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Effects of Over-burnt Bricks on Gradation, Water Absorption and Specific Gravity of Aggregates, Workability and Compressive Strength of Concrete

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ABSTRACT

Demand of bricks is increasing day by day by the requirement of new structures. Due to manufacturing of bricks, over-burnt bricks are also made. Generally over-burnt bricks are the waste materials which is generally used for dumping purpose and sometime it is thrown in useful land that create social and environmental problems. Therefore, this material should be properly treated, recycled and used in concrete as coarse aggregate. In this research work, six (06) batches were made with 1:2:4 mix and 0.5 water cement ratio. Each batch consists of five (05) samples. Six (06) batches were made with 0%, 20%, 40%, 60%, 80% and 100% replacement of natural coarse aggregates with over-burnt bricks aggregates. The outcome of study reveals that the gradation of both the aggregates shows same pattern and the trend of curve was almost similar, with minor difference in range values over a sieve. The water absorption of over-burnt bricks aggregates was more than the water absorption of natural coarse aggregates and the specific gravity of over-burnt bricks aggregates was less than the specific gravity of natural coarse aggregates. The result of slump test shows that there was continuous decrease in workability of concrete mix, as replacement of over-burnt bricks aggregates increased. 30 concrete cubes of (6" x 6" x 6") size were prepared and cured for 28 days followed by compressive strength. The result shows that the concrete derived from over-burnt bricks aggregates attained lower compressive strength than the regular concrete. However, the values obtained from over-burnt bricks aggregates are still acceptable, especially for reasonable levels of the replacement ratio up-to 60%. This concrete can be used in new constructions, but it is proposed to be initially utilized in low load areas.

1. INTRODUCTION

The construction industry is a pillar of modern society, with concrete being one of its fundamental building blocks. Over the years, efforts have been made to improve the sustainability and performance of concrete, and one avenue of exploration has led to the utilization of industrial by-product. One such by-product, over-burnt bricks, produced from excess heating during the brick manufacturing process, has garnered attention for its potential to influence the properties of concrete. In the pursuit of more sustainable & efficient construction practices, it is crucial to understand how the inclusion of over-burnt bricks affects key attributes of concrete, including gradation, water absorption, specific gravity of aggregates, workability, and compressive strength.

A good number of publications about the processing, use, aggregates properties and the behavior of concrete at fresh and hardened state is available in the literature. Author [1] has presented the evaluation of the compressive strength of hybrid clay bricks from interlocking brick making machine. The mixture of clay and cement at varying proportions was loaded into the mould compartment, mechanically rammed and hydraulically controlled. The raw clay was sourced from Ilesa and Akure in the south-western part of Nigeria. Ilesa hybrid bricks possess better reliability and workability under loading than the Akure bricks. Burnt clay brick is one of the ancient building materials. The use of waste materials in bricks can lessen the consumption of clay material and reduce the environmental burden due to accumulation of waste materials [2]. The results indicated that the incorporation of

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up to 20 weight percentage of CFA produced fired clay bricks with physical and mechanical properties similar to control bricks without waste. However, additions of a higher amount (30–50 wt%) of residue resulted in a more pronounced decrease in mechanical properties (between 25–50%) due to an increase in open porosity [3]. The history of bricks making dates back to 7000 BCE, when the bricks used to be in the form of sun-dried mud blocks. Since then, a lot of modifications have been done in the composition of bricks and in brick making procedures. As a result, in today's world, brick is considered as one of the most sought after materials used in the construction of various civil engineering structures [4].The concrete tiles with 15% (LS2) partial substitution had the highest average flexural and compressive strengths, while the tiles with 45% (LS4) partial substitution had the lowest average values. As to the type of solid waste material, the study revealed that the concrete tiles with pulverized clear-plastic solid waste materials had numerically higher flexural and compressive strengths than those concrete tiles with pulverized aluminized plastic solid waste material for gravel [5]. Common ways of disposing waste plastic such as incineration and land-filling have negative impacts on the environment. Partial replacement of natural aggregate in concrete with waste plastic including polyethylene terephthalate (PET) is more environmental friendly and sustainable [6]. In an earlier study, a comprehensive and critical review of previous investigations into the assessment of the strength of concrete incorporating aggregates from demolished wastes was conducted and it was concluded that there was a stark absence of results from the South African sub-continent including Botswana [7]. A detailed chemical/physical characterization of the geopolymer is given, evidencing the completion of the geopolymerization reaction and the good stability of the geopolymer to leaching, freeze-thaw cycles and high temperature treatments as well as its adequate mechanical properties. Pull-off tests proved the excellent adhesion strength of the geopolymer grout, also embedding meshes and fabric, to both types of clay bricks [8]. Olive pomace bottom ash was used to replace different amounts (10–50 wt%) of clay in brick manufacturing. Fired bricks fulfil standards requirements for clay masonry units, offering, at the same time, better thermal insulation of buildings due to a reduction in thermal conductivity of 14.4% and 16.8% respectively, compared to control bricks (only clay) [9]. Clay bricks were amongst the first artificial materials produced by men for building purposes that proved to be easy to produce, resistant, and durable, as attested by the numerous examples that can be seen all around the world that endured centuries of rough climacteric conditions and wars. Clay bricks are simply produced by mixing clay and water. Hardening methods evolved from sun drying to industrial ovens, which allowed strength and durability to increase [10]. Manufacturing of bricks, using clay or fly ash, is one of the major contributors to greenhouse gas emissions as their manufacturing involves utilization of coal and cement. To overcome this limitation, alternative construction materials are developed by author using industrial and agro wastes like cotton mill waste, recycled paper mill waste, and rice husk ash [11]. Clay brick is the most common construction material used in the historical buildings of Diyarbakır (Turkey). Many clay brick manufacturing workshops and numerous brick masters have emerged. Diyarbakir currently has two clay brick workshops that face the problem of being closed down. Therefore, manufacturing of clay brick by traditional methods may be forgotten in Diyarbakir [12]. Oad et. al. [13] used recycled coarse aggregate from demolish waste as replacement of conventional aggregates up to 100% replacement level. Based on the laboratory investigations of compressive strength of concrete cylinders, the authors concluded 50% replacement as optimum because the loss of compressive strength was least at this level of replacement. Author [14] used silica fume as replacement of cement up to 25% and recycled coarse aggregate from demolishing waste as 50% replacement of conventional aggregates. Based on the laboratory investigations of compressive strength of recycled aggregate concrete cubes, the authors concluded 15% replacement as optimum dosage and can be used in those areas where the load carrying capacity of structural members is not of primary importance. Bio-solids are a major by-product of the wastewater treatment process. Bio-solids-amended bricks fulfilled the standard requirements, particularly in terms of compressive strength, while, at the same time, they offered light weight bricks compared to the control bricks [15].

In summary, the importance of this research lies in its potential to bridge the gap between sustainability and construction by exploring the impact of over-burnt bricks on the concrete. As we move forward in an era where environmental considerations are paramount, understanding the effects on gradation, water absorption, specific gravity of aggregates, workability, and compressive strength is crucial to improving the efficiency and eco-friendliness of the construction industry.

2. MATERIALS AND METHODS

Over-burnt bricks used in this research were collected from kiln of Nawabshah city. The collected over-burnt bricks were hammered to get aggregate of minimum size of 25mm [19]. Sieving was done to get the over-burnt bricks aggregates (OBBA). Similar sized natural coarse aggregates (NCA) were obtained from local market of Nawabshah city. Fine aggregates (Bolhari Sand) used in the mixes were obtained from the local market of Nawabshah City. The Sand was sieved to remove lumps and larger particles before used in the concrete. After hammering and removing the unwanted material from over-burnt bricks aggregates, sieve analysis of both the aggregates were done.

Grading for nominal size coarse aggregates shall comply with ASTM C-33 standard gradations: 1-inch Nominal size coarse aggregate. After gradation of aggregates, natural & over-burnt bricks and natural coarse aggregates were washed & oven-dried to check the water absorption & specific gravity (Figure 1). Table 1 shows the water absorption & specific gravity of aggregates.

Table 1. Water absorption and Specific gravity of natural and over-burnt bricks aggregates

Test	NCA	OBBA
Water Absorption (%))	1.6	4.0
Specific Gravity	2.64	2.2

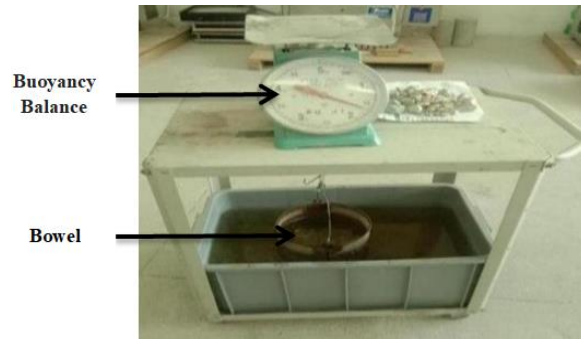

Fig. 1. Setup of Water absorption and specific gravity test

Fig. 2. Setup of Slump Cone Test

Ordinary Portland Cement (Lucky Cement) used in the mixes was obtained from the local market of Nawabshah city.

In this research work, six (06) batches were made with 0%, 20%, 40%, 60%, 80% and 100% replacement of natural coarse aggregates with over-burnt bricks aggregates.

To check the workability of concrete, slump cone test was done for all concrete mixes [18]. The slump cone test was performed following the standard procedure prescribed by the relevant testing standard (Figure 2). The obtained results are given in Table 2.

In this research work 30 concrete cubes of (6″ x 6″ x 6″) size with 1:2:4 mix, and 0.5 water cement ratio were prepared in six (06) batches [16], [17]. Each batch consists of 05 samples. Table 3 shows specimen details. Mould preparation, pouring of concrete & compaction was done in accordance with ASTM 943-17. After 24 hours, the specimens were demoulded and left to air dry. All the specimens were cured by fully immersing in potable water for 28 days (Figure 3). After 28 days, the specimens were air-dried for 24 hours. Then, specimens were tested for compressive strength by using Universal Testing Machine (UTM). The UTM was set to apply the load until failure (Figure 4). The compressive strength of each batch of cubes is evaluated and listed in Table 4.

Table 2. Results of Slump Cone Test

S.No	% OBBA	% NCA	W/C Ratio	SLUMP (mm)
1	0	100	0.5	35
2	20	80	0.5	30
3	40	60	0.5	26
4	60	40	0.5	23
5	80	20	0.5	20
6	100	0	0.5	19

Table 3. Specimen details

Batch No.	No. of cubes	Cement (%)	NFA (%)	OBBA (%)	NCA (%)	W/C ratio	Curing period
B1	5	100	100	0	100	0.5	28 days
B2	5	100	100	20	80	0.5	28 days
B3	5	100	100	40	60	0.5	28 days
B4	5	100	100	60	40	0.5	28 days
B5	5	100	100	80	20	0.5	28 days
B6	5	100	100	100	0	0.5	28 days

Fig. 3. Curing of specimens for 28 days

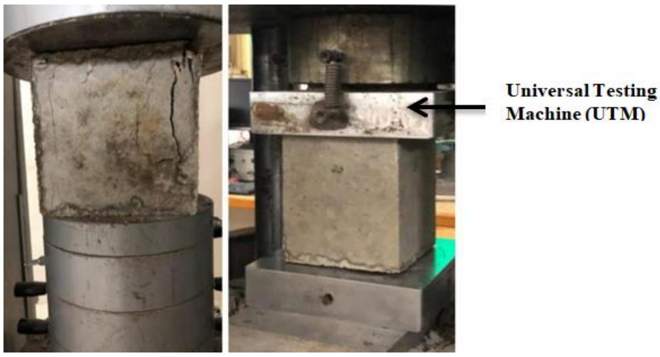

Fig. 4. Concrete cubes under testing

Table 4. Average compressive strength of cubes for 28 days

Batch No.	%OBBA	%NCA	Loading (N)	Average Compressive Strength		% Change
				MPa	Psi	
1	0	100	588600	26.16	3794.1872	……….
2	20	80	542250	24.10	3495.409	-7.87
3	40	60	487350	21.66	3141.5174	-17.20
4	60	40	436500	19.40	2813.732	-25.84
5	80	20	394425	17.53	2542.5115	-32.99
6	100	0	364950	16.22	2352.5121	-38

3. Results and Discussion

3.1. Sieve Analysis Test

The sieve analysis results shown in Figure 5 show that both aggregates confirm the standard requirements of well graded aggregates. The trend of both curves is almost similar, with minor differences in range values over a sieve.

3.2. Water Absorption

- **Over-burnt Bricks Aggregates (OBBA):** When bricks are over-burnt during the manufacturing process, they tend to have more open pores and cracks. This increased porosity allows over-burnt bricks to absorb more water compared to natural coarse aggregates. The excessive heat during the firing process can lead to the formation of voids and fractures, providing more pathways for water to penetrate the material.
- **Natural Coarse Aggregates (NCA):** Natural aggregates, such as gravel or crushed stone, generally have a more solid and compact structure. This result in lower porosity and less ability to absorb water compared to over-burnt bricks aggregates. Figure 6 shows water absorption of both aggregates (OBBA and NCA).

3.3. Specific Gravity

- **Over-burnt Bricks Aggregates (OBBA):** The specific gravity of over-burnt bricks aggregates is typically lower than that of natural coarse aggregates. This can be due to the presence of voids and lighter materials resulting from the over-burning process. The increased porosity and the incorporation of lightweight particles contribute to the lower specific gravity.
- **Natural Coarse Aggregates (NCA):** Natural aggregates are often composed of dense and heavy minerals, leading to a higher specific gravity. The absence of excessive voids or lightweight components contributes to the overall higher density of natural coarse aggregates. Figure 7 shows specific gravity of both the aggregates (OBBA and NCA).

In other words, the over-burning process in bricks can create a more porous and lightweight material compared to natural coarse aggregates. These differences in structure and composition result in over-burnt bricks aggregates having higher water absorption and lower specific gravity than natural coarse aggregates.

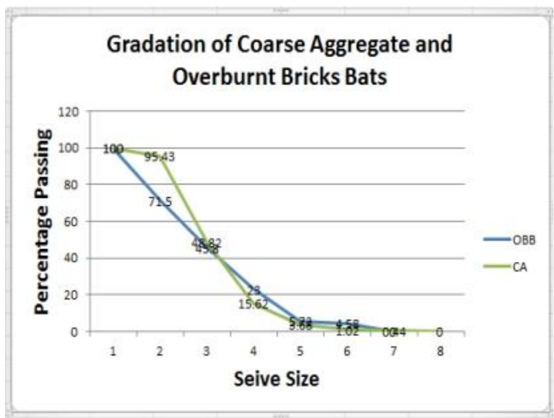

Fig. 5. Comparison of Gradation of aggregates

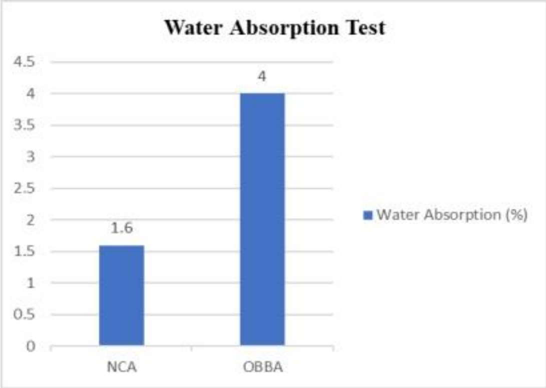

Fig. 6. Comparison of water absorption of aggregates

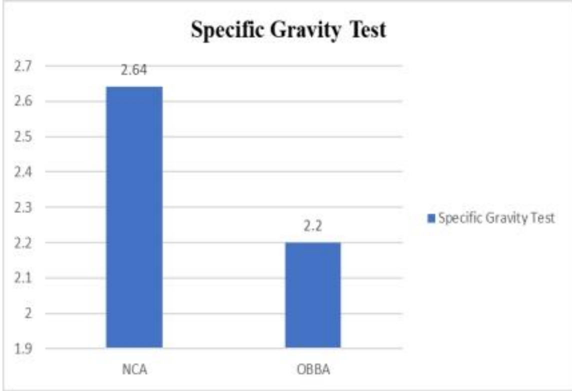

Fig. 7. Comparison of specific gravity of aggregates

3.4. Workability by Slump Cone Test

The percentile reduction in slump of the tested proposed mixes is shown in Figure 8. It may be observed that increasing dosage of over-burnt bricks aggregates increased the reduction in the slump value of the mix. This shows that the mix water requirements are more with over-burnt bricks. Over-burnt bricks aggregates might possess a rougher surface texture compared to natural coarse aggregates. This increased surface roughness can create a greater surface area for water absorption, consequently requiring more water to achieve the desired workability. The pore structure within over-burnt bricks aggregates could differ from conventional aggregates, influencing water retention and release characteristics. This variation in pore structure affects the water demand of the concrete mix and requires adjustments in the mix design process. This should be considered while selecting the water/cement ratio for the mix otherwise more mechanical effort or admixture will be required to maintain the required workability.

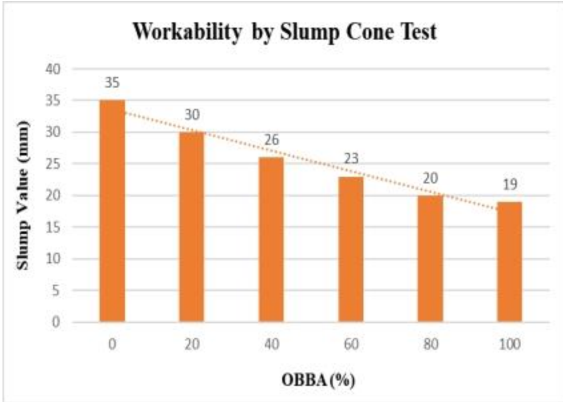

Fig. 8. Bar chart of Slump cone test

3.5. Compressive Strength of Cubes

The average results of compressive strength of concrete cubes made with 0%, 20%, 40%, 60%, 80% & 100% replacement of natural coarse aggregates with over-burnt bricks aggregates is shown in Figure 9 with 28 days curing period. It is observed that compressive strength of cubes is reduced with the increase of the replacement ratio (Figure 10). The reduction in compressive strength with increasing replacement ratio of natural coarse aggregates with over-burnt bricks aggregates can be attributed to factors like higher water absorption and lower specific gravity of over-burnt bricks. The 28-day curing period is chosen as it aligns with standard industry practices, offering a comprehensive evaluation of long-term strength development. While shorter curing periods could provide insight into early-age strength, 28 days is crucial for assessing the concrete's performance in structural applications. This focus ensures the study captures the critical stage of strength gain, facilitating informed decisions for practical construction needs.

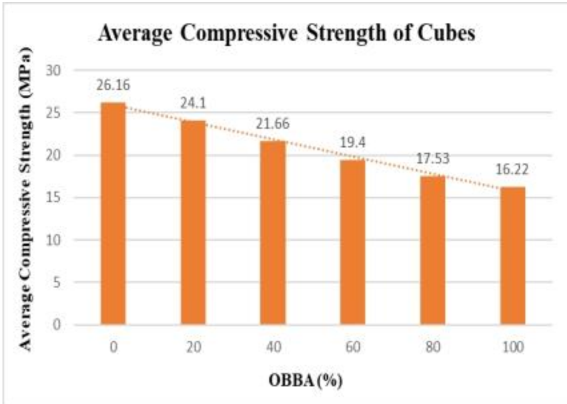

Fig. 9. Average compressive strength at 28 days

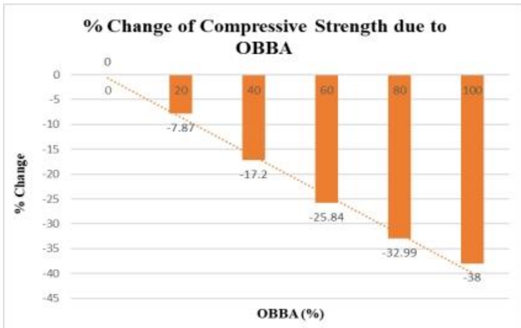

Fig. 10. Percentage change in compressive strength

4. CONCLUSION

In this research work, over-burnt bricks obtained from the kiln of Nawabshah city were used in concrete mixes and their effect on the gradation, water absorption and specific gravity of aggregates, workability and compressive strength of concrete was studied. The results show that the curve of gradation of both the materials shows same pattern, with minor differences in range values over a sieve. Hence the materials are in same range. water absorption of over burnt brick is more than water absorption of coarse aggregates and specific gravity of over burnt brick aggregates is less than specific gravity of coarse aggregates. Crushed over Burnt Bricks however, had a high water absorption and low specific gravity probably because it is an artificial aggregate whose strength depends on those of the clay brick in which it is produced form. Also due to its dryness, more porous and its burnt temperature, the slump value reduces with increase in over-burnt bricks aggregate dosage, hence the concrete requires more mechanical effort in compaction or use of admixture to maintain its workability. It is observed that compressive strength is reduced with the increase of the replacement ratio. however, the obtained values are still acceptable, especially for reasonable levels of the replacement ratio up to 60%. This suggests that, while there is a reduction, it is within an engineering tolerance. The specified replacement ratio of 60% indicates a pragmatic compromise between sustainability and strength. The recommendation to initially use the concrete in low load areas aligns with a cautious approaches, ensuring practical application aligns with observed strength levels. This conclusion highlights the material's viability for new constructions, subject to targeted usage in less demanding areas, demonstrating a balanced consideration of performance and sustainability.

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