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Use of Incinerator Bottom Ash Aggregates (IBAA) in Concrete Masonry Blocks

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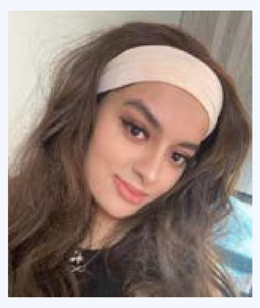

1. Introduction

Concrete is made of cement, and its production accounts for 7% of global carbon dioxide (CO2) emissions (Miller et al., 2021). As a result, in order to meet the UK's 2050 Net Zero Target (HM Government, 2021), we must change and improve our traditional methods of making concrete.

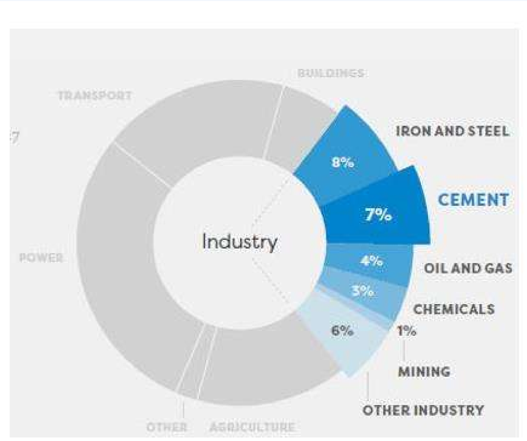

Figure 1—Global C02 emission caused by cement industry (Singla Veena & Stashwick Sasha, 2022).

IBA (Incinerator Bottom Ash) is a sustainable and recycled material derived from the incineration of non-recyclable domestic waste that can be combined with limestone to produce an aggregate (Brett, 2019). This underutilised processed by-product could be used as a fine aggregate replacement to allow the cement content ratio to be reduced when making concrete masonry blocks, lowering the embodied carbon of masonry blocks.

Figure 2— unprocessed Incinerator bottom ash delivered at Fortis IBA

Figure 4—IBA Aggregates after being processed at Fortis IBA

Figure 3—Fortis IBA processing site plan

3. Aim & Objectives

The Aim:

- To develop a concrete mix design for masonry blocks that uses IBAA to reduce embodied carbon.

The Objectives:

- To identify the manufacturing process of IBAA and masonry blocks by attending site visits to Fortis IBA processing plant and mix It a masonry block manufacturing plant in Barking.
- To produce several mix design samples with different IBAA content by following requirements set by the British Standard in BS EN 12390.
- To determine the mechanical properties of the concrete samples after 28 days.
- To evaluate the most appropriate IBAA replacement ratio which results in the greatest mechanical and durability characteristics.
- To provide an applicable concrete mix design for cubes which can then be implemented in the manufacturing of masonry blocks.

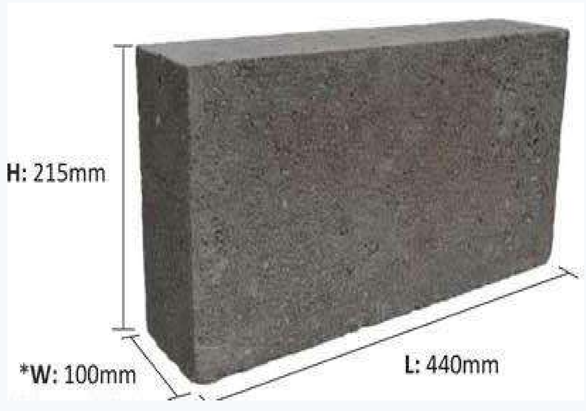

Figure 7— Dimensions of solid concrete masonry block

6. Ethics

Figure 12: University of Portsmouth Certificate of Ethics Review

Risk Assessment

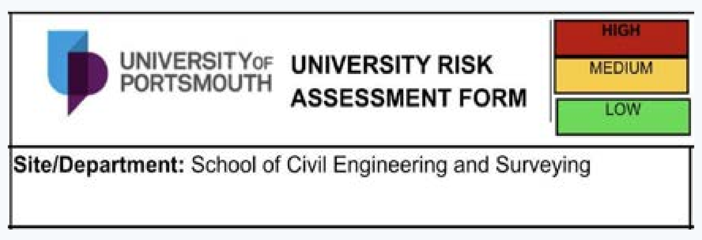

Figure 13: University of Portsmouth Risk Assessment Form

5. Discussion

- The attempt of full replacement of cement in masonry blocks was done by Milling et al. (2020) as they replaced cement with Expanded Polystyrene (EPS) mortar.
- Determining that the bond strength of EPS mortars is two times stronger than cement mortar, but the compressive, flexural,
- and tensile strengths are higher in samples containing cement (Milling et al., 2020).
- Even though EPS masonry blocks have a lot of environmental benefits, they lack stronger mechanical properties which are essential for this product to be adopted through the construction industry.

- Alternatively, in the study done by Pera et al. (1997) IBA aggregates that passed through the 20mm sieve and stopped at the 4mm sieve were used as a replacement of coarse aggregates instead of gravel.
- The results indicated cracking, and swellings caused by the reaction between cement and metallic aluminium. Therefore, a sodium hydroxide treatment would be necessary to replace the cement content by 50% (Pera et al., 1997).
- Their research alerts me regarding the chemical changes occurring when cement is in contact with metallic aluminium, necessitating special consideration for these two components when analysing the best use of IBA.

Figure 11 — processed Incinerator bottom ash delivered at Fortis IBA

2. Literature Review

Not much research has been done in this field but one of the ways IBAA can be used is as a replacement of fine aggregates.

Holmes et al. (2016) created IBAA Masonry blocks (100mm x 215mm x 440mm) with 0%, 10%, 20%, 30%, 50%, 75%, and 100% fine aggregate replacement, and the mechanical properties of these samples were tested after 28 days. When the IBAA content was less than or equal to 20%, their findings demonstrate that a compressive strength of 7MPa was maintained (Holmes et al., 2016).

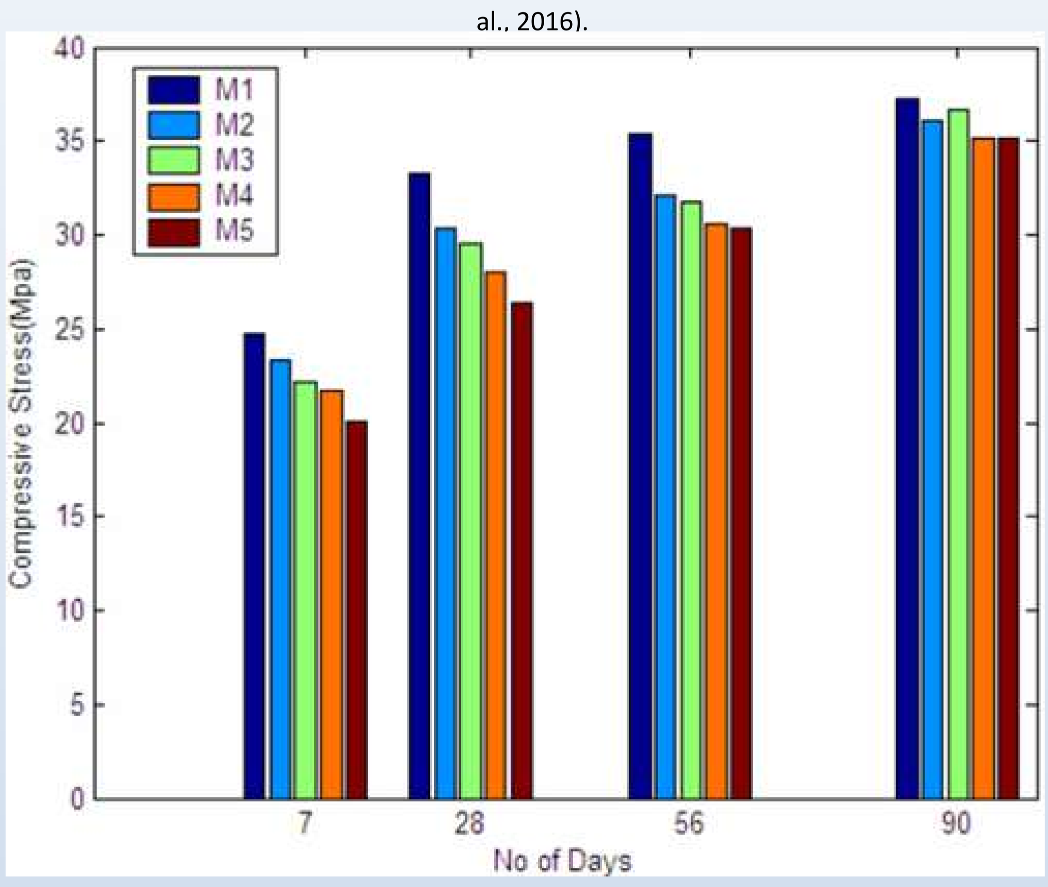

Figure 6— Compressive strength of 0%, 20%,30%, 40% and 50% IBAA replacement at 7, 28, 56 and 90 days (Aggarwal et al., 2007).

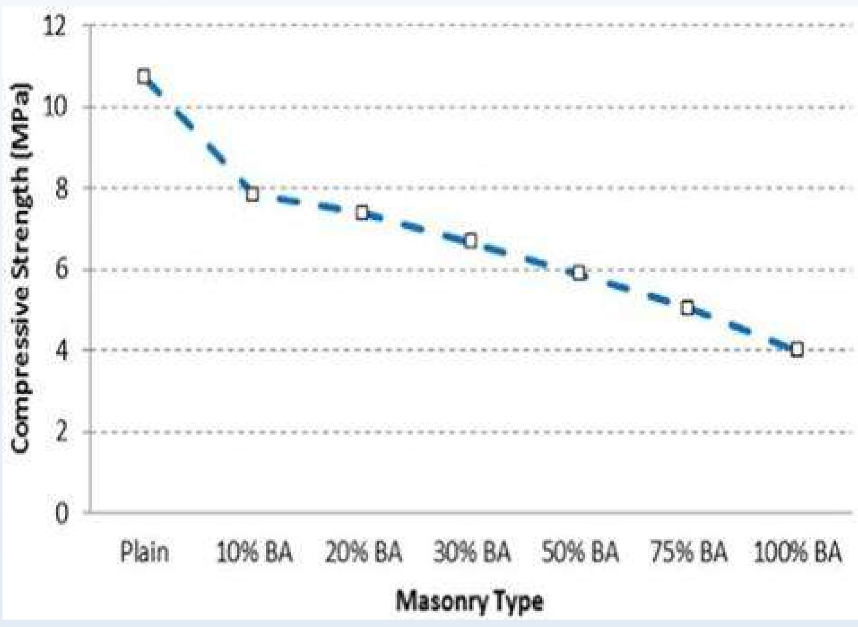

Figure 5— Compressive strength results achieved at 28 days at different IBAA contents (Holmes et al., 2016)

Aggarwal et al. (2007) conducted another study in which they tested 150mm concrete cubes with 0%, 20%, 30%, 40%, and 50% IBAA replacement of fine aggregate. They concluded that the compressive strength of samples containing 50% IBAA replacement after 28 days was acceptable because it exceeded the minimum required strength of 20MPa (Aggarwal et al., 2007).

Previous research (Aggarwal et al., 2007) and (Holmes et al., 2016) have shown that 20% IBAA replacement results in the best mechanical properties at 28 days. However, both papers used CEM 1 (100% cement) to achieve their conclusion. As a result, a predicted outcome for this research would be a lower compressive strength at 28 days due to the use of CEM 2 (65% cement) and also because of the higher water cement ratio as we used 0.5 while Holmes et al. (2016) used 0.42 and Aggarwal et al. (2007) used 0.43. This should still determine a percentage of around 20% to be the most suitable replacement, reducing the embodied carbon even further.

4. Methodology

Site Visits — Fortis/MixIt

- The IBAA used for the concrete mix design was collected from the Fortis IBA site visit
- The IBAA was then sieved and aggregates size of 2-4mm were used as a fine aggregate replacement as according to BS EN 12620.

Figure 8—IBAA being dried for 24hrs

Figure 9—Sieving IBAA in different sizes once dried

Figure 10—Concrete cubes made with various IBAA content

Experimental method

- A risk assessment and COSHH forms for the laboratory work has been completed and signed by the supervisor Muhammad Ali prior to the work.
- By following BS EN 12390-2 , a water/ cement ratio of 0.5 was used to make 3 concrete cubes for each of the 6 different proportions of IBAA content used (0%, 10%, 20%, 30%, 50% and 100%). Therefore a total of 18 concrete cubes with 100mm dimensions were made and placed in a curing tank for 28 days.
- All the concrete cubes will be tested for their compressive strength using BS EN 12390-3 and the density of the concretes will be measured using BS EN 12390-7.

Mix design

MIX DESIGN - w/c 0.5 - all Kg/m3 except admixture						
Material	Control	0% IBA	10% IBA	30% IBA	50% IBA	100% IBA
w/c	0.50	0.50	0.50	0.50	0.50	0.50
Cement CEM2	330	330	330	330	330	330
Free water	165	165	165	165	165	165
FA	600	600	540	420	300	0
CA 4/10	1111	1111	1111	1111	1111	1010
IBA	0	0	60	180	300	600
Admx (l/m3)	10	10	11	5	7	25

Table 1—Amount of material used for each IBAA replacement

7. References

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