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ASSESSMENT OF THE UTILIZATION OF DIFFERENT STRENGTH CLASSES OF CEMENT IN BUILDING CONSTRUCTIONS IN LAGOS, NIGERIA

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ABSTRACT

Building collapse in Nigeria is so rampant now to the extent that it's gradually not becoming a news when one occurs. Several factors being attributed as the cause of building collapses are based on opinions and in some cases based on investigative reports of selected buildings collapse. These factors are speculative since some intrinsic properties of debris materials tested during the investigation of selected collapse might be lost due to the impact of the collapse as a result of falling from great height and other debris falling on the tested material that these properties were intact before the collapse. Also, since the major causes of collapse in Nigeria is mostly attributed to poor construction process and the use of substandard material, this study assesses the quality of cements used in some selected sites and freshly produced cement from factory to compare with relevant standards, it also assesses the level of knowledge of the Nigerian construction professional using these cements to measure its applications. It was found out that the cements used in these selected sites were not all to standard even though all the freshly purchased cements met the required standard, this indicates that other factors might be responsible for the drop in *standard properties. It was also observed that many of the professionals still need more training on the application of the different cement classes in structural concrete work.*

Key words: Cement-Class, Cement-Grade, Concrete-Grade, Cement and Concrete.

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1. INTRODUCTION

There are many factors contributing to building failures in Nigeria but from the study of technical reports by the Nigeria Building and Road Research Institute (NBRRI), [1] [2], amongst other building(s) that collapsed in Nigeria, it was found that amongst these cases, there were no specific reasons attributed to these collapses. In these reports, samples as concrete, steel and other debris were tested and the results that fails to meet the relevant standards were termed the cause(s) of collapse. There were multiple causes that were attributed to the cause of the collapse in both cases but in the actual sense, the impact of collapse on these materials as a result of dropping from high distances and other debris falling on them could result in the loss of some of the intrinsic strength and other properties that was intact just before the collapse. This makes the results of these causes of collapse a probable one rather than getting the exact cause(s) of the collapse. These collapse reports are inconclusive or speculative (intelligent guess) even though they could be pointers to the eventual cause of collapse.

Most factors that can lead or that led to building failure Nigeria include the corrupt practice of economizing core and active materials in attempt to save cost thereby compromising the structural integrity of buildings; use of incompetent construction personnel mostly for cheaper labour; poor construction regulatory enforcement by regulatory agencies; use of substandard construction materials are among host of other causes [3] [4]. Most if not all these causes translate to the production of substandard structural building members and as a result, the production of substandard reinforced concrete elements since the vast majority of structural buildings in Nigeria are made of reinforced concrete [5]. In Nigeria, where over 95% of the cases of building collapse affect reinforced concrete structures, a lot need to be done to understand effectively the true causes of the building collapses [6].

This study looks at building collapse in Nigeria due to failure in reinforced concrete which could be induced by several factors including the ones highlighted above. This failure from the structural point of view could either be that the concrete strength wasn't enough to bear the service loads due to poor design/bad-construction or the service loads overpowers the concrete strength due to mostly upward adaptation of buildings beyond what the building was originally designed for. Failure in substandard reinforced concrete is broadly based on the use of substandard materials or poor production process. This study was further limited to the role of cement in the production of low standard concrete.

Studies are also looking for cement replacements that could enhance concrete performance and researchers are researching into pozzolanic sources to achieve this purpose. Most agricultural and industrial wastes are under study for pozzolanic activity [7].

[8] studied the physical, mechanical and chemical properties fourteen brands of cements in use in Nigeria and found out that they all met the requirements of the Nigerian cement standard as specified in [9] except one of the brands signifying that about ninety-two percent (92%) of cements used in Nigeria are of good standard. Initial good and standard cements can be compromised by many factors including re-bagging activities like reducing the cement content and mixing with firewood ash; use of cement that have stayed longer than its expired times; poor storage system that exposes the cement to air and moisture during storage; and other market and haulage conditions. These could result to the use of substandard cement that was initially a standard cement in building construction.

Also, cements in use in Nigeria are of three different cement strength classes which are 32.5, 42.5 and 52.5. The most common of these in Lagos from the preliminary market survey for this study are the 32.5 and 42.5 strength class. The 52.5 strength class is majorly produced on request as explained by one of the brand manufacturers. Below are the range of uses of these different strength classes:

- Class 32.5: They are used for normal plastering, flooring, grouting of cable ducts in Pre-Stressed concrete (PSC) and other concrete works whose compressive strength requirements is below 20MPa. It is not suitable where sulphate is in the soil or below the phreatic level [10].
- Class 42.5: They are used where early strength in the first-twenty eight (28) days range are required. These cements are mainly for reinforced concrete works where high tensile strength are required, also, its best used where concrete strength of between 20MPa to 30MPa is required, in precast structural elements and for marine structures [10].
- Class 52.5: they are best used in concrete grade higher than 30MPa, PSC works, bridge, roads, multistoried buildings, cold weather concreting and for marine structures [10].

It's of no doubt that the strength-class of cement used has a bearing on the resulting concrete strength. Wrong application of these various classes has significant effect on the concrete strength produced, for instance, when a concrete mix design is based on a higher cement class and a lower one is used, the actual concrete will definitely fail to meet the designed target strength.

According to [11], all concrete mix specifications is based on the assumption on the use of 42.5 strength class and incase the use of the cement class 32.5 becomes inevitable, the cement content of the concrete should have at least ten percent (10%) more than specified with other concrete's constituent materials constant.

The vast majority of our structural drawings in use in Nigeria only have mix ratios but the cement grades are not specified putting the building production managers at liberty to use any kind of cement irrespective of the nature and size of construction which is a wrong practice.

This work studies the utilization of cement in use in Lagos metropolis.

2. MATERIALS AND METHODS

2.1. Materials

The main materials for this study are basically cement samples sourced from fifteen (15) different construction sites within the Lagos Island as majority of the incidences of the building collapse occurs there [12]

Other materials like the fine aggregate used for the determination of cement mortar strength is the standard sand that complies with the provisions in the [13] while the fine and coarse aggregates used in the concrete production are those that comply with the specifications in [14]. And finally, water used is underground water from boreholes that is suitable for drinking.

2.2. Methods

Cement used in constructions were sampled from fifteen (15) different sites and the size of the construction was noted during the sample collection by interviewing the site managers of the various projects. The strength class of the cements collected was also noted by observing the cement bags of both the used and unused cements on site. Two (2) freshly supplied cements of class 23.5N and 42.5N was gotten from the market to represent quality from the manufacturers and to serve as control for the test cement samples.

Well-structured questionnaires were distributed to the professionals in the construction industry to assess their awareness and level of knowledge on the utilization of the different strength classes of cement.

Survey of ten structural designs of a storey building and above was studied for its specifications and detailing.

One hundred and fifty three (153) cement mortar prisms of 40x40x40mm were produced to standard specified in [13] with mix ratio 1:3 and at 0.5wc (water/cement) ratio batched by weight and their compressive strength determined after a curing ages of 2, 7 and 28days. Three replicates of each sample were produced and the average values were used to represent actual values. These compressive strengths were compared with standard values in [9] and [15] to check for level of compliance.

Also, fifty-one (51) concrete cubes of 150x150x150mm were produced and their 28-day compressive strength determined. The mix was 1:2:4 with 19mm aggregate size as this were the specifications in the observed structural drawings used in this study and all was batched by weight.

3. RESULTS AND DISCUSSIONS

3.1. Structural Designs Study Observations

From the survey of the ten structural drawings, it was observed that they all proposed a concrete nix of 1:2:4 with aggregate size and desired concrete strength. Some included water cement ratios but none specified the cement’s strength class, aggregate quality and slump value among others. All these were specified in standard for concrete production [11]. The failure to specify the concrete qualities mentioned earlier puts the constructor in a position to use the structural drawing’s incomplete specifications and yet produce substandard concrete which makes the designer responsible for inconsistencies in concrete property and not the constructor.

3.2. Cement Samples from Various Sites

Table 1 shows the various cement samples collected from the fifteen (15) building construction sites and they are simply tagged samples A-Q. The cements used in these sites were just two brand which are Dagote cements from the Dangote group of companies and Elephant from Larfarge Plc. The specific brands used for specific projects will not be mentioned for reasons due to privacy but their strength class will be represented. It’s seen that eight of the fifteen samples were cement class 32.5N signifying 53.33% utilization while the remaining seven samples were of cement class 42.5N signifying 46.67% utilization.

Table 1 Cement Strength Class Relationship with Project Size.

Samples	Strength Class	Project Size.
A	42.5 N	2 Storey Buildings
B	32.5 N	3 Storey Building (Block of Flats)
C	32.5 N	Construction of Hotel (high rise)
D	32.5 N	Construction of central Mosque.
E	42.5 N	Shopping Complex (High Rise)
F	42.5 N	Construction of Bungalows
G	42.5 N	Blocks of Residential Flats. (3 storey)
H	32.5 N	Blocks of residential Flats.
J	42.5 N	Construction of Bungalows
K	42.5 N	Block of Residential Flats
L	42.5 N	Shopping Complex (2 storey)
M	32.5 N	2 and 3 Storey Buildings (Estate)
N	32.5 N	Construction of Bungalows (Estate)
P	32.5 N	Shopping Complex (2-storey)
Q	32.5 N	Blocks of Residential Flats
Control 42.5	42.5N	Control sample
Control 32.5	32.5 N	Control sample

It can be deduced from Table 1 that the cements samples B, C, D, M and P were used for storey buildings whose minimum concrete compressive strength requirement is 20MPa as specified in [11] and [10] specified that 42.5 strength class be used for compressive strength of 20MPa and above. In this case even if a standard concrete of strength class 32.5 that conform to [9] is used, the wrong application could possibly produce lower standard concrete.

3.3. Setting Times of the Cements Samples

The cement's minimum initial and final settings times specified by [9] and BS EN 197-1:2011 are 60 and 75 minutes for strength class 42.5 and 32.5 respectively.

All initials setting times values for the class 32.5 samples B, C, D, M, N, P and Q exceed the minimum value of 75minutes as all bars in this category are above the orange line (higher horizontal line on the chart) in Figure 1. Also, all initial setting times for the class 42.5 samples A, E, F, G, H, J, K and L exceeds the minimum of 60 minutes as all bars in this category are above the blue line (the lower horizontal line on the chart) in Figure 1.

All the cement sample's initial setting times comply with the specified standards.

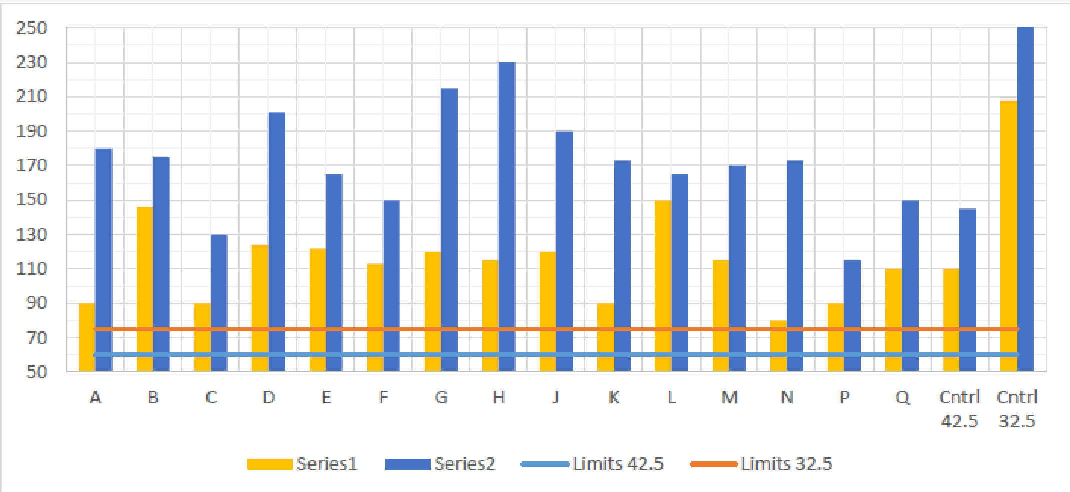

Figure 1 Initial and Final Setting Times of the Cement Samples

3.4. Mortar strengths of the cement samples

Figure 2 shows the mortar strengths of the cement samples determined to [13]. [9] and BS EN 197-1:2011 specifies that strength class 42.5N should have attained a strength of 10MPa after a 2-day curing age and 32.5N should have attained a strength of 16MPa after a 7-day curing age. These are indicated by the green and the navy-blue lines respectively across the bars in Figure 2. Of the eight strength class 32.5N samples (B, C, D, H, M, N, P and Q), only three of the samples (D, H and P) met this 7-day strength requirement and of the seven strength class 42.4N samples (A, E, F, G, J, K and L) only one of the samples (A) didn't meet the 2-day strength requirement.

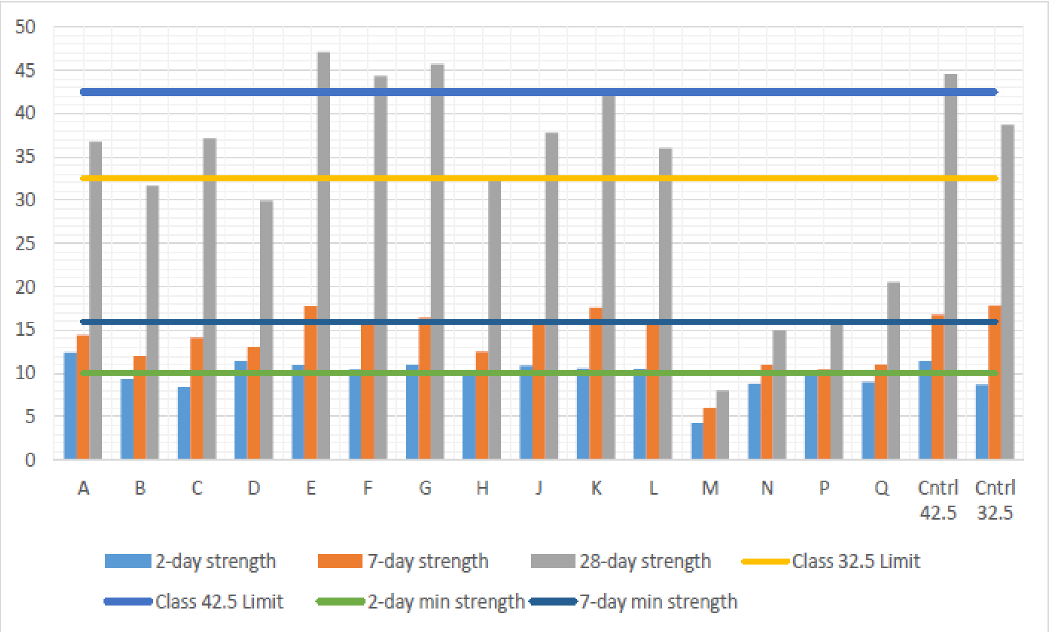

Figure 2 Mortar Strength of the Cement Samples.

Approximately, only three of the eight class 32.5N samples (B, C and H) met the 28-day strength of 32.5MPa indicated by the yellow line across the bars, though sample-D was very close and four of the seven class 42.5N samples (E, F, G and K) met the 28-day strength requirement of 42.5MPa indicated by the lighter blue line across the bars.

Though the class 32.5N cements were more used in this study than the 42.5N (53.3% and 46.7% utilization respectively) but the later used conform more to the mortar strength standards. In all cases, the control samples of the 32.5 and 42.5 classes conforms to all standard requirements investigated.

In summary, 38% and 57% of the 32.5N and 42.5N cement strength class respectively met the required 28-day mortar strength. 47% of all the cements tested met the standard strength to NIS 444-1:2003 and BS EN 197-1:2011.

3.5. Compressive Strength of Concretes Made from the Cement Samples

From the compressive strength test results of concrete made with the cement samples tested as shown in Figure 3, only eight of the samples' concrete strengths exceeded 20MPa which is the benchmark above which 32.5 class is not recommended for use but the 42.5 class. Only one sample (C) of the 32.5N class and the rest seven samples (A, E, F, G, J, K and L) are of the 42.5N class.

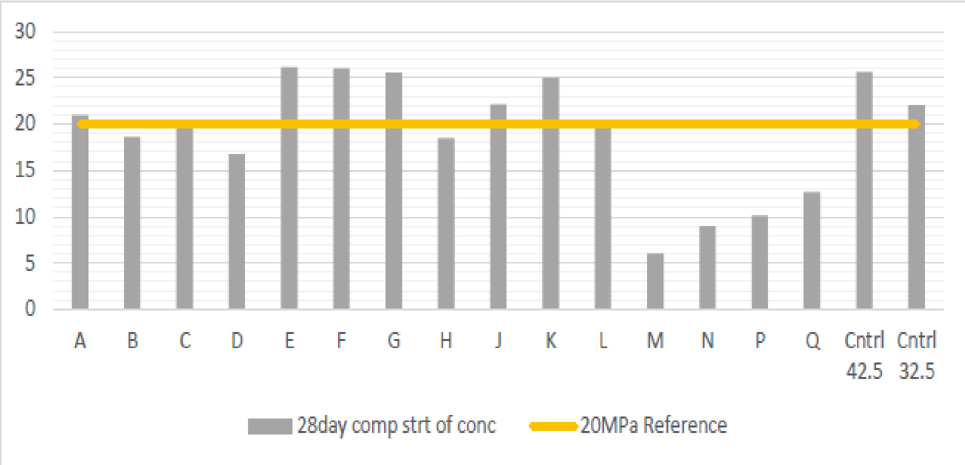

Figure 3 Concrete Strength of the Cement Samples

The minimum designed concrete cube strength specified in the studied structural drawing was 25MPa which only about 27% of all the cements met and all were the 42.5N class. None of the 32.5N class met this including the control 32.5N sample.

All the 42.5N produced concrete of compressive strength above 20MPa benchmark and only one of the 32.5N class tested produced concrete above this benchmark which confirms Indian Railway, (2014) assertion that it should be used in concrete works with cube strength demand less than 20MPa though both control samples produced concrete with compressive strengths greater than 20MPa.

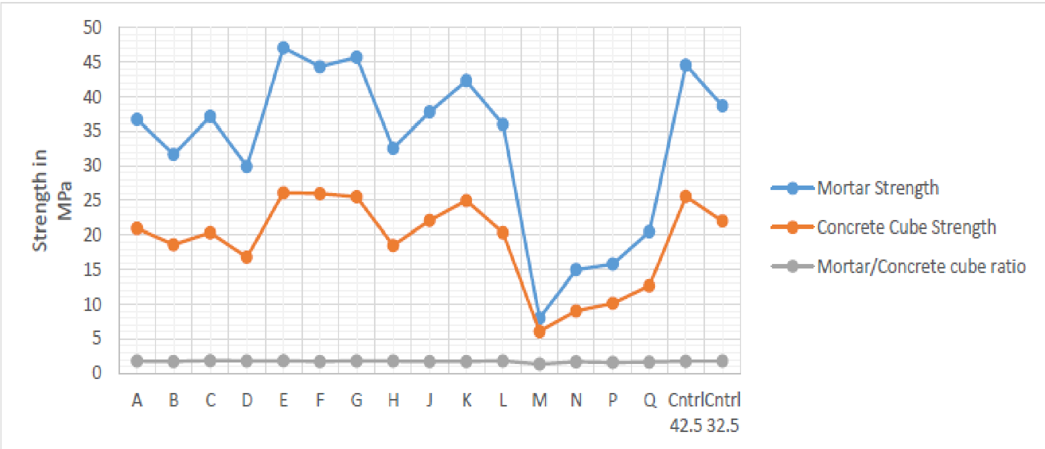

Figure 4 Mortar and Concrete Cube Strength Relationship

Figure 4 shows the relationship between the mortar and the concrete cube strength. The mean of the ratios is 1.71, median is 1.75, standard deviation is 0.12 and mean absolute deviation is 0.08. With a small difference between the mean and median, 0.04; and small standard and absolute deviations, this imply that the relationship between the mortar strength and the concrete cube strength are almost the same for all the samples. From the ratio's curve almost being a straight line in Figure 4, it justify this implication.

3.6. Questionnaire Results and Discussions

This phase entails the result derived from the data obtained for this study. These results are collected data from the respondents of the randomly distributed survey questionnaire. The data collected are represented in tabular form and pie charts, and analyzed using percentage distribution so as to obtain a comprehensive and accurate analysis in the descriptive statistics as applicable.

From the analysis, the recognized professionals in the Nigerian construction industry are the registered Builders, Architects, Structural Engineers, Quantity Surveyors, Estate Managers, Land Surveyors and Town Planners. The professionals used in this study are as shown in Figure 5 with their corresponding percentage composition.

3.7. Respondents' Professional Percentage Composition

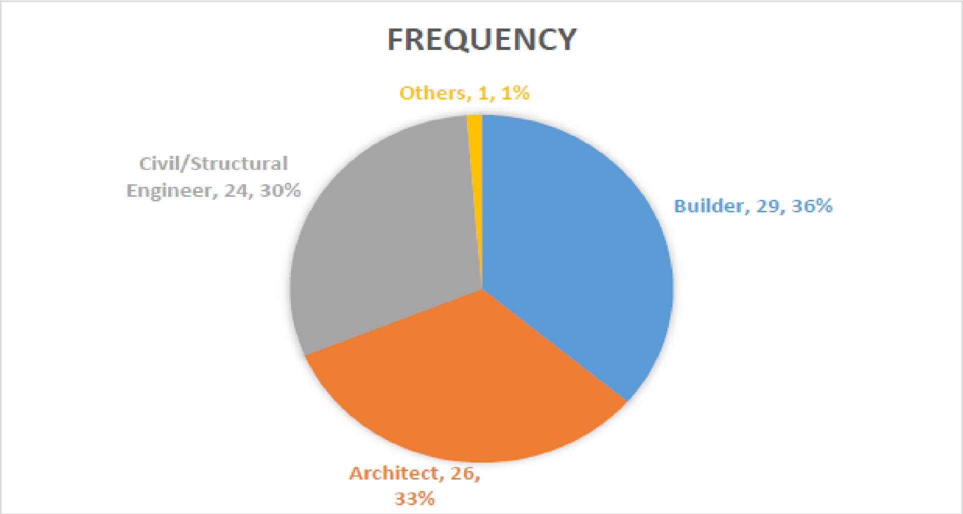

Figure 5 Results of profession of respondents

3.8. Result of Respondents' Educational Qualification

As shown in Figure 6, all respondents have higher educational qualification and so can be deduced that all respondents are educated.

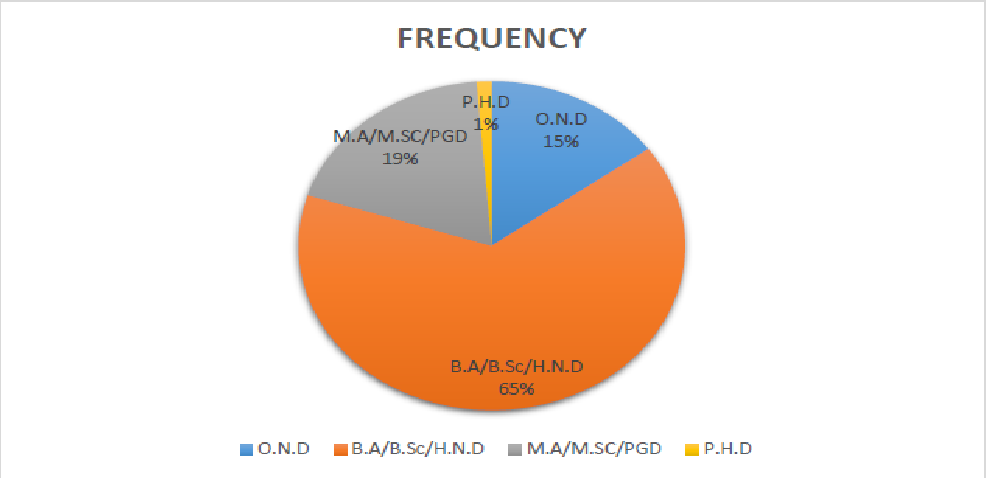

Figure 6 Respondents' Educational Qualification.

3.9. Result of years of working experience of the respondents

Table 2 Percentage of years of working experience of the respondents

S/N	Working Experience.	Frequency	Percentage
1.	Less than 2 years	10	12.5%
2.	3-5 years	28	35%
3.	6-10 years	22	27.5%
4.	11-15 years	14	17.5%
5.	16-20yrs	6	7.5%
6	20 yrs and above	0	0

On the percentage of years of working experience of the respondents, (10) 12.5% of the respondents have less than 2 years working experience, (28) 35% of the respondents have 3-5 years working experience, (22) 27.5% of the respondents have 6-10 years working experience, (14) 17.5% of the respondents have 11-15 years working experience, (6) 7.5% of the respondents have 16-15 years working experience and 0% has 21yrs and above working experience.

Table 3 Knowledge of Respondent on Cement's General Use.

S/N	Profession	Frequency	Knowledge on cement	Usage of cement.	Percentage (%)
1.	Builder	29	29	29	36.3
2.	Architect	27	27	27	33.7
3.	Civil/Structural Engr.	24	24	24	30
4.	Total	80	80	80	100

Table 3 shows that all the respondents are familiar with cement and have used cement before.

3.10. Respondents most preferred choice of cement

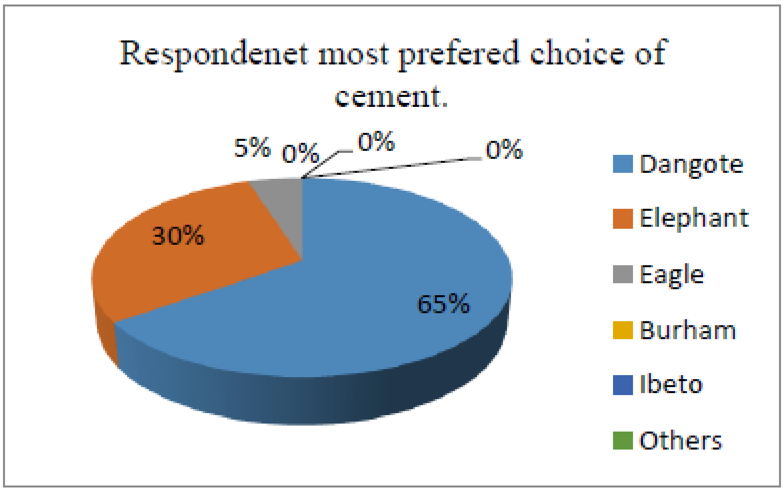

Figure 7 Respondents Most Preferred Choice of Cement.

The chart further explained that 65% of the respondents prefer to use Dangote cement, 30% of the respondents prefer to use Elephant and 5% prefer to use the rest which are Burham, Eagle and Ibeto.

3.11. Familiarity of respondents on the different strength classes/grades of cement

Figure 8 shows that 39% of the respondents are aware of the different strength classes/grades of cement, 54% are not aware while 7% are indifferent about the strength classes/grades of cement.

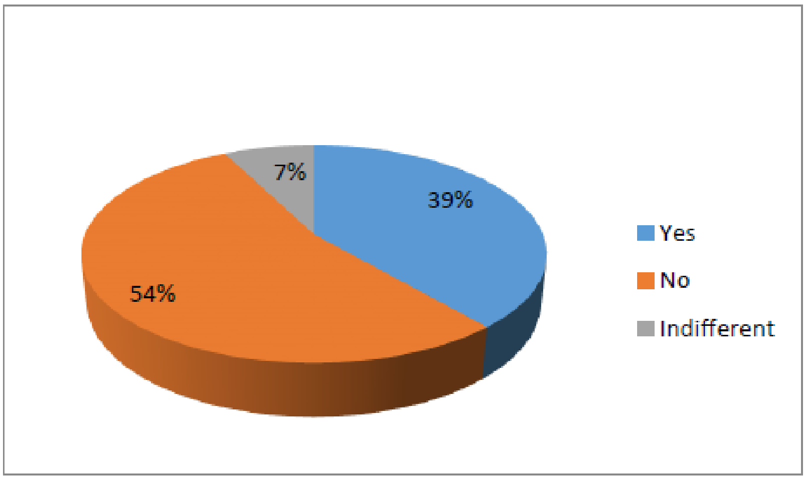

Figure 8 level of respondents on the different strength classes/grades of cement

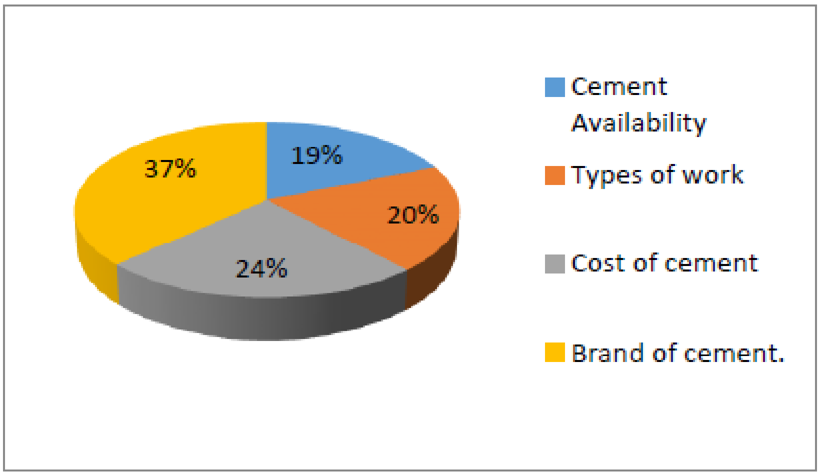

Figure 9 Respondents Basis for choice of cement class/grade for projects.

Figure 9 shows the basis on which the respondent uses a particular cement strength class/ grade. 19% use a particular strength class/ grade because of the availability of the cement. 20% use a particular strength class/ grade based on the type of construction work, 24% use a particular strength class/ grade because of the cost of cement while 37% because of the brand of cement.

But in actual practice, the use of various cement class/grade should be based primarily on the type of work (strength demand), then other reasons should be secondary. Only 20% of the respondents use a particular cement strength class for the primary reasons.

3.12. Knowledge on the applications of the different strength class/grade of cement

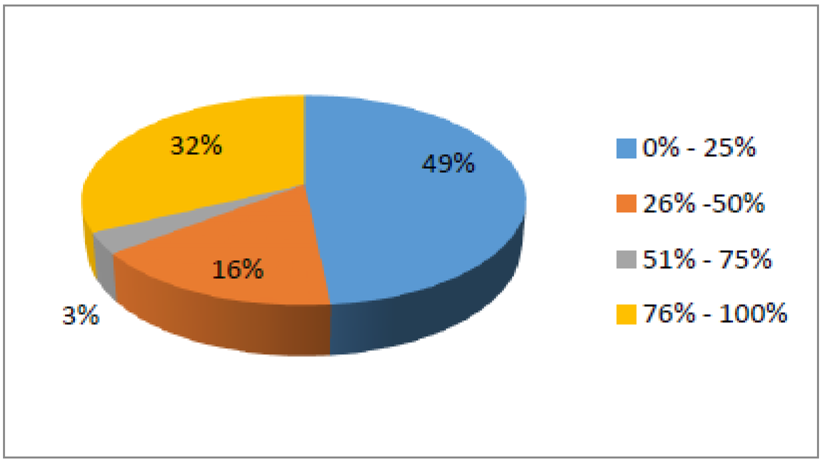

Figure 10 Assessed Knowledge on the applications of the different strength class/grade of cement by respondents.

Figure 10 indicates that out of the 39% of the respondents in Figure 8 that claimed awareness of the different strength classes/grade of cement only 32% scored between 76-100% on the assessment of application of cement class/grades, 3% scored between 51-75%; 16% scored between 26-50%; and 49% got between 0-25%. Only 35% of the respondents scored above average of over 50% mark.

4. CONCLUSIONS

- From Table 1, the cement class used for the size of that project was not appropriate, at least, 42.5 class would have been more appropriate since a minimum of 20MPa concrete would be needed in such circumstance.
- All the sampled cements conform to the setting times requirement as specified in [9] and BS EN 197-1:2011 as shown in Figure 1.
- Though the class 32.5N cements were more used in this study than the 42.5N (53.3% and 46.7% utilization respectively) but the later used conform more to the mortar strength standards. In all cases, the control samples of the 32.5 and 42.5 classes conforms to all standard requirements investigated.
- From Figure 3, only eight of the samples' concrete strengths exceeded 20MPa which is the benchmark above which 32.5 class is not recommended for use but the 42.5 class. Only one sample (C) of the 32.5N class and the rest seven samples (A, E, F, G, J, K and L) are of the 42.5N class.
- In Figures 4 and 5, Tables 2 and 3, all respondents are experienced professionals and all have gone through higher institutions and are all familiar with cement and have used it before.
- Figure 7 shows that most respondents preferred to use Dangote cement and Elephant cement in Lagos state.
- Figure 9 indicates that most of the respondents based their choice of the application of cements on secondary reasons of cost, availability and brand of cement rather than the type of work the cement is to be used for.

- Figure 8 indicates that 39% of the respondents belong to the class of those that are aware on the different strength classes of cement but on assessment, only 35% of the 39% have a fair knowledge of the classes and applications of cement based on Figure 10.

5. RECOMMENDATIONS

- All structural documents or drawings in the study area should contain more details as the standard of aggregates, strength class, workability values and other relevant details as specified in BS EN 5328-2:1997.
- As observed in Figures 1 and 2, all the control met the strength standards but not all the test samples did. It's most likely that other factors as haulage, poor storage and use of expired cements compromised the test samples. Cements should bear expiry dates to guide consumers. Regulatory agencies should be active in monitoring the materials used in construction sites as much as possible to ensure the right materials are used.
- Based on findings in Figures 2 and 3, class 32.5 control cement sample produced concrete strength of 22MPa which is about the marginal value of 20MPa that limits its use but all other class 32.5 tested except one failed to reach this marginal value. It is recommended that class 42.5 cements be used in storey structures that uses design concrete values greater than 20MPa since all the class 42.5N cement produced concrete over 20MPa. It is therefore recommended to use more of the cement class 42.5N in storey buildings and if class 32.5N is to be used, the cement content should be increased by at least 10% as indicated in [11].
- Professional institutions in Nigeria should intensify training and retraining of their professionals to better educate them especially on cement utilization. Only eleven of the eighty professionals possess average knowledge and above on cement utilization despite the fact that majority of the respondents are experienced, all uses cement, all are educated but majority still have deficient knowledge on cement utilization.

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