Paper ID: CE 0385

Influence of Recycled Concrete Aggregates in Addition with Ceramic Dust on Strength Properties of Concrete

M. Hasan[1], D. Mojumder[2], R. A. Abir[3]

[1] Department of Civil Engineering, RUET, Bangladesh. (mhasance037@gmail.com)
[2]Department of Civil Engineering, RUET, Bangladesh. (diganto.ruet.ce.2017@gmail.com)
[3]Department of Civil Engineering, RUET, Bangladesh. (rejwanahammedabir@gmail.com)

Abstract

The use of Recycled Concrete Aggregates (RCA); specifically used stone's chips and supplementary cementitious materials (SCMs) into concrete mix design is a promising step toward more sustainable construction practices. The purpose of this research is to look into the effect of incorporating RCA and Ceramic Dust (CD) on the strength properties of concrete. As a partial replacement for natural coarse aggregate and cement, concrete mixtures are prepared with varying levels of RCA (0%, 25%, 50%, 75%) and CD (0%, 5%, 10%, 15%). At various curing times, the compressive strength of the samples are evaluated. The findings show that incorporating RCA and CD into concrete mix design has a significant impact on the strength properties of concrete. Concrete's compressive strength decreases as RCA content increases, on the other hand compressive strength increases as CD content increases. The highest strength is obtained at a CD replacement level of 15-20%. Furthermore, the test results show that the strength properties of concrete containing RCA and CD can meet the structural concrete standard requirements. Overall, the findings of this study indicate that RCA and CD can be used as sustainable alternatives to natural aggregates and cement in concrete mix design without compromising concrete strength.

Keywords: *ceramic dust; Recycled Concrete Aggregates; Compressive Strength.*

1 Introduction

The use of recycled materials in concrete production has gained significant attention in recent years due to its potential for sustainable construction practices and waste reduction. Recycled concrete aggregates (RCA) and ceramic dust are two such materials that have shown promise in enhancing the performance of concrete while addressing environmental concerns. Recycling coarse aggregates from scrap concrete has benefits for the environment, reduces the need for landfill space, and conserves natural aggregate resources (Tabsh and Abdelfatha, 2009). The use of RCA can reduce the demand for virgin aggregates, conserving natural resources and reducing the environmental impact of aggregate extraction. In spite of the fact that recycling concrete is not currently primarily influenced by economics in all parts of the world, this may change in the future due to lower costs and recycling materials are frequently linked to reduced energy use and transportation costs (Tabsh and Abdelfatha, 2009). Another recycled material that can be incorporated into concrete mixes is ceramic dust, which is produced as a byproduct of ceramic manufacturing or processing units. Pottery items, including figurines from 27,000 years ago, were the earliest ceramics created by humans (Ramadevi, 2017). They were made from clay, either by itself or when combined with other materials, and were then hardened in fire (Ramadevi, 2017). This waste accounts for up to 30% of the total output of the local ceramic industry. Ceramic waste, by the way, accounts for 30% of all demolition waste (Torkittikul and Chaipanich, 2010). In the ceramics industry, 15% to 30% of the total production results in waste (Chalishazar et al., 2015). Ceramic waste powder is settled through sedimentation and then discarded, endangering both public health and agriculture in addition to causing environmental pollution. Use of the ceramic waste powder in various industrial fields, particularly in the building, farming, glass, and paper industries, will therefore contribute to environmental protection (Raval and Pitroda, 2013). Despite efforts by the ceramic industries to find appropriate waste disposal solutions, ceramic waste cannot currently be reused in the production of new material. As a result of these manufacturing criteria, the amount of ceramic waste will continue to grow. Ceramic waste, on the other hand, has several advantages: it is hard, durable, and chemically resistant (Targan et al., 2002). Because ceramic dust contains pozzolanic materials that react with calcium hydroxide in cement to form additional cementitious compounds, it has the potential to improve the properties of concrete. This has the potential to improve the strength and durability of concrete. Research’s says ceramic dust provides a promising strength values in order to use it for the concrete pavement road (Fatima et al., 2013). The purpose of this research is to look into the effect of incorporating recycled concrete aggregates along with ceramic dust on the strength properties of concrete. It requires quality control to conduct the test however practical implementation is comparatively tough (Sua et al., 2001). To get the maximum effective value we considered the effective size and gradation for aggregate selection (Ekwulo and Eme, 2017). Compressive strength is taken into account as important indicators of concrete's structural performance. Understanding how RCA and ceramic dust affect concrete strength properties is critical for optimizing their use in concrete production. It can provide insights into the feasibility and practicability of using these recycled materials as alternatives to traditional concrete mixes, while also contributing to sustainable construction practices and lowering the construction industry's environmental footprint. This study aims to evaluate the effects of varying proportions of RCA and ceramic dust on the strength properties of concrete using a comprehensive experimental program. The research findings can help engineers, designers, and construction professionals make informed decisions about incorporating RCA and ceramic dust into concrete mix designs, ensuring structural integrity as well as environmental sustainability. By investigating the influence of recycled concrete aggregates in addition with ceramic dust on strength properties, this study contributes to the body of knowledge in sustainable construction materials and provides valuable insights into the development of eco-friendly concrete mix designs.

2 Methodology

2.1 Experimental plan

This study involves experimental tests on thirty concrete specimens prepared with the replacement of coarse aggregate and cement with RCA and CD accordingly. For the research M20 grade concrete is taken under consideration. The specimens are prepared for evaluating and comparing the concrete strength properties for 7 days, 14 days and 28 days curing. For this consideration 10 specimen for each case with varying percentage of CD (0%, 5%, 10%, 15%) and RCA (0%, 25%, 50%, 75%) are prepared using different combinations.

Figure 1. Recycle Concrete Aggregate (RCA) & Ceramic Dust (CD).

2.2 Mix Proportions

A control mix made for conventional M20 grade concrete is required to benchmark the results in order to compare them objectively. The mixing proportions are described in Table 1. All the different ten concrete mixes were proportioned for 76 mm slump.

Table 1: Mix design proportion used for the experiment

Specimen	Cement (%)	Sand (%)	Aggregate (%)	CD (%) (replacement of cement)	RCA (%) (replacement of aggregates)
1	95	100	75	5	25
2	95	100	50	5	50
3	95	100	25	5	75
4	90	100	75	10	25
5	90	100	50	10	50
6	90	100	25	10	75
7	85	100	75	15	25
8	85	100	50	15	50
9	85	100	25	15	75
10	100	100	100	0	0

2.3 Collection of CD & RCA and Gradation of Aggregate

The CD is collected through crushing the waste Ceramics by Jaw crusher and sieving through a 200 no. sieve as it is used replacement of cement. The RCA is collected from the demolition of concrete construction and uniform gradation is selected through sieving. For conducting the experiment with even consistency, the recycled concrete aggregate's gradation matched that of the raw aggregate. Initially, the natural aggregate's gradation is obtained through sieving, as shown in Table 2. The recycled aggregate's final gradation matched that of the natural aggregates.

Table 2. Gradation of coarse aggregate

Opening size (mm)	Percent retained
25	0
19	8.9
12.5	48.0
9.5	10.5
6.3	14.9
4.75	9.7
2.36	8.0

2.4 Casting

Coarse aggregate, RCA, fine aggregate, cement and CD are thoroughly mixed together, and the required water, estimated at 0.52 water-cement ratio (w/c), is added. The entire mixture is mixed until it formed an even paste. Before casting into 4 in × 8 in cylindrical mold, the various proportional mix are conducted through a slump for the research’s betterment

Figure 2. Concrete casting

2.5 Slump test

Three layers of material are poured into the slump mold, and before the next layer is added, each layer is compacted with 25 blows by a steel rod. After filling the slump cone and waiting for two minutes, the surface is leveled. The pile of unsupported concrete then collapsed as a result of the slump cone being raised off the surface. The slump is calculated as the difference between the concrete's initial and final heights.

2.6 Curing

Three (3) cylinders are cast for each of the different ten (10) concrete specimens made according to the different percentage of CD & RCA, totaling thirty cylinders. The cylinders are cast by adding small layers of material to each mold and compacting them with a tamping rod before adding the next layer of material. They are demolded and put into a curing tank with clean water after being allowed to set in the mold for 24 hours at laboratory temperature. Each of the ten (10) different specimens are cured into curing tank for 7 days, 14 days & 28 days.

Figure 3. After Curing of specimens

2.7 Compressive Strength test

Ten number of cylinder specimens of average size 106 mm diameter for compressive strength test are cast and tested at 7 days, 14 days and 28 days after curing. The cylinders are removed from the curing tank, taken the measurements after polishing, and tested with the Universal Testing Machine at 7 days, 14 days and 28 days. The compressive strength at each curing age is calculated using the value of the load at which the test cylinder failed.

Figure 4. Compressive strength test of specimens

3 Results and Discussion

In this study, the concrete specimens are prepared and tested for evaluating the strength properties. Figure 5 represents a comparison among the obtained compressive strength for 7 days, 14 days & 28 days curing of four different types concrete specimens. It is clear that the compressive strength for RCA & CD replaced concrete sample is about 35-42% less than the conventional concrete for 14 days curing. The percentage of strength increase after 28 days are quite impressive where 50% RCA with 5% CD added specimen gains M20 grade concrete strength. Figure 5 also shows that the replacement of higher percentage of RCA with constant percentage of CD (5%) has drawn a significant improvement in compressive strength of concrete.

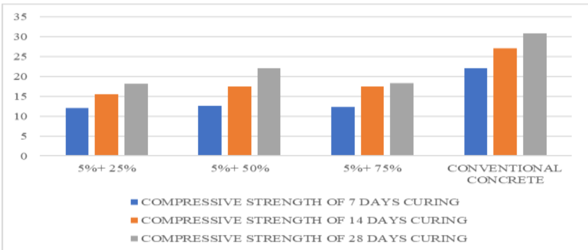

Figure 5. Compressive strength of concrete specimen with 5% CD with various percentage of RCA

From Figure 6, the compressive strength of concrete specimens with constant percentage of CD (10%) with varying percentage of RCA are obtained and a comparison among them is observed. Almost similar pattern graph of Figure 5 is noticed for Figure 6, where the compressive strength of concrete specimen with varying percentage replacement of RCA with 10% CD are reduced from 35% to 40% compared to conventional concrete after 14 days of curing. Besides the strength increase from the ascending order use of RCA which is almost 22% to 39% after 28 days. All the concrete specimens achieve the desired M20 grade compressive strength after 28 days of curing compared to conventional concrete.

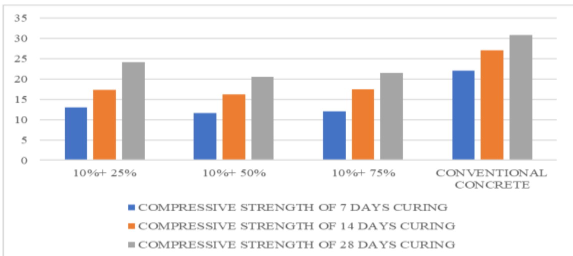

Figure 6. Compressive strength of concrete specimen with 10% CD with various percentage of RCA

For 15% CD mixes with various percentage of RCA replacement, the Figure 7 shows a very impressive result comparing to the previous Figure 5 and Figure 6 where all the specimen gains M20 grade concrete’s strength at 28 days. Also at 28 days the strength increase upto 13% to 28% compared to 14 days curing. For 50% aggregate replacement, the concrete achieves M20 grade concrete’s compressive strength after 14 days of curing.

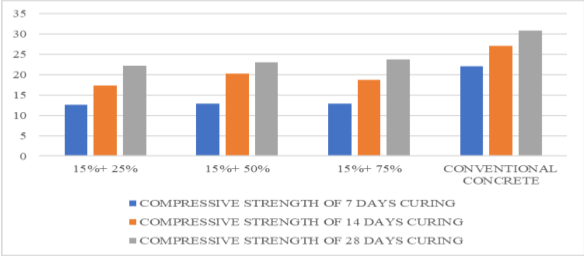

Figure 7. Compressive strength of concrete specimen with 15% CD with various percentage of RCA

From Figure 8 it is clear that 25% of RCA replaced with natural aggregate and 10%, 15% of CD replacement with cement show that the compressive strength is comparatively higher than 5% CD replaced concrete which is almost 40% less than the conventional concrete where 10% and 15% CD replacement improves the strength of concrete up to 10-12% with respect to 5% CD added concrete. 10% CD with 25% RCA added concrete shows a very impressive result at 28 days curing where the strength reduced with respect to conventional concrete is up to 21%.

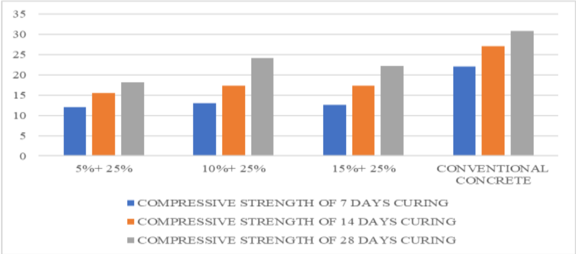

Figure 8. Compressive strength of concrete specimen with 25% RCA with various percentage of CD

Form Figure 9, the graph shows the most effective output which come from 10% CD and 15% CD with 50% RCA replacement which achieve M20 grade concrete strength at 28 days curing. The second higher compressive strength compared to conventional concrete is for 10% CD which is 35% less after 14 days curing. Besides the strength, increase for 5% CD to 15% CD is up to 76%-79% at 28 days curing as compared to 7 days curing.

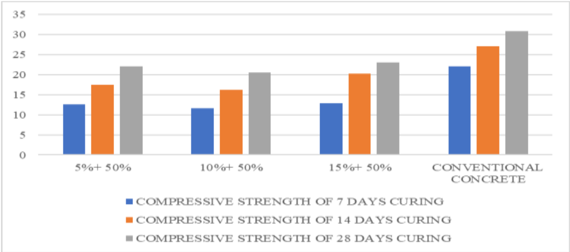

Figure 9. Compressive strength of concrete specimen with 50% RCA with various percentage of CD

For 75% RCA replaced mixes with various percentage of CD, Figure 10 has shown that 10% and 15% CD added concrete provide higher strength compared to 5% CD replaced concrete. But, for the specific replacement of RCA (75%) with various percentage of CD replaced concrete, the strength deteriorates from 34-36% with compared to conventional concrete. So, it is clear that higher value of strength is achieved for using higher percentage of CD addition.

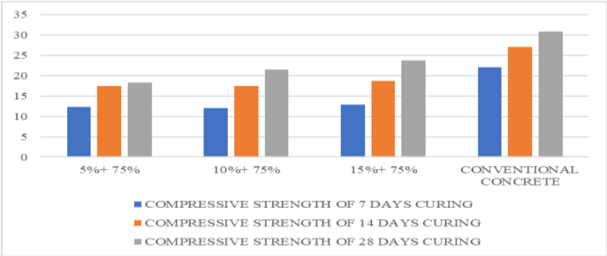

Figure 10. Compressive strength of concrete specimen with 75% RCA with various percentage of CD

4 Conclusion

In this study various percentage of recycled aggregates and ceramic dust are used in concrete to investigate that which mix proportion of RCA and CD can achieve the strength of M20 grade concrete after 7 days, 14 days and 28 days curing. From the experimental data, the following conclusions are drawn:
Several factors may play a role in the observed rise in compressive strength when ceramic dust is used as a cement substitute in concrete made with recycled aggregates. It's crucial to keep in mind that the results can change based on the unique characteristics of the ceramic dust, the type of recycled aggregates, and the overall mix design. In ceramic dust, reactive pozzolanic materials are frequently present. The calcium hydroxide formed during the hydration of cement reacts with pozzolanic materials to produce more calcium silicate hydrate (C-S-H) gel. This gel has a big impact on the durability and strength of concrete. Besides ceramic dust particles can act as microfillers to close up spaces between aggregate particles and produce a matrix that is denser. This could enhance the overall cohesion of the concrete mixture and increase compressive strength and ceramic dust may reduce the amount of reactive aggregates or minerals that can contribute to the alkali-silica reaction. This reaction could cause concrete to degrade and expand over time. By substituting ceramic dust for some of the cement, the likelihood of this reaction could be reduced while also improving the compressive strength as compared with only RCA added concrete. Addition of RCA usually reduces the strength of concrete. But addition of percentage of CD with RCA achieves higher strength because of the above properties of CD. That's why after 14 days of curing 15% CD in addition with 75% RCA added specimen shows the maximum strength compared to others. All the CD and RCA added concrete specimen achieve M20 grade strength after 28 days of curing where 10% CD with 25% RCA shows the most impressive result which is almost 25MPa. Besides the concrete which are prepared using 50-75% of RCA with 15% of CD can be preferable where strength is required as similar to M20 grade concrete. Therefore it can be said that reuse of recycled aggregate in addition with ceramic dust can improve the compressive strength in practical application for eco-friendly and reusing purpose.

References

Chalishazar, J. R., Jamnu, M. A., and Purohit, B. M., (2015). Study on Use of Recycled Concrete Aggregate and Ceramic . International Research Journal of Engineering and Technology (IRJET), 1418-1425.

Ekwulo, E. O., and Eme, D. B., (2017). Effect of Aggregate Size and Gradation on Compressive Strength of Normal Strength Concrete for Rigid Pavement. American Journal of Engineering Research (AJER), Volume-6, Issue-9, pp-112-116

Fatima, E., Jhamb, A., and Kumar, R. (2013). Ceramic Dust as Construction Material in Rigid Pavement. American Journal of Civil Engineering and Architecture, 2013 1 (5), pp 112-116. DOI: 10.12691/ajcea-1-5-5

Ramadevi, K. (2017). A Study on Properties of Concrete With Ceramic Waste Replaced For Fine Aggregate. International Journal of Civil Engineering and Technology (IJCIET), 1730-1737.

Raval, A. and Pitroda, J., (2013). Ceramic Waste : Effective Replacement Of Cement For Establishing Sustainable Concrete. International Journal of Engineering Trends and Technology (IJETT), 2324-2329.

Sua, N., Hsub, K. C., and Chai, H. W., (2001). A simple mix design method for self-compacting concrete. Cement and Concrete Research, 1799-1807.

Torkittikul, P. and Chaipanich, A. (2010). Utilization of ceramic waste as fine aggregate within Portland cement and fly ash concretes. Cement & Concrete Composites, 440-449.

Tabsh, S. W., and Abdelfatha, A. (2009). Influence of recycled concrete aggregates on strength properties of concrete. Construction and Building Materials, 1163-1167.

Targan, S., Olgun, A., Y. Erdogan, Y., and Sevin, V. (2002). Effects of supplementary cementing materials on the properties of cement and concrete. Cement and Concrete Research, 1551-1558.