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Strength of cold bonded quarry dust aggregate concrete subjected to high temperatures

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Abstract: - The experimental investigation on the mechanical properties of quarry dust aggregate concrete subjected to high temperature is presented in this paper. Concrete cubes are prepared and tested at an age of 28 days. Cubes are heated to elevated temperatures of 200°C, 400°C, 600°C for different durations. Tests were conducted to determine the influence of heating on the compressive strength of concrete. Test results indicated that quarry dust which is waste material can be used for the manufacture of cold bonded artificial coarse aggregate and that the quarry dust aggregate concrete can withstand a temperature up to 400°C.

Keywords: - *quarry dust; artificial aggregate; temperature study; compressive strength*

I. INTRODUCTION

Concrete is a common construction material for building purpose. But now due to its vast usage the resources for making concrete is depleting day by day. In this situation the necessity of using waste material in place of natural aggregates is fast becoming a fact of life. One of such waste material is quarry dust. These are rock particles which are mostly grey in color. Green concept of construction leads the construction industry to use materials of low energy and also the materials which reduces the destabilization of environment. When there is sudden fire, the concrete elements such as columns and beams will be subjected to high temperatures demand repair. Hence, it is important to understand the changes in the concrete properties due to its exposure to extreme temperatures. Concrete has got good fire resistant properties. The property of concrete to resist the fire reduces damage in a concrete structure in the event of fire exposure.

II. LITERATURE REVIEW

Josephet.al [1] investigated the structural characteristics of concrete using various combinations of lateritic sand and quarry dust as complete replacement for conventional river sand fine aggregate. Lohani et al. [2] investigated the optimum utilization of quarry dust as partial replacement of sand in concrete. Sivakumar et.al. [3] investigated the properties of controlled low-strength material (CLSM) made using industrial waste incineration bottom ash and quarry dust. Addition of quarry dust improved the performance of CLSM made using bottom ash with regard to stability, strength, and California Bearing Ratio (CBR) and hence both the industrial waste incineration bottom ash and quarry dust are potential materials for use in CLSM. Farah et.al. [4] came to a conclusion that the use of quarry dust as partial sand replacement, in combination with silica fume increases the properties of concrete and increases the pull-out force. The mechanical properties of quarry dust addition in conventional concrete Sivakumaret.al. [5] investigated the hardened and durable properties of concrete using quarry dust. Raman et.al. [6] evaluated the suitability of quarry dust as a partial substitute for sand in high-strength concrete (HSC) containing rice husk ash (RHA).The effect of high temperatures on the mechanical properties of concrete made with different types of aggregates was studied by Netinger et.al. [7] and Felekoglu [8] investigated the usability of a quarry dust limestone powder in self-compacting paste and concrete.

III. NEED FOR THE STUDY

Environmental pollution is the main hazard faced today. Dumping of wastes will cause pollution to the environment. Treating of these quarry dust wastes is a main threat today. So by making use of these quarry dust for making aggregates, we can reduce pollution to some extent.

IV. MATERIALS AND METHODOLOGY

Cold bonded pelletızatıon

Design a concrete mix with cold bonded pelletized aggregates. Prepare the specimens,a total of 216 cubes (150x150x150mm). These cubes are heated to different temperatures for different durations. Compressive strength of these specimens heated to elevated temperatures is tested and is compared with that at ambient temperatures. Cold bonding is nothing but normal water curing. In this study, quarry dust aggregates are formed by cold bonding technique. The ratio of Ordinary Portland cement used as the binder material to quarry dust is 1:4.The physical properties of the cement used are depicted in Table 1.To make cold bonded pelletized aggregates a pelletizer is needed. Disc or pan type, drum type, mixer type and cone type are the different types of pelletizing machines available. Instead of pelletizer a mixer machine is used here for making cold bonded pelletized quarry dust aggregates. Quarry dust along with the binder was mixed well initially for 2 minutes in the mixer and water is sprinkled into it every minute. Water is sprinkled properly to get the aggregates in a ball shaped form. Large and small sized balls are formed. But if it is very large, it is crushed and again put back to the mixing machine; again water is sprinkled and continue to rotate in the mixer. The angle of rotation is an important factor which determines the shape of the aggregates. Moisture content also influences the size growth of pellets [5]. The fresh pellets formed were taken out and kept at room temperature for one day to attain initial strength and then water cured for 28 days. The pellets are formed approximately in duration of 20 minutes [5]. Investigators found that quarry dust aggregate concrete have higher value of compressive strength compared to normal aggregate concrete. The round shape of the aggregates improves the workability of concrete.

Table 1 Physical properties of cement

Sl. No.	Properties	Value
1	Specific gravity	3.20
2	Standard consistency (%)	32
3	Initial setting time (min.)	40
4	Final Setting time (min.)	600

Details of specimen

Cube moulds of 150 mm size were used for making quarry dust aggregate concrete specimen for compressive strength study. Moulds were properly maintained by cleaning and oiling before each casting. Vibrating table was used for better compaction and filled in three layers. A total number of 216 cubes were cast. The quantity of materials required for preparing one cubic meter of concrete are tabulated in Table 2.

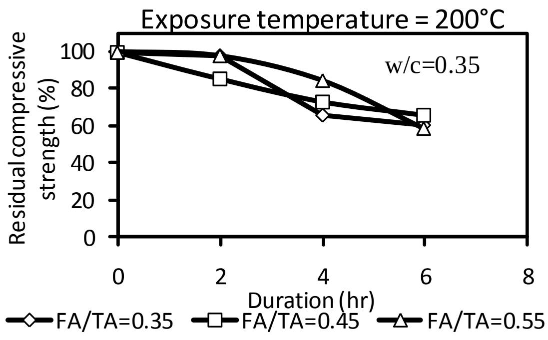
Table 2 Quantity of materials required in 1 m^3 of concrete

FA/TA	W/C (kg)	water (kg)	cement (kg)	fine aggregate (kg)	course aggregate (kg)	mix designation
0.35	0.35	186	530	585	920	Q-A
	0.45	186	415	620	975	Q-B
	0.55	186	340	645	1110	Q-C
0.45	0.35	186	530	755	780	Q-D
	0.45	186	415	800	825	Q-E
	0.55	186	340	825	855	Q-F
0.55	0.35	186	530	920	640	Q-G
	0.45	186	415	975	675	Q-H

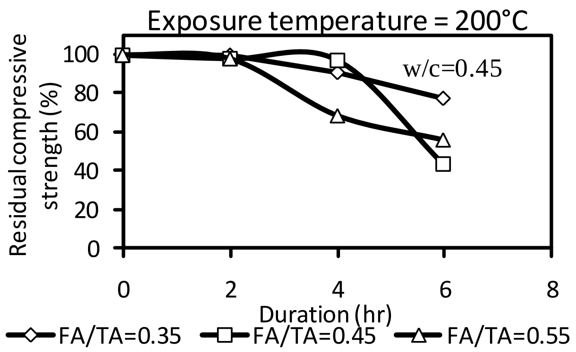
In this experimental programme, unstressed residual strength test is used to study the effects of high temperature on the cold bonded pelletized quarry dust aggregates. The specimens after curing for 28 days were placed in the electric furnace. It is a cylindrically shaped furnace having a diameter of 400mm and a depth of 600mm. The temperatures can be set accordingly using the temperature controller. The maximum exposure temperature of the furnace is 750°C-800°C .The exposure duration used are 2 hours, 4 hours and 6 hours. And the exposure temperature are 200°C, 400°C and 600°C.The test results indicated that each temperature range had a distinct pattern of strength loss or gain. Generally, it is expected that for unheated specimens, as water cement ratio and or fine aggregate to total aggregate ratio increases, the compressive strength should decrease. Also there is a fact that as the temperature increases; the strength is expected to decrease. But special cases are observed from the graphs. There has not been any study conducted to find out the formation or release of any compound from the specimen during, exposure to temperature. The increase of strength at high temperatures may be due to the formation of tobermorite which is a product of unhydrated cement particles at high temperatures. However no tests have been performed to confirm the formation of tobermorite in this study.

V. RESULTS AND DISCUSSION

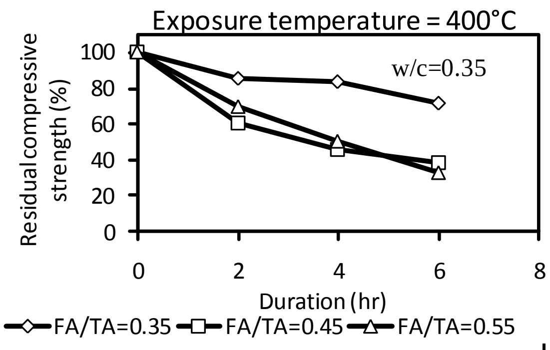
The expectation is that as exposure temperature or duration increases the compressive strength should decrease. Also, we know that as water cement ratio increases or fine aggregate to total aggregate ratio increases strength of the concrete decreases. The Fig s 1(a) to 1(c) compare the variation of cube compressive strength of cold bonded pelletized quarry dust aggregate concrete of water cement ratio of 0.35 and different FA/TA ratio with the duration at different exposure levels of 200 °C, 400°C and 600°C. From Fig1(a) to 1(c) it could not be possible to draw any general trend but it can be observed that at an exposure temperature of 200°C, concrete with FA/TA= 0.35 and FA/TA 0.55 did not show any decrease in strength by 2 hour duration of exposure to 200°C. But concrete with FA/TA= 0.45 showed a reduction in strength by 10% by exposure to 200°C for 2 hour duration. It can be observed from Fig 1(a) that, concrete with FA/TA 0.55 showed the higher reduction in strength(to 60% of the initial value) by 6 hour exposure to 200°C, even though concrete with FA/TA= 0.35 and FA/TA= 0.55 also showed a similar descent. It can be observed from Fig 1(b) that the reduction in strength for concrete with FA/TA =0.45 and FA/TA =0.55 are similar and higher than that for concrete with FA/TA 0.35. At an exposure of 6 hour duration to a constant temperature of 400°C, the decrease in strength for concrete with FA/TA = 0.35 is only10% whereas for concrete with FA/TA ratio = 0.45 and FA/TA ratio = 0.55,is 60%. It can be also observed from Fig 1(c) that concrete with FA/TA ratio 0.45 and FA/TA ratio 0.55 lost almost complete strength by 2 hour duration of exposure to 600°C. In general, concrete with higher FA/TA ratio showed sudden loss in strength at higher exposure temperature levels.



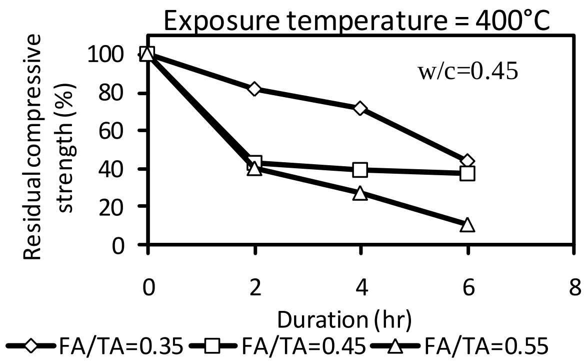
(a) Temperature 200°C



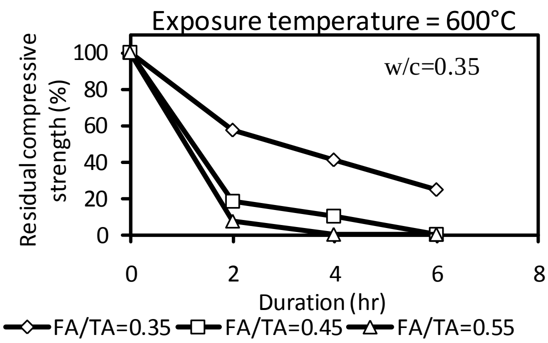
(a) Temperature 200°C



(b) Temperature 400°C

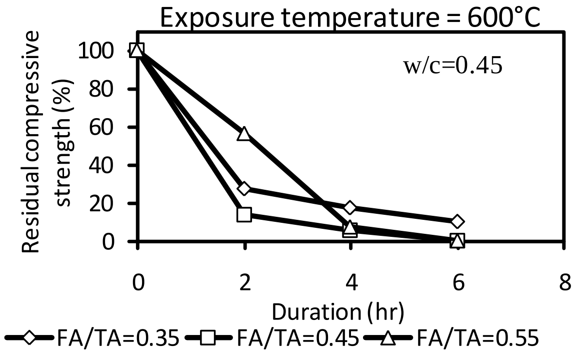


(b) Temperature 400°C



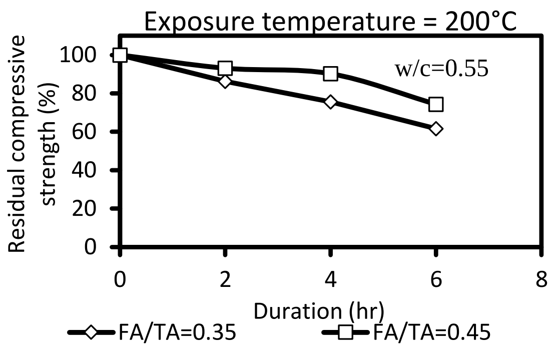
(c) Temperature 600°C

Fig. 1Residual compressive strength of concrete with w/c =0.35 versus duration at different exposure durations

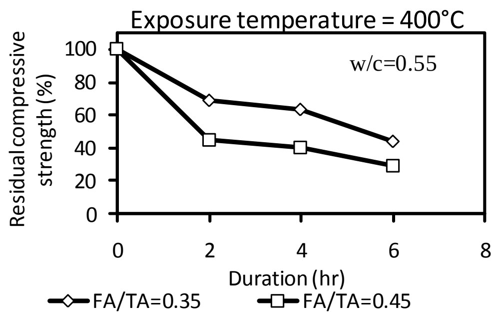


(c) Temperature 600°C

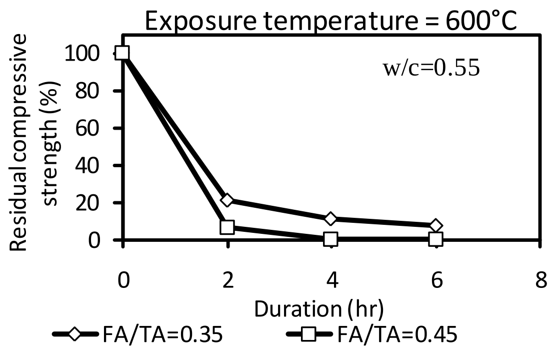
Fig. 2 Percentage variation in compressive strength with duration for concrete cubes with w/c =0.45 exposed to durations



(a) Temperature 200°C



(b) Temperature 400°C



(c) Temperature 300°C

Fig. 3Residual compressive strength of concrete with w/c =0.55 versus duration at different exposure levels

The Figures 2(a) to 2(c) compare the variation of cube compressive strength of cold bonded pelletized quarry dust aggregate concrete of water cement ratio of 0.45 and different FA/TA ratio with the duration at different exposure levels of 200 °C, 400°C and 600°C.From Fig 2(a) to 2(c) it could not be possible to draw any general trend. In Fig.2(a), it can be observed that, at an exposure temperature of 200°C, concrete with FA/TA= 0.35, FA/TA= 0.45 and FA/TA= 0.55 showed no decrease in strength by 2 hour duration. But concrete with FA/TA=0.35 showed a steady reduction in strength to 90% of the initial value, whereas that with FA/TA=0.55 reduced to 70% of the original strength, and the concrete with FA/TA=0.45 showed no reduction in strength, by 4 hour exposure to 200°C.By 6 hour duration exposure to200°C, concrete with FA/TA = 0.45 showed a sudden decrease in strength by 60%. But the concrete with FA/TA=0.35 did not show considerable reduction in strength during the same exposure duration (strength decreased only by 20%). In Fig.3(b), it was observed that at 400°C, the strength of concrete with FA/TA= 0.45 and 0.55 decreased to 40% of the initial strength, while that with FA/TA= 0.35 decreased only by 20%, when exposed for 2 hour duration. The strength descent of concrete with FA/TA=0.35 is almost steady, but for that with FA/TA= 0.45 the strength did not show further decrease after 4 hour exposure till 6 hour duration. In the case of FA/TA=0.55, the strength got reduced further to 20% of the initial value by 6 hour exposure to 400°C. In Fig.2(c), a sudden decrease in strength in the range of 25% to 15% is seen by 2 hour exposure to 600°C, for FA/TA = 0.35 and FA/TA= 0.45 respectively. By 4 hour duration of exposure to 600°C, it is seen that concrete with all the three FA/TA ratios showed a decrease in strength to zero.

The Figures 3(a) to 3(c) compare the variation of cube compressive strength of cold bonded pelletized quarry dust aggregate concrete of water cement ratio of 0.55 and different FA/TA ratio with the duration at different exposure levels of 200 °C, 400°C and 600°C.From Fig 3(a) to 3(c), it could not be possible to draw any general trend. For w/c ratio = 0.55 and exposure temperature = 200°C for 6 hour duration, the reduction in strength for FA/TA ratio = 0.35 and 0.45 is in the range 30% and 20 % respectively. Fig 3(b) shows that at 400°C, decrease in the compressive strength for FA/TA =0.35 and FA/TA=0.45 respectively are 30% and 50%. From Fig.3(c),for concrete with w/c ratio = 0.55 and FA/TA=0.35, we can observe that80% reduction in strength is observed exposed to temperature 600°C by 2 hours. But for FA/TA =0.45 there is a remarkable strength reduction and the strength got reduced to zero for both the FA/TA ratios by 4 hour exposure. The reason for no decrease in strength on exposure to temperature may be attributed to the increase in content of hydration products occurring in that temperature range. The decrease in strength as exposed duration increases can be to the fact that weakening of cement paste- aggregate bond may occur as temperature or duration increases.

VI. CONCLUSIONS

Based on the experimental study of quarry dust aggregate, following conclusions were drawn at.

- In such a case quarry dust which is waste materials can be used for the manufacture of cold bonded artificial coarse aggregate.
- From the tests it is clear that it can withstand a temperature up to 400°C and the designers can adopt the correct quantity of steel for strengthening.

However more studies are required in this work to ensure the properties of aggregates to evaluate the strength of artificial aggregate concrete containing different types of admixtures.

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