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Contributions of the Weakness of Local Aggregates to the Failure of Buildings in Anambra State of Nigeria

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Abstract:- There appears to be an increase in the frequency of building collapse in Nigeria, especially in Anambra state where the Governor recently opened what is widely believed to be the first building and construction materials quality control laboratory in Nigeria. This was to ensure that substandard materials are not used in construction. This paper investigated the contributions of the weakness of substandard local broken stone aggregates (commonly used in the study area as a substitute for granite chippings) to the incessant collapse of buildings. Using a $1:1\frac{1}{2}:3$ concrete mix ratio, concrete cubes containing various percentage replacements of granite chippings with broken stone aggregates were cast and tested. It was found that the use of washed broken stone aggregates in place of granite chippings lowered the strength of the concrete member by 12.50%, while unwashed local broken stone aggregates contributed to the weakness of the concrete member by as much as 28% of the design strength. It was therefore concluded that if washed broken stone aggregates are to be used in buildings as replacement for crushed granite chippings, richer mix proportions would be required to attain the same concrete strength as that of granite chipping concrete. The study also revealed that impurities in the particular local broken stone aggregates accounted for about 16% of the weakness of the concrete member where they are used.

Keywords:- aggregates, Anambra State, building failure, concrete, compressive strength

I. INTRODUCTION

The cases of building failures and consequent collapse in Nigeria have reached an alarming and lamentable stage. It is a disaster comparable to flood disaster, earthquake and plane clash considering the loss of life and destruction of property, [1]. The major causes of building failure have been identified as: poor workmanship, use of cheap and inferior materials, wrong interpretation of building design, inadequate supervision, non adherence to due process in building construction, lack of maintenance culture, greedy attitude of contractors, professional incompetence, the activities of quarks, the use of plans approved for one storey building for multi-storey building and the nature of soil, [1].

Greed is seen on the part of diversion of building materials and the use of substandard materials so as to achieve high profit, [2].

Between 2012 and 2013, Anambra State in Nigeria experienced a spate of building collapse which compelled the Government to set up a panel of experts to investigate the incidents and their respective causes, [3]. Worried by the spate of collapse of buildings in the State, Governor Willie Obiano of Anambra State opened what is widely believed to be the first building and construction materials quality control laboratory in Nigeria, [4]. This was to ensure that substandard materials like broken stone aggregates are no longer used in construction. The use of local broken stone aggregates as a substitute for crushed granite chippings for construction of low and medium rise buildings appear to be a common practice in the are.

In this paper attempt is made to ascertain the contribution of the weakness of local aggregate material (broken stone aggregates) to loss of strength in concrete members. Design specifications for grades of concrete are usually based on the use of granite aggregates. Where weaker local aggregate materials are used, it is pertinent that trial mix ratios be carried out to obtain the mix ratio that is equivalent in strength to the specified concrete grade using crushed granite chippings. Where this requirement is neglected as is common in the study area, the local aggregates contribute to loss of strength in the structural member where they are used. Consequently, the structural member, at service load, will be subjected to higher stress than otherwise would have been the case if crushed granite chippings were used. In some cases, the stress may cause the structural members to fail while in severe cases, incipient collapse of the entire structure may ensure.

II. REVIEW OF PAST WORK

The aggregate component of a concrete mix occupies 60 to 80% of the volume of concrete and their characteristics influence the properties of the concrete. In any concrete mix design, granite chippings are the course aggregates that give maximum strength and workability in concrete. However, design mix ratios may not always give the stated concrete grade due to the fact that materials from different locations may not have the same properties, [5]. This implies that the concrete grades commensurate with cement: sand: aggregate ratios can be re-organized as a trial mix design to achieve the design strength based on availability of materials in the locality, [6].

Various researchers, [2], [7], [8], [9], [10] studied the causes of building failures and collapse in Nigeria, and all agreed that the use of substandard materials is a major contributory factor towards building collapse. Essentially, these substandard materials include cement, fine aggregates, course aggregates, steel reinforcement etc. The extent to which these component structural materials influence the performance of structural components in buildings is not yet well established as there is a dearth of literature in this area. Thus, this work focuses on the contributions of substandard coarse aggregates (in the form of local broken stones) to strength impairment of building elements such as beams, columns and slabs.

III. MATERIALS AND METHOD

The materials used in this work are granite aggregates (chippings) obtained from quarry site in Abakaliki area of Ebonyi State in Nigeria, local broken stones obtained from borrow pits in Udi in Enugu State, Nigeria and fine (river sand) aggregates from local streams around Awka in Anambra State of Nigeria. These are essentially some of the major sources of fine and course aggregates used for building construction within the study area. Ordinary Portland cement, elephant brand, in 50kg bags were obtained from local market. Bore hole water.(free from impurities) supplied to Nnamdi Azikiwe University, Awka was used for mixing and curing the concrete. The batching of the concrete was by weight and a mix ratio of $1:1\frac{1}{2}:3$ was used. Partial replacement of crushed granite chippings (CGC) with washed broken stone (WBS) aggregates were carried out at 0%,10%, 30%, 50% and 100% replacements. Such samples were designed to ascertain the contributions of weakness of local aggregates on the strength of concrete members. Again, 100% replacement of CGC with unwashed broken stone (UBS) aggregates was carried out to determine the degree of strength impairment of UBS aggregate concrete due to aggregate impurities. The maximum size of aggregates use for the mix design was 19mm and water / cement ratio of 0.5 was adopted.

For each percentage replacement of CGC with WBC and UBS, six concrete cubes were cast and two of the samples were tested at 7^{th} ,14^{th} and 28^{th} day. Thus. The average 7, 14 and 28 day strengths were obtained. Table 1 shows the percentage replacement of CGC with WBS and UBS, the number of samples cast and the various components of cement, sand, local broken stones(washed and unwashed), crushed granite chippings and water in every sample of six cubes.

Table I: Data for Sample Preparation

Sample	% replacement of CGC with broken stone	Replacing aggregate type	No. of cubes cast	Cement content (kg)	Fine aggregate (kg)	Granite chipping (kg)	Broken stone aggregate (kg)	Water (litre)
1	0	WBS	6	9.72	14.58	29.16	0.00	**5.35**
2	10	WBS	6	9.72	14.59	26.24	2.92	**5.35**
3	30	WBS	6	9.72	14.58	20.41	8.75	**5.35**
4	50	WBS	6	9.72	14.58	14.56	14.58	**5.35**
5	100	WBS	6	9.72	14.58	0.00	29.16	**5.35**
6	**100**	**UBS**	**6**	**9.72**	**14.58**	**0.00**	**29.16**	**5.35**

A. *The Tests*

The physical properties of the fine and coarse aggregates, namely, specific gravity, water adsorption and dry unit weight were determined. Grading of fine and coarse aggregates was also carried out using procedure [11]. For each sample mixed, slump test was carried out according to [12] to determine the workability of the fresh concrete. The samples were cast in 150mm x 150mm x150mm cube moulds and cured in water bath after 24hrs of casting. All batches were properly labeled and tested for compressive strength at 7th, 14th and 28th day. All tests were carried out in the soil and materials laboratory of Civil Engineering Department, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

IV. RESULTS AND DISCUSSION

Table 2 shows the physical properties of the various aggregates from where it was calculated that crushed granite chippings has about 17% higher unit weight than washed broken stone aggregates. Consequently, concrete members cast with CGC aggregates are expected to be denser than those cast using

WBS aggregates under the same conditions. This fact is collaborated by the average densities of CGC and WBS aggregates in Table 3, where the variation of the density of concrete with washed broken stone aggregate content is presented.

The effect of inherent weakness of local broken stone aggregates on the compressive strength of concrete was evaluated by studying the concrete properties in fresh and hardened states. In fresh state the workability of the mix was evaluated using slump test while in hardened state the compressive strength was measured.

Table II: Physical Properties of the Aggregates

Aggregate type	Specific gravity	Dry unit weight (kg/m3)	Adsorption (%)
Fine aggregate	2.65	1670	**0.75**
Crushed granite chippings	2.50	1610	**0.15**
Washed broken stone aggregate	**2.30**	**1387**	**3.96**

Table III: Variation of Density of Concrete with Washed Broken Stone Aggregate Content

S/No.	% replacement of CGC with WBS	Average density (kg/m3)
1	**0**	**2632**
2	**10**	**2594**
3	**30**	**2496**
4	**50**	**2470**
5	**100**	**2467**

Table IV: Compressive Strength of Various Samples

Sample No.	Local aggregate content	7 days strength (N/mm2)	14 days strength (N/mm2)	28 days strength (N/mm2)
1	0%, WBS	16.445	17.045	**20.311**
2	10%, WBS	16.267	16.400	**18.445**
3	30%, WBS	16.045	16.223	**18.178**
4	50%, WBS	15.734	16.089	**17.822**
5	100%, WBS	15.689	16.000	**17.778**
6	**100%, UBS**	**13.867**	**14.311**	**14.534**

A comparison of the water adsorption values , Table 2, for CGC and WBS aggregates shows that concrete cast with WBS has a higher affinity for water than those cast with CGC aggregates. The implication is that enough water will be available for early strength development of concrete member cast using WBS aggregates. Figure 1 shows the variation of slump height with percentage replacement of local broken stone aggregates (washed and unwashed). Slump test as we know is a measure of the workability of fresh concrete. Therefore, crushed granite aggregates with higher slump values will be more workable than washed broken stone aggregate concrete which in turn will be more workable than unwashed broken stone aggregate concrete. Again, workability refers to the ease at which concrete can be placed, shaped and compacted in the mould or form wok. Therefore, loss of quality will attend to any concrete with low workability since the ease of placement and densification will be lacking. This argument suggests that concrete members cast with WBS aggregates may not be of the same quality as those cast using crushed granite chippings of the same size and mix proportion. Table 4 and Fig.2 show the variation of the compressive strength of concrete containing various percentage replacements of crushed granite chippings with washed and unwashed broken stone aggregates.

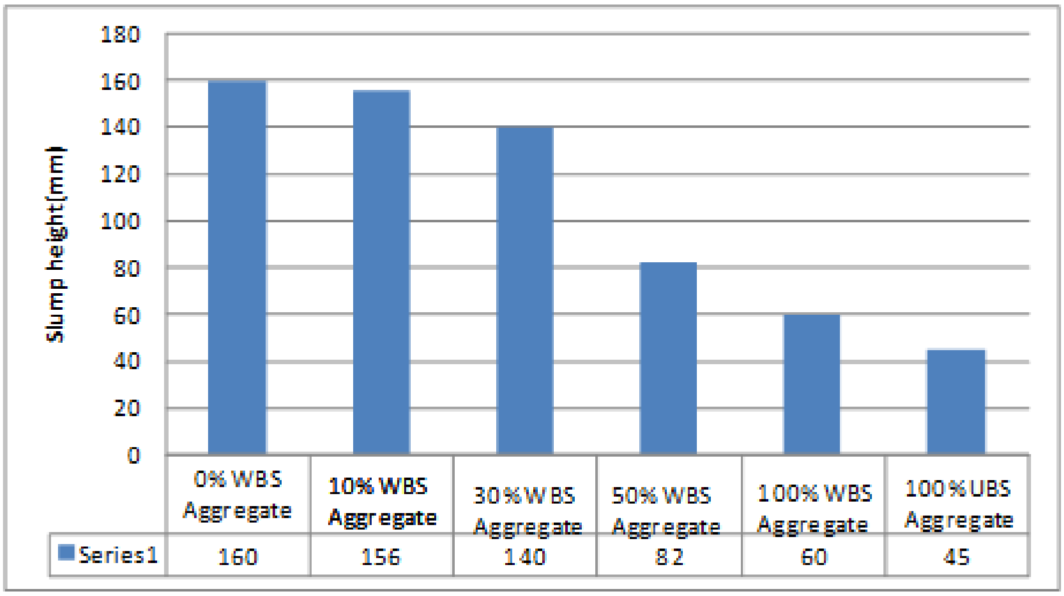

Fig. 1: Workability of concrete with broken stone aggregate contents

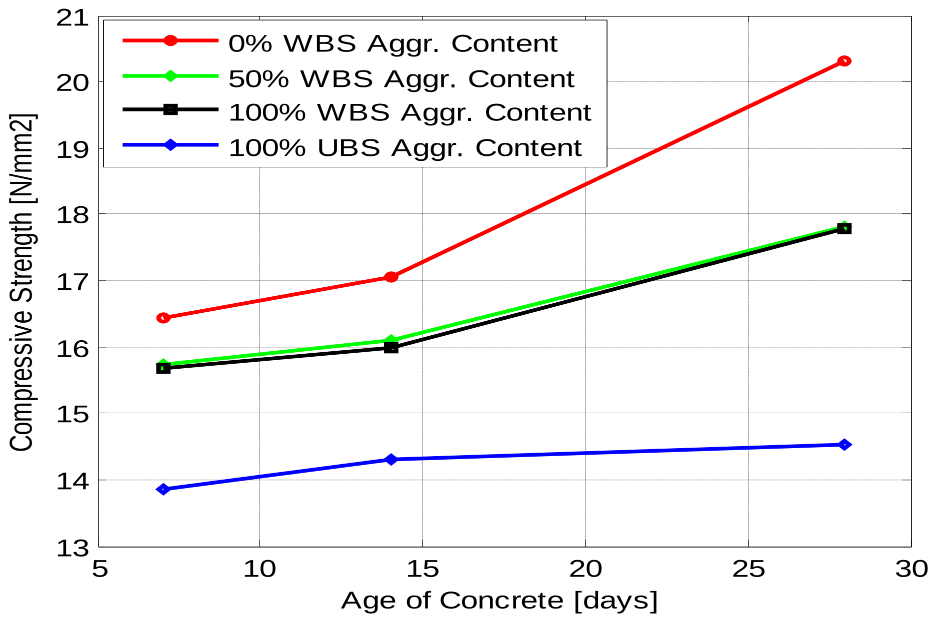

Fig. 2: Comparison of the strength of various aggregate content concrete

The following deductions are made.

1. The compressive strength of washed broken stone aggregate concrete at maturity is 12.5% less than that of crushed granite aggregate concrete of the same mix design.
2. Use of unwashed broken stone aggregate in concrete production lowers the strength of the concrete member by about 28% when compared with concrete cast with CGC aggregates of the same size and mix proportion.
3. Local aggregate impurities account for about 16% reduction of strength of concrete members cast with UBS aggregates
4. Partial replacement of CGC aggregates with WBS aggregates has commensurate reduction in the strength and quality of concrete members cast with such blended aggregates. For example, 50% replacement of CGC with WBC aggregates lowered the strength by 12.25% while 100% replacement lowered the strength by 12.47%, as can be seen in Fig.3.

In Anambra State of Nigeria, it is not un-common for property developers to use even unwashed local broken stone (UBS) aggregates in construction of buildings. This has the most deleterious effect on the quality of the structural members for which strength alone has been found to be impaired to the degree of 28%. Blending of aggregates especially for construction of slabs, column footings and stair case are also cost saving device which tends to sacrifice safety on the threshold of economy.

V. CONCLUSIONS

1. Use of unwashed local aggregate in concrete production lowers the quality and strength of the concrete member by about 28% when compared with concrete cast with CGC aggregates of the same size and mix proportion.
2. The compressive strength of washed local aggregate concrete was found to be 12.5% less than that of crushed granite aggregate concrete of the same mix design.
3 Local aggregate impurities account for about 16% reduction of strength of concrete members cast with UBS aggregates
4. Blending of aggregates (CGC and WBS) which is a common practice in construction of floor slabs in the study area is only a cost saving practice which sacrifices quality at the altar of economy. It should be restricted to over-site concrete and other areas where strength is not of paramount importance.
5. If washed broken stone aggregates are to be used in place of crushed granite chippings, trial mix proportions that would increase the factor of safety for strength of the concrete member by at least 12.5% should be adopted to avoid failures. This requires increase in cement content.

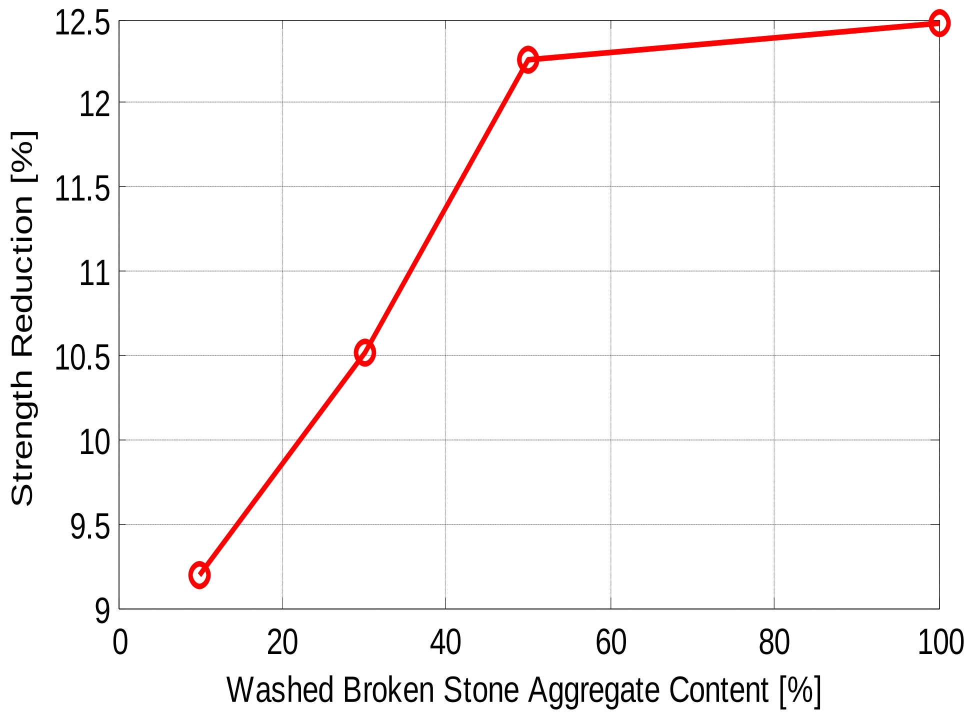

Fig. 3: Contribution of broken stone aggregate to strength reduction in concrete

VI. RECOMMENDATIONS

In this work the compressive strength of concrete was used as a representation of the strength of concrete members in building. A balanced report requires the incorporation of the flexural strength of concrete members which study is hereby recommended. Characterization of aggregate impurities will throw more light on the chemical and physical deleterious effects of the local aggregate impurities on the strength of concrete members and this is also recommended. Further (on-going) research is to determine the various concrete mix ratios, using local broken stone aggregates that would give compressive strength equivalent to grades 15, 20, 25, 30, and 35 concrete using crushed granite chippings, so as to empower builders on the strength implications of local aggregate concrete structures.

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