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Enhancing the strength of sandcrete blocks using coarse aggregates

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This current article explores the possibility of adding aggregate (10 mm size) to sandcrete mixes in order to enhance the strength of the sandcrete blocks. Four different kinds of mixes were made; the first one was used as a reference without the addition of course aggregate, and in the remaining three, course aggregates were added in percentages of 5, 10 and 15% by volume of the reference mix. Laboratory experimental tests were carried out in order to obtain the compressive strengths of the blocks moulded at 14, 21 and 28 days, respectively. The results of the tests revealed that the higher the percentage course aggregate content in the mix, the higher the compressive strength of the blocks. The improvement in the compressive strength was 12.78% more when 15% of the course aggregate was added as compared to 0% of the course aggregate in the mix.

Key words: Sandcrete blocks, cement, coarse aggregates, compressive strength.

INTRODUCTION

Countries like Ghana, which is developing needs a lot of infrastructural expansion as it plays a pivotal role in her economic development. The needed physical infrastructural development cuts across all facets, like industrial buildings, commercial buildings, engineering projects and the housing stocks. In fact, these developing countries are facing the challenge of decreasing their housing deficits. Both the formal and informal sectors provide for housing needs especially in Ghana, Anosike and Oyebade (2012). Walling elements in this infrastructure are mostly done using sandcrete blocks. Baiden and Tuuli (2004) attest to the fact that sandcrete blocks are widely used as walling units in Ghana. Anosike and Oyebade (2012) reinforce this assertion by stating that sandcrete blocks are used in over 90% of physical infrastructures in Nigeria. In Ghana, sandcrete blocks as masonry units in assemblages of walls are used either as load bearing or non-load bearing walls. In most cases they are used in both the substructure and super structure of buildings especially in the urban centers or dwellings where demands for housing units are on the ascendancy. It is expected of these sandcrete blocks to perform their intended functions in structures whether they are serving as load bearing wall units or non-load bearing wall units.

In recent years, there has been much concerns about the strength of the sandcrete blocks produced and used as walling units in the construction sector both (formal and informal) in Ghana. According to Kolovos et al. (2016), sandcrete blocks can only be acceptable for

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construction only when they are properly manufactured with good compressive strength and high bulk density. Studies on the compressive strength of sandcrete blocks are numerous; their findings suggest that sandcrete blocks are not meeting their expected strengths (Baiden and Tuuli, 2004; Anosike and Oyebade, 2012; Ngugi et al., 2014). Some researches like Chindaprasirt et al. (2005), Saraswathy et al. (2002) and Manikandan and Ramamurthy (2007) explored the magnitude of the effects of the continuous usage of constituents of sandcrete and concrete blocks on the environment and recommended the need for alternative materials or reduction in the use of them to safe guard the environment.

The rapid growth in infrastructural development has led to an increase in the demand for sandcrete block. This in effect has consequently increased the demand for Ordinary Potland Cement (OPC) since cement is the main constituent in sandcrete block production yet it is expensive. OPC, as a constituent of the sandcrete blocks plays a vital role in the strength. However, the cost of the cement especially in Ghana keeps rising day by day mainly because of the imported components such as clinker and the method of manufacturing which depends on electricity. For instance, the Saturday February 22nd of 2003 issue of the 'Daily graphic page 14, the president of Ghana Institute of Engineers (GhIE) expressed concern about over-reliance on the use of foreign materials in the building industry, adding that "in the year 2000 alone Ghana imported hundred million dollars' worth of clinker for cement production". Currently Ghana imports clinker and even OPC from outside the country for her construction industry. Rajdev et al. (2013), compares the use of Pozzolana cement, fly ash blended cements as alternatives to OPC. In the light of all these, it is important to find an effective way of enhancing the strength of sandcrete blocks without necessarily increasing the cement content. This work seeks to do this by introducing a percentage of coarse aggregates into the mixture of the sandcrete blocks. The objective of the study was to find out whether the strength of the traditional sandcrete blocks could be enhanced without necessarily increasing the cement content by introducing a percentage of coarse aggregates in the batching of the constituents of the sandcrete blocks.

LITERATURE REVIEW

There are numerous researches on improving the compressive strength of sandcrete block by limiting cement content and adding other constituents. The findings of these researches are presented in Table 1 below. The researchers explored whether sawdust ash and other substitutes have great potential to perform as a Pozzolanic material, and concluded that the use of the substitutes can be considered for the normal and high strength concrete as a cement replacement. Thus reducing the environmental burden and creates a solution to the sustainable construction material to build cost-effective structures.

METHODOLOGY

Samples of the traditional sandcrete blocks were prepared and tested for compressive strengths, using a mix proportion of cement to sand aggregate ratio of 1:12. In all four different kinds of mixes were made; the first one was used as a reference without the addition of course aggregate, and in the remaining three, course aggregates were added in percentages of 5, 10 and 15% by volume of the reference mix. Laboratory experimental tests were carried out in order to obtain the compressive strengths of the blocks moulded at 14, 21 and 28 days, respectively.

Material preparation

Gradation of aggregates

The BS 882: 1989 part 2 procedures were followed for the grading of the aggregates using test sieves. The fine and coarse aggregates were obtained from the stockpile of Building Technology Department by picking pieces from different parts of the stock. The test procedures for result for coarse and fine aggregates were as follows:

Coarse aggregates

(1) Samples of both fine and course aggregates were taken from a stockpile from Building Technology Department and brought to the laboratory.
(2) A 10 kg of coarse aggregates was weighed using the measuring scale and was poured into an empty pan.
(3) The measured coarse aggregates were further proportioned into four parts using the riffle box.
(4) Then a 2.5 kg sample was weighed. The sieves were arranged with the largest at the top.
(5) The weighed coarse aggregate was poured on the sieve.

The following precautions were taken during the grading test result:

(1) It was ensured that the sample aggregates were fetched from different parts from the stockpile for use.
(2) The measuring scale was set to zero before usage.
(3) During the weighing of the sample, it was ensured that the working platform was not harkening to prevent inaccurate reading.
(4) It was ensured that sieving was actually completed as taking readings (Baiden and Tuuli, 2004)

Table 1. Summary of previous researches on sandcrete blocks.

Year	Author	Location	Results
2017	S. A. Mangi, N. Jamaluddin, W. I. M.H, N. Mohamad, S. Soh	Malaysia	Observation: Between 10 to 20% of wood ash can be used to replace cement to achieve a good compressive strength (batching by weight)
2017	B. M. Desai, N. Umravia , K. B. Parikh	India	20% of cement can be replaced with PKSA and CSA in concrete to get an average optimum compressive strength at 28 days
2018	C. Fapohunda, B. Akinbile, A. Oyelade	Nigeria	That concrete containing wood waste has the potential to be used for structural concrete. With regards to appropriate mix design and adoption of appropriate water-cement ratio, whether the partial replacement is for ash, or for coarse aggregate, or fine aggregate
2015a	S. Chowdhury, M. Mishra, O. Suganya	India	Compressive strength of concrete decreases slightly with increase in wood ash content
2013	C. B. Cheah, M. Ramli	Malaysia	Silica fume, OPC and 6% wood ash gives higher compressive strength.
2002	A. U. Elinwa, Y. A. Mahmood	Nigeria	Compressive strength at 28-day, increased by 68% with 15% of cement replacement
2011a	C. B. Cheah, M. Ramli	Malaysia	Use of wood ash as a cement replacement in concrete up to 25% of binder weight does not affect concrete adversely
2011b	C. B. Cheah, M. Ramli	Malaysia	Use of wood ash as replacement of cement up to 16% by weight of binder corresponding with small quantity (7.5%) of DFS contribute to refinement in pore structure of a cement matrix, hence, it reduces the chloride diffusivity in mortar.
2005	D. Tonnayopas, C. Ritawirun	Thailand	Increased 51% with 40% of LFA for curing period of 28 days.
2012	A. A. Raheem, B. S. Olasunkanmi, C. S. Folorunso	Nigeria	Compressive strength of SDA concrete was inferior at early age but progresses well up to 90 days. The optimum compressive strength values were recorded as 23.26 N/mm^2 with 5% SDA replacement at 90 days.
2015b	S. Chowdhury, A. Maniar, O. M. Suganya	India	Utilizing wood ash as replacement of OPC, decreases the slump values of concrete even increases the water demand. 10% replacement by weight of binder found to be good for structural grade concrete.
2004	A. U. Elinwa, S. P. Ejeh	Nigeria	At 10% replacement of cement with SDA for curing of 28 and 60 days 17.63 and 21.45 N/mm^2.
2014	I. O. Obilade	Nigeria	Compressive strengths (at 28 days) were recorded as 19.05 N/mm^2 with 15% cement replacement with SDA; compressive strengths were increased by 32% as compare with control mix.

Coarse aggregates and fine aggregates

Coarse aggregates (10 mm maximum) were obtained by sieve analysis from an all in aggregates heaped in front of the new Building Technology Laboratory.

Batching

Batching of the constituent materials was in terms of the dried weight of the materials and it was done by volume using cement to sand ratio of 1:12. This method and ratio were used based on the fact that Baiden and Tuuli (2004) recommended a ratio of 1:12 when using mechanical vibrator during compaction. This research contends that it is possible to achieve a good result using the coarse aggregates. The measuring was done using the 17 L bucket by measuring each quantity for materials with respect to their ratios for mixing. The cement to sand ratio for all the mixtures in this study was 1:12.

Table 2. Gradation of coarse aggregates results.

BS sieve size (mm)	Weight retained on each sieve (%)
37.5	0
20	0.14
14	0.52
2.36	0.272
2.36	0.036
1.18	0.032

Mixing

The water cement ratio used in this research was 0.35 for all the blocks made. The batched cement and sand were thoroughly mixed until a uniform mixture was obtained using shovel. The required percentage of coarse aggregates was then introduced and uniformly mixed with the required water content. During the batching and mixing of the aggregates, all unwanted materials were carefully removed from the mix.

Moulding

After the constituents have been mixed uniformly, the resultant mixture was then loaded into the Simple Single Hand Manually Operated Block Moulding Machine of which the initial pallet has been introduced. The machine was filled fully allowing the material to protrude. The content of the machine was hence compacted while conserving consistent blows of 6. After this, the freshly moulded blocks with the wooden pallets were vigilantly removed from the machine and sent to curing place.

Curing

The blocks were placed in the new Building Technology Laboratory where they were protected against rain and direct sunshine in order to avoid shrinkage. The first curing was done 48 h after moulding by spraying tap water onto the blocks to enhance strength mobilization and this was done for 7 days. The spraying was done early in the morning and in the evening.

Weighing

Each block was weighed on the various crushing days using an electronic weighing scale in the newly built Building Technology Laboratory of Ho Technical University (HTU) in order to be able to determine the various densities of the blocks and the results are as shown in Table 4.

Testing

The blocks (that is, 125 × 450 mm surface) were tested on the edge for compressive strength using Compressive Strength Testing Machine at 14, 21 and 28 days, respectively. The tests results obtained are as shown in Tables 8 to 9.

Analysis of the test results

The result of the text conducted is shown in all the previously presented tables. The general trend of compressive strength development of the sandcrete blocks with various material compositions. The following analyses were made from the result obtained.

Grading of the aggregates

The results of coarse and fine aggregates obtained from the experiment are shown in Tables 2 and 3, which falls within the BS 882; Part 2; 1983 B and Limits. From Table 3, it can be seen that the results of the aggregates from the grading experiment conform to the BS 882 specification as its line falls within the band limit. However the result of the fine aggregates did not fall completely within the band limit.

Density of sandcrete blocks

The weights of the sandcrete blocks as shown in the tables 4 to 8 above are used in calculating the densities of the sandcrete blocks. This was done by dividing the weight in (kg) by the volume of the block which is given by multiplying the length × width × height of each block. The results of these are shown in Table 8.

It can be observed from the calculation of the densities in Table 9 that the densities of the sandcrete blocks increase with an increase in the coarse aggregates percentage content. Thus, the higher the percentage of coarse aggregate contents in the mix, the higher the density of each block.

Table 3. Gradation of fine aggregates results.

BS sieve size (mm)	Weight retained on each sieve (%)
10	0
5	0
2.8	0.17
1.18	0.33
0.6	0.3
0.30	0.2
0.15	0

Table 4. Crushing strength of sandcrete blocks containing 0% of coarse aggregates at 14, 21 and 28 days, respectively.

Days	Dimension (mm)	Average weight (kg)	Average maximum load (kN)
14		20.89	79.21
21	125 × 225 × 450	22.38	89.17
28		22.64	104.31

Table 5. Crushing strength of sandcrete blocks containing 5% of coarse aggregates at 14, 21 and 28 days, respectively

Days	Dimension (mm)	Average weight (kg)	Average maximum load (kN)
14		21.05	79.38
21	125 × 225 × 450	22.39	89.93
28		23.52	111.22

Table 6. Crushing strength of sandcrete blocks containing 10% of coarse aggregates at 14, 21 and 28 days, respectively

Days	Dimension (mm)	Average weight (kg)	Average maximum load (kN)
14		22.69	87.87
21	125 × 225 ×450	23.43	91.98
28		21.54	117.93

Table 7. Crushing strength of sandcrete blocks containing 15% of coarse aggregates at 14, 21 and 28 days, respectively.

Days	Dimension (mm)	Average weight (kg)	Average maximum load (kN)
14		22.37	97.84
21	125 × 225 × 450	22.63	102.97
28		23.21	124.63

Compressive strength of sandcrete blocks

The compressive stress was determined by dividing the crushing load by the total surface area of each block tested and the results of the calculation are shown in Table 8. The results are plotted in the graph as shown in Figure 1.

The compressive strength test result as plotted in

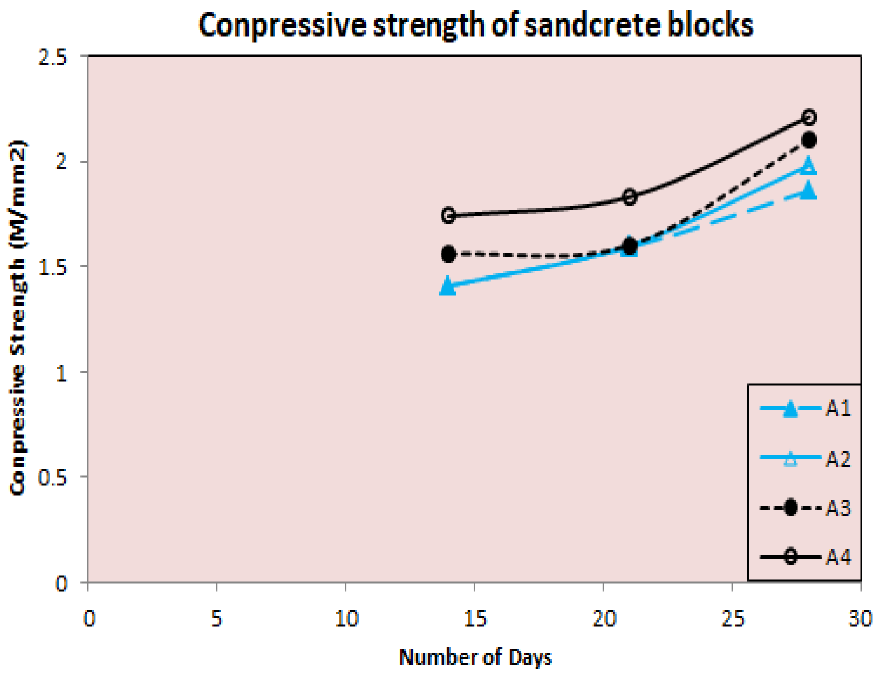

Figure 1. A graph of compressive strength of sandcrete blocks. A1-Curve for sandcrete blocks containing 0% coarse aggregate; A2-Curve for sandcrete blocks containing 5% coarse aggregates; A3-Curve for sandcrete blocks containing 10% coarse aggregates; A4--Curve for sandcrete blocks containing 15% coarse aggregates.

Table 8. Analysis of density and compressive strength test of sandcrete blocks.

Identification	Age (days)	Average weight (kg)	Cross sectional area (mm^2)	Average density (kg/m^3)	Average crushing load (kN)	Compressive stress (N/mm^2)
	14	20.89		1650.57	79.21	1.41
SB0%	21	20.96	56,250	1656.10	89.17	1.59
	28	21.54		1701.93	104.31	1.86
	14	22.38		1768.30	79.37	1.41
SB5%	21	22.39	56,250	1769.09	89.93	1.60
	28	22.37		1767.51	111.22	1.98
	14	22.64		1788.84	87.86	1.56
SB10%	21	22.64	56,250	1788.84	91.98	1.64
	28	22.63		1788.05	117.93	2.10
	14	23.54		1859.95	97.83	1.74
SB15%	21	23.41	56,250	1859.95	102.96	1.83
	28	23.52		1858.37	124.68	2.21

Figure 1 revealed the compressive strengths at 14, 21, and 28 days for the sandcrete blocks. However, the strengths of the sandcrete blocks increase as the percentage of coarse aggregate content also increases. The sandcrete blocks developed 1.98, 2.10 and 2.21 N/mm^2 strength at 28 days for sandcrete blocks containing 5, 10 and 15% of coarse aggregates, respectively, as against sandcrete blocks containing 0% of coarse aggregates showing 1.86 N/mm^2. The percentages increase in compressive strength was 6.5, 13, and 18.8% for sandcrete blocks containing 5, 10 and 15% of coarse aggregates, respectively. Hence, the average percentage

Table 9. Densities and compressive strengths of the sandcrete blocks produced and tested.

Variable	SB0%		SB5%		SB10%		SB15%	
Age (days)	Density (kg/m^3)	Compressive strength (N/mm^2)	Density (kg/m^3)	Compressive strength (N/mm^2)	Density (kg/m^3)	Compressive strength (N/mm^2)	Density (kg/m^3)	Compressive strength (N/mm^2)
14	1650.57	1.41	1768.30	1.41	1788.84	1.56	1859.95	1.74
21	1656.10	1.59	1769.09	1.60	1788.84	1.64	1859.95	1.83
28	1701.93	1.86	1767.51	1.98	1788.05	2.10	1858.37	2.21

compressive strength increase in the blocks is 12.78% indicating a possible average increase in strength of sandcrete blocks that can occur when coarse aggregates are added.

Conclusion

A sample of 10 blocks were moulded for all the four kinds of sandcrete blocks, that is; sandcrete blocks containing 0, 5, 10, and 15% maximum coarse aggregates size of 10 mm. These blocks which were of size 125 × 225 × 450 mm were tested for their densities and compressive strengths. The test results of the block indicated that the densities increase slightly with increasing coarse aggregates percentage contents.

Furthermore, the compressive strengths of the blocks at the age of 28 days revealed that the sandcrete blocks developed strength of 1.98, 2.10 and 2.20 N/mm^2 for sandcrete blocks containing 5, 10 and 15%, respectively as against 1.86 N/mm^2 for sandcrete blocks containing 0% of coarse aggregates. This indicates 6.5%, 13% and 18% increases in strength as the coarse aggregates contents increase from 5 to 10 and to 15%, respectively. Hence On the average, the strength of the sandcrete block can be increased to 12.78% by the introduction of 10 mm maximum coarse aggregates.

RECOMMENDATIONS

That, coarse aggregates can be used in the sandcrete block production for building element at various levels provided the compressive strength required falls within the result. However, it is recommended that this project should be carried on further, with varied maximum sizes of coarse aggregates either less or above 10 mm. Also, since the strength of the sandcrete blocks keeps increasing with increasing coarse aggregates percentage contents, another investigation should be carried out to ascertain the right percentage of 10 mm maximum aggregate size that can give the best strength. Lastly, a research should be undertaken to ascertain the economy of the introduction of the coarse aggregates to determine whether they are economical to be used.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Anosike MN, Oyebade AA (2012) Sandcrete Blocks and Quality Management in Nigeria Building Industry. Journal of Engineering, Project, and Production Management 2(1):37-46.

Baiden BK, Tuuli M (2004). Impact of quality control practices in sandcrete blocks production. Journal of Architectural Engineering 10(2):55-60.

BSI (1983). Aggregates from Natural Resources fur Concrete. BS 882: Part 2: 1983, London 1983.

Cheah CB, Ramli M (2011a). Properties of high calcium wood ash and densified silica fume blended cement. International Journal of the Physical Sciences 6(28):6596-6606.

Cheah CB, Ramli M (2011b). The implementation of wood waste ash as a partial cement replacement material in the production of structural grade concrete and mortar: An overview. Resources, Conservation and Recycling 55(7):669-685.

Cheah CB, Ramli M (2013). The engineering properties of high performance concrete with HCWA-DSF supplementary binder. Construction and Building Materials 40:93-103.

Chindaprasirt P, Jaturapitakkul C, Sinsiri T (2005). Effect of fly ash fineness on compressive strength and pore size of blended cement paste. Cement and Concrete Composites 27:425-428.

Chowdhury S, Maniar A, Suganya OM (2015a). Strength development in concrete with wood ash blended cement and use of soft computing models to predict strength parameters. Journal of Advanced Research 6(6):907-913.

Chowdhury S, Mishra M, Suganya O (2015b). The incorporation of wood waste ash as a partial cement replacement material for making structural grade concrete: An overview. Ain Shams Engineering Journal 6(2):429-437.

Desai BM, Umravia N, Parikh KB (2017). Experimental Study on Concrete by Partial Replacement of Cement with Coconut Shell Ash, Incorporating Steel Fibres: A Review. International Journal for Research in Applied Science and Engineering Technology 5(3):160-164.

Elinwa AU, Mahmood YA (2002). Ash from timber waste as cement replacement material. Cement and Concrete Composites 24(2):219-222.

Elinwa AU, Ejeh SP (2004). Effects of the Incorporation of Sawdust Waste Incineration Fly Ash in Cement Pastes and Mortars. Journal of Asian Architecture and Building Engineering 3(1):1-7.

Fapohunda C, Akinbile B, Oyelade A (2018). A Review of the Properties, Structural Characteristics and Application Potentials of Concrete Containing Wood Waste as Partial Replacement of one of its Constituent Material. YBL Journal of Built Environment 6(1):63-85.

Kolovos KG, Asteris PG, Tsivilis S (2016). Properties of sandcrete mixtures modified with metakaolin. European Journal of Environmental and Civil Engineering 20(sup1):s18-s37.

Mangi SA, Jamaluddin N, Wan Ibrahim MH, Mohamad N, Sohu S (2017). Utilization of Sawdust Ash as Cement Replacement for the Concrete Production: A Review. Engineering Science and Technology International Research Journal 1(3):11-15.

Manikandan R, Ramamurthy K (2007). Influence of fineness of fly ash on the aggregate pelletization process. Cement and Concrete Composites 29(2007):56-464.

Ngugi HN, Mutuku RN, Gariy ZA (2014). Effects of Sand Quality on Compressive Strength of Concrete: A Case of Nairobi County and Its Environs. Kenya Open Journal of Civil Engineering 4:255-273.

Obilade IO (2014). Use of Saw Dust Ash as Partial Replacement for Cement In Concrete. International Refereed Journal of Engineering and Applied Sciences 5(4):11-16.

Raheem AA, Olasunkanmi BS, Folorunso CS (2012). Saw Dust Ash as Partial Replacement for Cement in Concrete. Organization, Technology and Management in Construction: An International Journal 4(2):474-480.

Rajdev R, Shalini Y, Rakesh S (2013). Comparison between Portland Pozzolana Cement and Processed Fly Ash blended Ordinary Portland Cement. IISER Journal of Civil and Environmental Research 3(6):24-29.

Saraswathy V, Muralidharan S, Thangavel K, Srinivasan S (2002). Influence of activated fly ash on corrosion-résistance and strength of concrete. Cement and Concrete Composites 25:673-680.

Tonnayopas D, Ritawirun C (2005). Influence of Fly Ash and Rubber Sawdust Ash on Mortar. PSU-UNS International Conference on Engineering and Environment pp. 1-5. https://www.researchgate.net/publication/263234520_influence_of_fly_ash_and_rubber_sawdust_ash_on_mortar_influence_of_fly_ash_and_rubber_sawdust_ash_on_mortar

Appendix

Calculation of materials composition for one block unit

The following assumption were made in this report
(1) The percentage of change in the coarse aggregates was calculated based only on the ratio of the fine aggregates in the mixture
(2) The total volume of the aggregates comprised varying percentage of fine and coarse aggregates at sum total of 100%

Calculations

Dimensions of one block unit =125 × 225 × 450 mm^3
Volume of mixture required = 0.125 × 0.225 × 0.450 m^3 = 0.0127 m^3

Assume 10% decrease in volume when mixed and 5% waste. Hence, total percentage added = 15%
Total volume of mixture required = 0.0127 m^3 + (15% of 0.0127 m^3) = 0.0146 m^3

For percentage content of coarse aggregates:
Mixing ratio = 1:12
Total number of parts = 1+12 = 13

The volume of the constituents' materials is proportional to the number of parts in the normal mix therefore the total part is 13. However, as cement does not affect the volume of the mixture, only 12 parts were used. The 5, 10 and 15% coarse aggregates content were parts of the total volume of the aggregates and the volume of the materials for a unit block is as follows:

5% coarse aggregate
Volume of cement in the mixture = (0.0146 m^3 × 1) / 13 = 0.0012 m^3

Volume of sand in the mixture = (0.0146 m^3 × 12) / 13 = 0.0135 m^3

Volume of coarse aggregate = (0.0146 m^3 × 5) / 100 = 0.0008 m^3

10% coarse aggregate
Volume of cement in the mixture = (0.0146 m^3 × 1) / 13 = 0.0012 m^3

Volume of sand in mixture = (0.0146 m^3 × 12) / 13 = 0.0135 m^3

Volume of coarse aggregate = (0.0146 m^3 × 10) / 100 = 0.0015 m^3

15% coarse aggregate
Volume of cement in the mixture = (0.0146 m^3 × 1) / 13 = 0.0012 m^3

Volume of sand in mixture = (0.0146 m^3 × 12) / 13 = 0.0135 m^3

Volume of coarse aggregate = (0.0146 m^3 × 15) / 100 = 0.0022 m^3