Paper ID: CE 0214

Mechanical and non–destructive Characteristics of Over-Burnt Brick Aggregate for the Production of Structural Concrete

Z. S. Koma[1], M. H. R. Sobuz[2 *], S. Talukder[3]

[1]Department of Building Engineering and Construction Management, Khulna University of Engineering and Technology, Bangladesh (zhasnatkoma@gmail.com)
[2]Department of Building Engineering and Construction Management, Khulna University of Engineering and Technology, Bangladesh (habib@becm.kuet.ac.bd)
[3]Department of Building Engineering and Construction Management, Khulna University of Engineering and Technology, Bangladesh (shakiltlkdr.becm.kuet@gmail.com)

Abstract

In recent years, an increasing interest has been in using over-burnt brick aggregate (OBBA) in producing normal-strength concrete (NSC). However, the use of OBBA in NSC has not been extensively studied, and its effects on the properties of concrete are not fully understood. This type of aggregate has been shown to have the potential for use in producing normal-strength concrete. Thus, alternative sources of aggregates, such as over-burnt bricks, are being investigated. This study examines the influence of over-burnt brick aggregates (OBBA), silica fume, and steel fiber on normal-strength concrete (NSC) production. The study involved replacing natural aggregates with OBBA at varying percentages (0%, 20%, 40%, 60%, 80%, and 100%) by weight. The mix designs were prepared using a constant water-cement ratio of 0.6. The fresh density, compressive strength, and ultrasonic pulse velocity (UPV) of the NSC's fresh and hardened characteristics were assessed. The results showed that as the percentage of OBBA rise, the density of the NSC drop. The strength was within acceptable limits for NSC. The study also found that using OBBA up to 60% by weight could produce NSLC with a density of 1926.12 kg/m^3 and compressive strength of 30.5 MPa, which is within the range of NSC. In conclusion, for the creation of NSC, utilizing OBBA can be a practical substitute for natural aggregates.

Keywords: *Normal strength concrete; over burnt brick aggregate; silica fume; steel fiber; Destructive & Non-destructive characteristics.*

1 Introduction

Concrete is a combined material created by mixing fine and coarse materials with a fluid cement paste that hardened over time. It is an essential and frequent binding substance with benefits like fluidity before hardening, strong compressive strength, and the availability of its specific materials. For such dominance, the use of concrete is rapidly growing and leading to concern about waste management. Due to the enormous infrastructure being developed due to urbanization's rapid growth, an acute shortage of building supplies is driving up construction costs. The high cost and inadequate supply of natural stones in Bangladesh encourage the use of locally accessible resources as coarse aggregate (Rasel et al., 2011). Low–cost and locally available alternative building materials have drawn attention as a solution to this issue.
On the other hand, due to the kiln's inconsistent temperature distribution during production, about 13% of bricks are severely overburnt (Sarkar & Pal, 2016). Those burnt bricks (BB) have no use in the construction industry except crushed over-burnt brick aggregates (OBBA). Due to its application, which can significantly reduce the need of natural aggregate like stone, shrink aggregate expenses for transportation, and lower waste disposal challenges, OBBA has a very high level of acceptance. OBBA has a maximum Los Angeles Abrasion value of 30, which is acceptable for use as aggregate in the base course (Mazumder et al., 2006). Bricks are a very porous material with a great capacity to absorb water. A downgraded line in strength varies from 20-30% for fine and coarse crushed bricks depending on the replacement degree (da Conceição Leite et al., 2011). (Baspinar et al., 2010) investigated that Silica fume has a strong contribution to the vitrification and enhancement of the strength of brick–cement concrete. The characteristics of concrete produced by partially substituting ordinary brick aggregate (OBBA) for regular brick aggregate (RBA) in a range of 0 to 100% with water-cement ratios of (0.5,

0.55, and 0.6) demonstrates that when the fraction of OBBA expands, the concrete's compressive strength rises. For 75%, replacing RBA with OBBA in concrete increases the compressive strength by 33%. (Awall et al., 2017) studied that the least concrete unit weight ever obtained is 79% of the average concrete unit weight. Besides, With OBBA, stronger concrete can be produced (f_{cu} = 31.0–45.5 N/mm^2). (Rashid et al., 2009). Even (Cachim, 2009; Sable & Walke, 2015) suggested that up to 30% of aggregate can replace natural coarse aggregate without compromising strength, and replacing 15% of natural aggregate with brick aggregate is proven to be both practical and cost-effective. Another study was conducted by (N. Apebo et al., 2013) to assess the concrete's effective proportion of OBBA content, and observed that at 25% OBBA, strength increased swiftly, but decreased at 50% OBBA.

In this study, OBBA replaces natural aggregate in various weight-percentages, including 0%, 20%, 40%, 60%, 80%, and 100%. The laboratory has performed a fresh and durable properties test of normal strength concrete (NSLC) and other standard tests like density, compressive strength, splitting tensile strength, and flexural strength. The main objective of this work is to determine and improve the mechanical properties of normal strength concrete using OBBA, steel fiber, and silica, as well as a compare between controlled concrete with steel fiber, silica fume, and OBBA to consider alternatives to burn brick aggregate for these waste disposal and consumption.

2 Experimental Design

2.1 Materials

Overburnt brick aggregate and regularly accessible local brick chips were used as the coarse aggregate. The aggregates were evaluated in accordance with ASTM standards. The aggregate range in size from 10-18 mm, as shown in Figure 1, and it has been observed that the surface of brick chips has an exceptionally porous texture. Sylheti – sand was used as fine aggregate with a fineness modulus 3.21. Ordinary Portland Cement of type II was used as binding material which was gathered from the neighborhood market. Silica fume is the byproduct of ferrosilicon alloy construction. It has a 150 nm average particle size. The primary constitution of silica fume is SiO_2, around 85%. Besides, its specific gravity is 2.25. The Masterpolyheed Superplasticizer was used in this study as it may enhance both early and ultimate strength. Around 25% water content reduction was allowed by the superplasticizer. In addition, slump stability and workability of concrete are also improved by using this superplasticizer. The basic properties and configuration of the hook–end deformed steel fiber used, and the length was 20-25 mm. Its aspect ratio was 60%, with 228 kg/mm^2 tensile strength.

(a) (b)

Figure 1: (a) RBA and (b) OBBA

2.2 Mixture Proportion, Concrete Mixing, and Curing of Concrete

The study included creating divergent trial–error concrete mixes by changing the water–cement ratio and superplasticizer following the EFNARC (2002) guideline. Six different mixes were considered; the mix proportion of concrete 1: 1.56:3.14 for cement, sand, and brick chips, respectively, was used according to the ACI 211.1-91 code. The remaining five mixtures successively substituted 20%, 40%, 60%, 80%, and 100% of RBA by OBBA with a constant amount of steel fiber. The mixing procedure has been completed following ASTM C192-18. Total 72 cylindrical (100mm x 200mm) specimens were made for compressive strength test. Each batch of concrete's fresh characteristics was evaluated right away after mixing. After the molds were removed after 48 hours, the specimens were set in plastic curing tanks and completely drowned in potable water for 7, 28, and 56 days. The water was cured at 25 °C, or at room temperature.

2.3 Test Set – up and Instrumentation

All experiments on fresh, hardened, and durable concrete properties were carried out in the Structural and Material Engineering Lab of the Department of Building Engineering and Construction Management at Khulna University of Engineering and Technology in Bangladesh.

2.3.1 Fresh Density Test

According to the BS EN 12350-10:2010 standard, the fresh concrete's density was tested. A cylindrical container (1500mm x 200mm) was filled with fresh concrete. The container then vibrated to remove any air voids and ensure the concrete compacted uniformly. Then weighted, the container using a scale. Again, the second measurement was done after the container had been filled with concrete but had not been compacted. Figure 2 shows the water and concrete measurement for the density test.

Figure 2: Weighting container with fresh concrete

2.3.2 Compressive Strength Test

The compressive strength test was occupied in accordance with the standard ASTM C39 for the cylinder specimen in this investigation. The Universal Testing Machine (UTM) had a digital capacity to control its configuration and rate of loading, where its capacity was 3000kN. The different parameter was set on the machine screen, such as loading rate, specimen dimension, test type and specimen age, and specimen weight. Nine nos. of each batch cylinder specimens were tested at 7, 28, and 56 days. Using UTM, at a constant rate of 0.25 MPa/s, the compression load was applied continuously without disturbance in a single direction shown in Figure 3. The failure load was measured and used to calculate compressive strength. Additionally, the sample's appearance and failure type were noted.

Figure 3: Universal Testing Machine (UTM)

2.3.3 Ultrasonic Pulse Velocity Test

A non-destructive test called the ultrasonic pulse velocity (UPV) test uses sound wave velocity measurements to assess the quality of concrete. This experiment was conducted according to ASTM C597-16 at 7, 28, and 56 days.

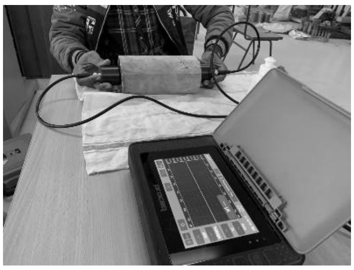

Figure 4: Testing specimen using UPV

The UPV test methodology relies on the direct arrival of compressional waves or an ultrasonic pulse was generated by the transducer when it was in close touch to one surface of the under investigation concrete portion. After traversing a known path length in the concrete sample, the pulse vibration was converted into an electrical signal by the second transducer held in contact with other surfaces, and an electronic timing circuit enabled the transit time of the pulse to be measured. With the receiver transducer situated on the opposite face of the concrete part (direct transmission or cross-probing), the ultrasonic pulse applied to the material's surface propagated with the greatest amount of energy at right angles to the transmitting transducer's face. The pulse velocity and compressive strength for NDT tests measured on different days, as in Figure 4.

3 Experimental Results

3.1 Fresh Density

When the coarse aggregate is partially replaced with OBBA, there is likely to be a decrease in the density of the mix, as illustrated in Figure 5. At a replacement level of 20%, the reduction in the density may seem relatively small, with the value of 2494.97 kg/m^3 still within an acceptable range for many applications. The observed tendency to lower fresh concrete density by adding OBBA is identical to other investigations. Based on previous research, a density of 2233.19 kg/m^3 was obtained when 20% of the coarse aggregate was replaced by OBBA (Ali et al., 2013). The decrease in density may be attributed to several factors. One of them is the lower specific gravity of OBBA compared to RBA. Another factor that can contribute to eliminating density is the air void in the mix, as OBBA is less uniform than RBA.

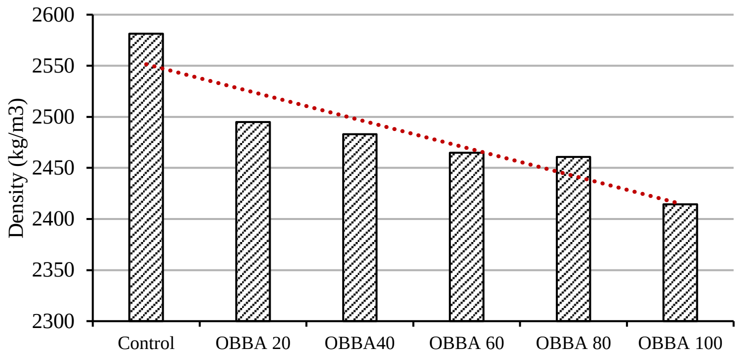

Figure 5: Density test result for different mixes

3.2 Compressive Strength

Examining the test findings from Figure 6, it is observed that contrasted to the control mix, the specimen's compressive strength rose. At 28 days, the mixture with 60% replacement had the highest compressive strength, 30.5 N/mm^2. However, the difference in strength between the batches was relatively small over time. (N. S. Apebo et al., 2013) investigated that the highest value for the 28th-day strength is 35.9 N/mm^2 for a gravel crushed over-burned bricks ratio of 2:2 and a w/c ratio of 0.4, while (Bhattacharjee et al., 2011) utilized after being crushed on

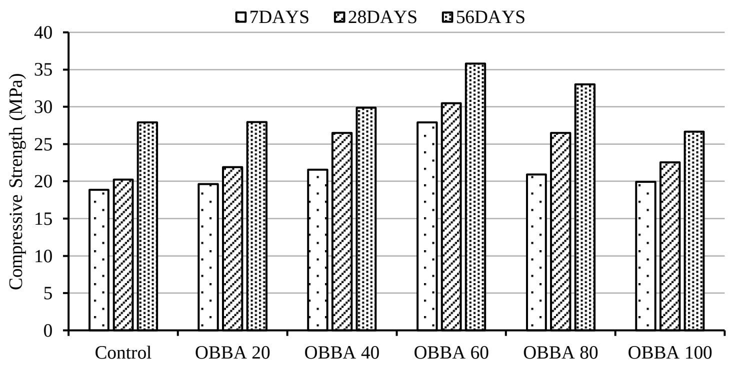

Figure 6: Compressive strength test results for various specimen

compressive strength of 29.16 N/mm^2 was obtained by burned bricks for 28 days in a mixture of 1: 1.24: 2.48 with a w/c ratio of 0.48. Since the compressive strength of concrete grows with concrete age, this conclusion might have come about as a result of water being absorbed by the crushed burnt bricks, which prolonged the hydration process over time and enhanced the concrete's compressive strength.

3.3 Ultrasonic Pulse Velocity

Figure 7 illustrates how the amount of OBBA affected the UPV of concrete specimens at 7, 28, and 56 days old, respectively It can be seen that as more OBBA replaces RBA, the UPV of concrete is substantially raised. In contrast, the velocity decreases after the OBBA60 batch mix, meaning more than 60% incorporated OBBA concrete shows reduced velocity. However, the pulse velocity of concrete at 56 days increased by 7.14% more than the control specimen. (Karimaei et al., 2021). It is observed that compared to replacing fine aggregates, replacing untreated coal waste in coarse aggregates shows the largest influence on boosting the pulse velocity. The greatest UPV is exhibited by substituting 60% of the regular aggregate with OBBA, which results in a pulse velocity of 3750 m/s. However, by 56 days of age, this substitution results in a pulse velocity decline of 5.71–6.15% when compared to the control specimen. Furthermore, it is also observed that because of the binder paste's ability to resist capillary pores and microcracks, the pulse velocity increases as concrete's age increases.

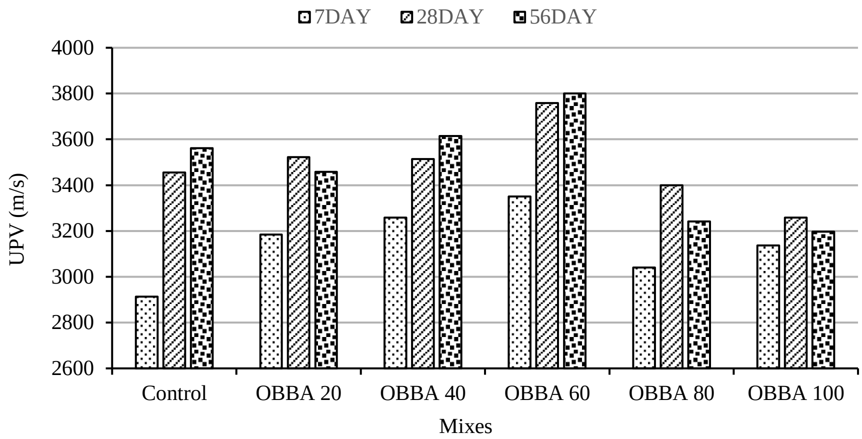

Figure 7: Ultrasonic Pulse Velocity of concrete for various specimen

4 Conclusion and Recommendation

The concrete's strength in compression is significantly influenced by the mortar-aggregate interlocking system. Because of its porous composition, OBBA interlocks with mortar more effectively, which has an impact on its ultimate compressive strength. At 60% OBBA content, concrete's compressive strength increases, while it decreases at 80% OBBA concentration. Consequently, the UPV also showed significant results till the 60% replacement of RBA by OBBA. However, when w/c proportions increase, concrete's strength drops.

In this study, it is obvious that increasing the amount of OBBA replacement rises the mechanical property of concrete. So, further percentage replacement of OBBA can be used to achieve more strength in concrete and High Strength Concrete (HSC) with reduced weights to increase its mechanical property.

References

Ali, T., Iqbal, N., Zeeshan, M., & Khan, M. Z. A. (2013). Evaluation of the Compressive strength of Concrete for partial replacement of Over Burnt Brick Ballast Aggregate. *International Journal of Science and Modern Engineering (IJISME)*, *2*(1), 232-234.

Apebo, N., Iorwua, M., & Agunwamba, J. (2013). Comparative analysis of the compressive strength of concrete with gravel and crushed over burnt bricks as coarse aggregates. *Nigerian Journal of Technology*, *32*(1), 7-12.

Apebo, N. S., Shiwua, A. J., Agbo, A. P., Ezeokonkwo, J. C., & Adeke, P. T. (2013). Effect of Water-Cement Ratio on the Compressive Strength of gravel-crushed over burnt bricks concrete. *Civil and Environmental Research*, *3*(4), 74-81.

Awall, M. R., Oli-Ur-Rahaman, M., Azad, M. S., & Rabbi, S. F. (2017). Compressive strength behavior of concrete by partial replacement of regular brick with over-burnt brick aggregate. *Innovative Infrastructure Solutions*, *2*, 1-7.

Baspinar, M. S., Demir, I., & Orhan, M. (2010). Utilization potential of silica fume in fired clay bricks. *Waste management & research*, *28*(2), 149-157.

Bhattacharjee, E., Nag, D., Sarkar, P. P., & Haldar, L. (2011). An experimental investigation of properties of crushed over burnt brick aggregate concrete. *International Journal of Engineering Research and Technology*, *4*(1), 21-30.

Cachim, P. B. (2009). Mechanical properties of brick aggregate concrete. *Construction and Building Materials*, *23*(3), 1292-1297.

da Conceição Leite, F., dos Santos Motta, R., Vasconcelos, K. L., & Bernucci, L. (2011). Laboratory evaluation of recycled construction and demolition waste for pavements. *Construction and building materials*, *25*(6), 2972-2979.

Karimaei, M., Dabbaghi, F., Dehestani, M., & Rashidi, M. (2021). Estimating compressive strength of concrete containing untreated coal waste aggregates using ultrasonic pulse velocity. *Materials*, *14*(3), 647.

Mazumder, A. R., Kabir, A., & Yazdani, N. (2006). Performance of overburnt distorted bricks as aggregates in pavement works. *Journal of materials in civil engineering*, *18*(6), 777-785.

Rasel, H., Sobhan, M., & Rahman, M. (2011). Performance evaluation of brick chips as coarse aggregate on the properties of bituminous mixes. *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology*, *2*(02), 37-46.

Rashid, M. A., Hossain, T., & Islam, M. A. (2009). Properties of higher strength concrete made with crushed brick as coarse aggregate. *Journal of Civil Engineering (IEB)*, *37*(1), 43-52.

Sable, S. G., & Walke, S. (2015). Experimental investigation on properties of concrete for partial replacement of brick ballast aggregate. *Int J Emerg Technol Adv Eng*, *5*, 246-252.

Sarkar, D., & Pal, M. (2016). Effect of cement on properties of over-burnt brick bituminous concrete mixes. *Journal of The Institution of Engineers (India): Series A*, *97*, 163-170.