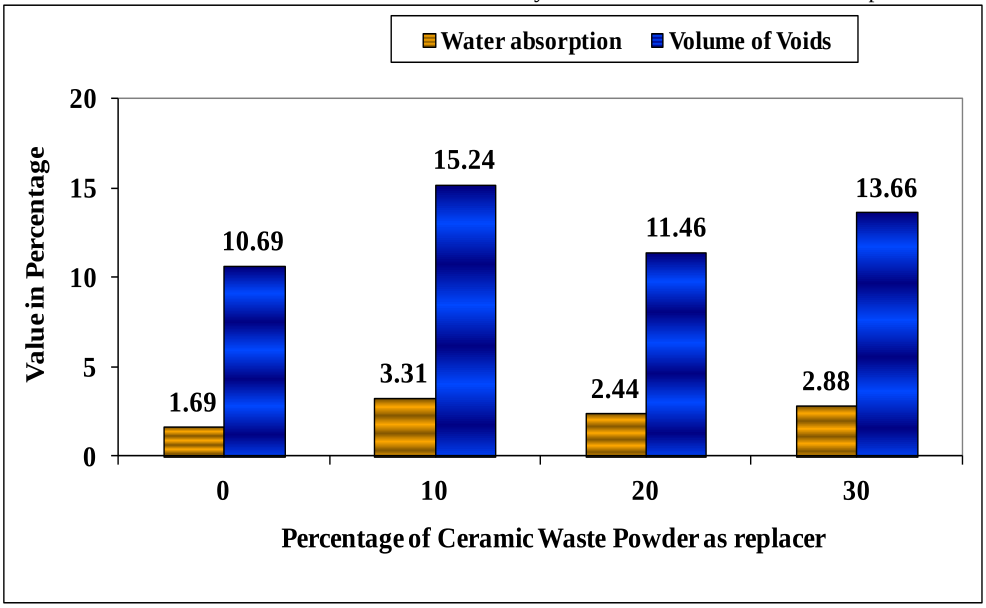

Fig. 1: Water absorption and volume of pores of Concrete with Ceramic Waste powder

Effect of Light Weight Expanded Clay Aggregate (LECA)

The variation of volume of permeable pores and water absorption due to the replacement of cement with different percentages of light weight expanded clay aggregate (LECA) is shown in Figure 2. Natural coarse aggregate was replaced with light weight expanded clay aggregate in three different percentages of 20, 30 and 40. From the results it was understood that the volume of voids and water absorption of control concrete was found to be 1.69% and 10.69%. Due to the replacement of cement with ceramic waste powder, both the values of water absorption and volume of voids were increased irrespective of percentage of substitution. For 20% replacement of natural coarse aggregate with light weight expanded clay aggregate, water absorption and volume of voids were 2.8% and 17.14%. Further increase of light weight expanded clay aggregate to 30%, these values has come down to 2.59% and 15.17%. It was inferred that this percentage of replacement lead to densification of mix by properly filling voids and could have modified the microstructure of concrete. Increase of light weight expanded clay aggregate substitution to 40% has shown a reverse trend in the results. The water absorption and volume of voids were 3.66% and 20.39 %. It means that use of light weight expanded clay aggregate beyond 30% made the concrete porous one.

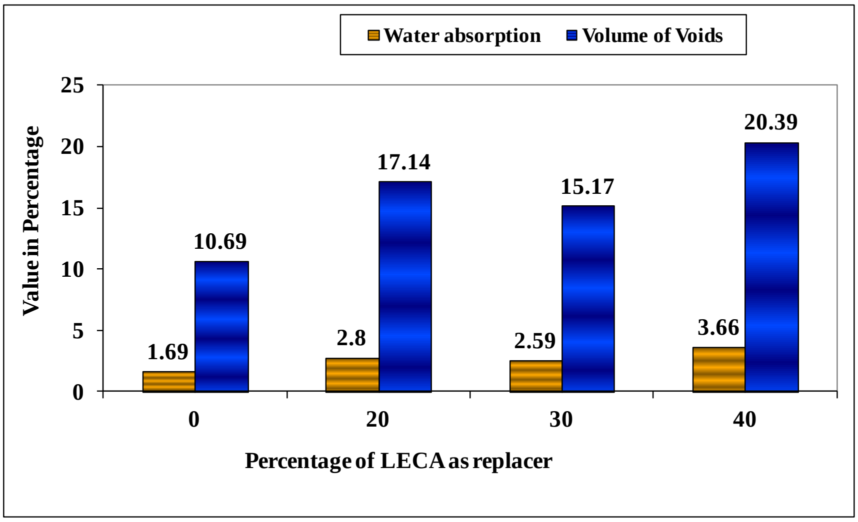

Fig. 2: Water absorption and volume of pores of Concrete with LECA

Effect of Combined mix of CW powder and LECA

The variation of water absorption and volume of voids of concrete due to the replacement of cement with different percentages of ceramic waste powder (CW) and natural coarse aggregate with different percentages of LECA are shown in Figures 3 to 5. From the results it was understood that the water absorption and volume of voids of concrete for the mix with 10% ceramic waste powder, increase of LECA from 20 to 30% reduced the water absorption and volume of voids. Further increase of LECA from 30 to 40% increased the water absorption and volume of voids making concrete more porous. Whereas in the case of concrete with 20% ceramic waste powder, increase of LECA from 20 to 40% decreased the water absorption and volume of voids making concrete more denser. For concrete with 30% ceramic waste powder, increase of LECA from 20 to 40% increased the water absorption and volume of voids making concrete more porous. Hence it was inferred that the concrete with 20% ceramic waste powder and 40% LECA found to be an optimum mix in terms of porosity.

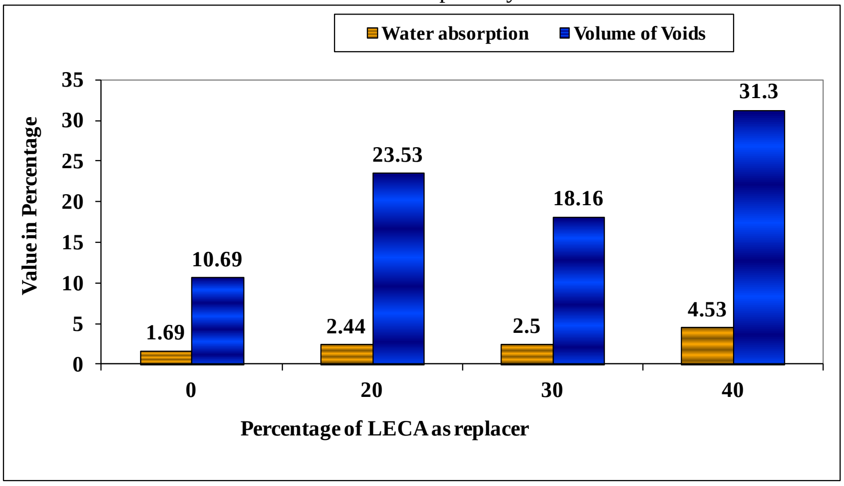

Fig. 3: Water absorption and volume of pores of Concrete with CW10% and LECA

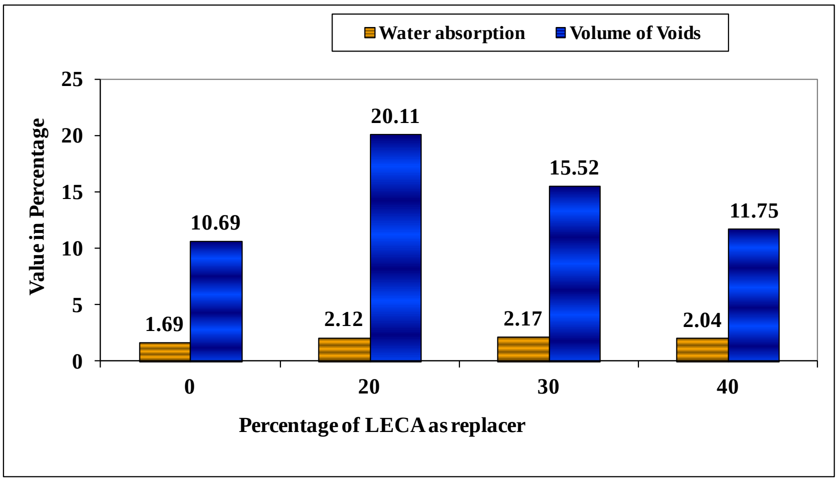

Fig. 4: Water absorption and volume of pores of Concrete with CW20% and LECA

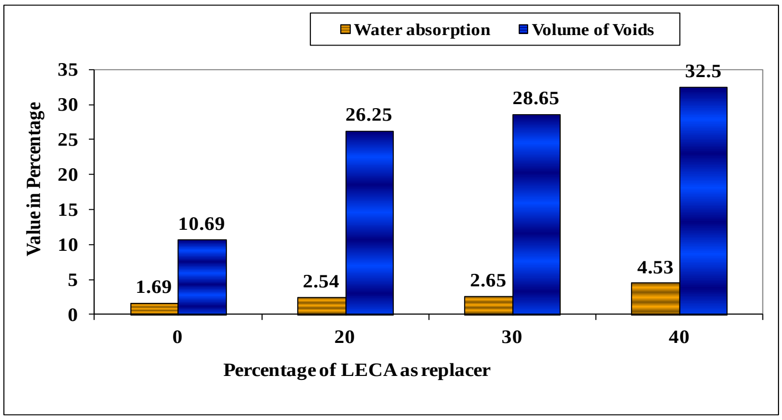

Fig. 5: Water absorption and volume of pores of Concrete with CW30% and LECA

3.2 Sorptivity

Effect of Ceramic Waste Powder

The variation of sorptivity of concrete due to the replacement of cement with different percentages of ceramic waste powder (CW) is shown in Figure 6. From the results it was understood that the sorptivity of concrete was found to be more in concrete with ceramic waste powder irrespective of its percentage of substitution. Similar trend as observed in porosity reflects here also. Hence it was understood that, concrete with ceramic waste powder as a substitute to cement exhibited similar behaviour in terms durability characteristics.

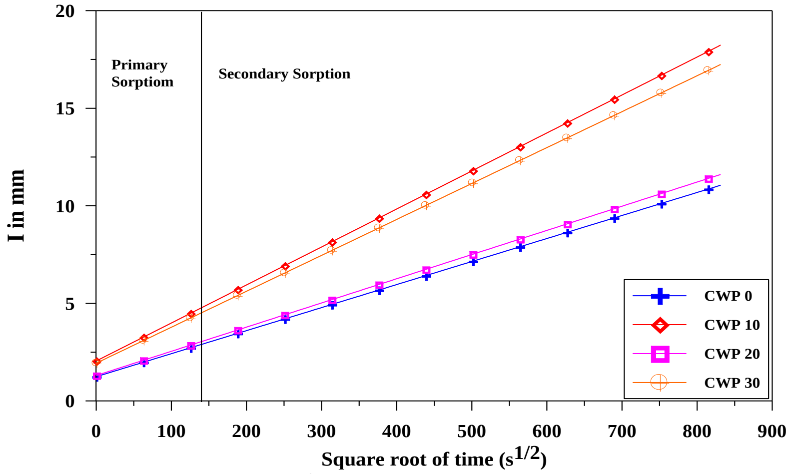

Fig. 6: Sorptivity of Concrete with Ceramic Waste powder

Effect of Light weight Expanded Clay Aggregate (LECA)

The variation of sorptivity of concrete due to the replacement of natural coarse aggregate with different percentages of light weight expanded clay aggregate is shown in Figure 7. From the results it was understood that the sorptivity of concrete was found to be more in concrete with light weight expanded clay aggregate irrespective of its percentage of substitution. Similar trend as observed in porosity reflects here also. Hence it was understood that, concrete with light weight expanded clay aggregate as a substitute to cement exhibited similar behaviour in terms durability characteristics.

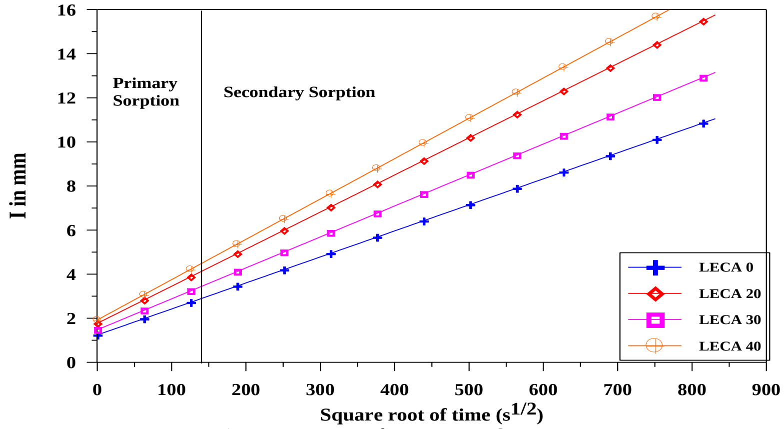

Fig. 7: Sorptivity of Concrete with LECA

Effect of Combined mix of CW powder and LECA

The variation of sorptivity of concrete due to the replacement of cement with different percentages of ceramic waste powder (CW) and natural coarse aggregate with different percentages of LECA is shown in Table 1. From the results it was understood that the sorptivity of concrete for the mix with 10% ceramic waste powder, concrete with 20% LECA subjected to lesser sorption.

Hence this mix has better resistance against sorption. In a similar manner, for the concrete with 20% ceramic waste powder, 40% LECA gave better results. For the concrete with 30% ceramic waste powder, 20% LECA gave better results.. Among all the mixes chosen concrete with 20% ceramic waste powder and 40% LECA gave better results and hence it was inferred that the concrete with 20% ceramic waste powder and 40% LECA found to be an optimum mix in terms of sorptivity also.

Table 1: Sorptivity Values of Concrete for combined replacement of Ceramic Waste Powder and LECA

Square root of time ($s^{1/2}$)	C0 LECA0	10C 20LECA	10C 30LECA	10C 40LECA	20C 20LECA	20C 30LECA	20C 40LECA	30C 20LECA	30C 30LECA	30C 40LECA
	mm									
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.75	0.51	0.67	0.91	0.88	0.77	0.68	0.51	0.68	0.78	0.96
17.32	0.51	0.67	0.91	0.88	0.77	0.68	0.51	0.68	0.78	0.96
24.49	0.64	0.83	1.14	1.10	0.96	0.85	0.64	0.85	0.97	1.20
34.64	0.76	1.00	1.37	1.32	1.15	1.02	0.77	1.02	1.17	1.44
42.43	0.76	1.00	1.37	1.32	1.15	1.02	0.77	1.02	1.17	1.44
60.00	1.02	1.33	1.82	1.76	1.54	1.35	1.03	1.36	1.56	1.91
84.85	1.27	1.67	2.28	2.20	1.92	1.69	1.29	1.71	1.95	2.39
103.9	2.55	3.34	4.56	4.41	3.85	3.39	2.57	3.41	3.90	4.79
120.0	4.46	5.84	7.98	7.71	6.73	5.93	4.50	5.97	6.82	8.38
134.1	5.09	6.67	9.12	8.81	7.69	6.77	5.14	6.82	7.79	9.57
146.9	6.37	8.34	11.40	11.01	9.61	8.47	6.43	8.53	9.74	11.97
415.6	7.64	10.01	13.67	13.22	11.54	10.16	7.72	10.24	11.69	14.36
509.1	8.28	10.84	14.81	14.32	12.50	11.01	8.36	11.09	12.66	15.56
585.8	8.40	11.01	15.04	14.54	12.69	11.18	8.49	11.26	12.86	15.80
657.2	8.66	11.34	15.50	14.98	13.07	11.52	8.74	11.60	13.25	16.28
720.0	8.91	11.68	15.95	15.42	13.46	11.85	9.00	11.94	13.64	16.76
831.3	9.55	12.51	17.09	16.52	14.42	12.70	9.64	12.80	14.61	17.95

4. Conclusions

Based on experimental investigations carried out on light weight concrete with ceramic waste powder and light weight expanded clay aggregate, following conclusions were made:

- Production of high strength concrete with ceramic waste powder and LECA as partial substitutes to cement and natural coarse aggregate respectively was made possible.
- If the concrete produced with CW powder as partial substitute to cement, 20% replacement was found to be optimum without compromising the durability of concrete.
- If the concrete produced with LECA powder as partial substitute to natural coarse aggregate, 30% replacement was found to be optimum by compromising durability of concrete to little bit extent.
- High strength concrete with combined replacement of cement and natural coarse aggregate with ceramic waste powder and LECA respectively to be produced means, a combination of 20% CW powder with 40% LECA could be tried with desirable durability characteristics.

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