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TESTING THE INTEGRITY, PERFORMANCE AND RELIABILITY OF APPLICATION SOFTWARE IN THE DESIGN OF THE M40 CONCRETE MIX

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ABSTRACT

The rate and speed with which computer and computer application software is fast taking over every sphere of human endeavor and walks of life are becoming increasingly attractive, with the construction industry not an exception to these developments. Before now, the methods of design followed a tedious use of design tables, charts, graphs and, of course, services of manipulation and calculations to arrive at a required proportion of concrete ingredients, including water, that will produce the desired concrete compressive strength in a stipulated period, usually 28 days. Although these applications (software) make work faster and easier, their integrity, reliability and performance must be tested before actual field application. In this work, an application software, Eigen A$^+$, for the mix design was given all the required inputs and raw data of the properties of the ingredients of the concrete to be used for the purpose as obtained in the laboratory. An output was immediately received comprising of cement, fine, coarse aggregate and the water proportions; a trial mix of these concrete constituents was conducted and tested for its compressive strength in 7, 14 and 28th days. The result shows that the application was of proven integrity and reliability with a strength of 38.52N/mm^2, 40.39N/mm^2 and 47.67N/mm^2 at 50-50 (20/10mm) coarse aggregate, respectively and at 60-40 coarse aggregates (20/10mm), strengths of 41.77N/mm^2, 48.10N/mm^2 and 50.86N/mm^2 were obtained respectively. Some factors above the design target strength, making the software of proven integrity. Therefore, all application software design output and modeling results should be tested in the laboratory with the actual components in place and the testing machines to arrive at the certainty of purpose.

Keywords: Mix Design, Concrete, Compressive Strength, Concrete Batching

INTRODUCTION

Concrete is a composition of a binder (cement) chemically inert mineral aggregate such as sand, gravel or crushed rock (referred to as fine and coarse aggregate) and water; as this composition dries, it acquires a stone-like consistency which makes it ideal for use in Civil Engineering structures (Encyclopedia., 2010).

Therefore, the process of proportioning and ascertaining all these ingredient compositions of concrete by determining their relative amount quantities either by volume or weight in such a way that a desired and required target strength, durability, workability and economy is achieved for a grade of concrete in a given specific period of days, usually 28 days. Before now, this process was mainly based on empirical relations of charts, tables and graphs, developed by extensive research experiments and investigations on the materials used for making concrete. It involves a whole lot of process guided by a set of rules, principles and regulations which is in accord with the British or American Concrete Institute Standards, which is long, tedious complicated and sometimes inefficient.

Therefore, employing the services of application software that goes through all these rigorous manual processes within a short while becomes a pertinent and inevitable way of solving this significant Engineering problem in order to provide an easy, fast and more efficient way of performing this excellent task of designing our mix for in as much as this software will actually arrive accurately and appropriately at the correct mix at the nick of time. In that regard, tests must be conducted in the laboratory to verify this software on a small scale before finally being used for field purposes.

Due to the complexity and dynamism of Engineering, the acquisition of tools becomes the wherewithal and fortune with which to accomplish and execute tasks effectively, efficiently and, above all, with relative ease and accuracy in the nick of time. Now that the trend is drifting far away from the usual manual process towards the use of computer and computer-aided means to do the design of concrete, the whole lot process is becoming a lot easier, faster, dependable, reliable and by no means equivalent, comparable or substitutable with the other means employable. However, nonetheless, these devices are subjects of tests, scrutiny and several other confirmatory exercises in the laboratory. The problem usually associated with the outcome of the application software is, of course, the interpretations and batching of the required proportions of the components specified on a small scale for a trial mix in the laboratory for certainty to stop the guesswork and produce much more accuracy a good quality of concrete (Neville, & Brook, 2010).

The design application software used for work is the A^+ Eigen Computer application software. It is application software used to design concrete mixes of different grades. Computer-Aided design is faster, dependable and by no means equivalent or comparable; however, and none the less, these devices are subject to test scrutiny and several other confirmations before actual implementation of their outcomes in the real sense of it and hence this paper.

This paper aims to test the integrity and rehabilitation of A^+ Eigen concrete mix design application software. The aim was achieved through the following objectives:

i. They generate the required input data by the application software from laboratory tests on concrete material to be used.
ii. I am performing a trial mix of the concrete proportion based on the output data of the application software.
iii. Casting and curing nine numbers of 15 x 15 x 5cm^3 concrete cubes.
iv. We are determining the compressive strength of the cube in 7, 14 and 28 days, respectively.
v. They are comparing their results with the targeted strength of concrete grade.

LITERATURE REVIEW

Concrete is a constituent material comprised of fine aggregate and coarse aggregate bonded together by cement and water, which hardens over time to become a solid mass (Gagg, 2014). However, (Majid, 1974) further defined concrete as something made by mixing cement, fine aggregate, coarse aggregate and water; sometimes, admixtures are added in the right proportion to give a specified property.

Although other methods exist by which the strength of concrete may be ascertained however, the major and the most widely used in the laboratory is the concrete cube compressive strength test, whose two main objectives of testing are to control the quality and as well to ensure compliance with specifications for as much as the project lasts (Neville, 1996). In standard construction work, the strength of concrete and the grade are usually specified. For this reason, various methods are employed in achieving the desired and required properties of concrete, including design and trial mix formation and testing the strength of the mixes (Teychenne et al., 1975).

Computer-Aided design is the application of computers (or workstations) to aid in creating, modifying, analyzing, or optimizing a design (Narayan, 2008). The software is usually used to increase the user's productivity, improve the design quality, improve the communications through documentation and create a database for manufacturing (Narayan, 2008). As a practice and by the standard in civil engineering, the compressive strength of concrete is the main measure of quality and the major properties. Usually, 28-day strength is the most considered and used in ascertaining the compressive strength of concrete. In order to determine this quality, the concrete (fresh) is usually placed in a 150 x 150 x 150mm mold before finally, when hardened, it is put under a compressive strength test machine to determine its strength (Islam et al., 2005).

MATERIALS AND METHODS

Materials

The concrete materials that are used in the formation of the concrete in the laboratory include the following.

- Cement with 42.5N grade
- Fine aggregate sourced from Gwadabawa town.
- Coarse aggregate sourced from the Quarry site at Maru Local Government Area of Zamfara state.
- Clean borehole water sourced from Umaru Ali Shinkafi Polytechnic, Sokoto main campus.
- Concrete molds size 15x15x15cm^3 – Nine numbers
- Weighting Balance (Digital) 0.01 Accuracy
- Compressive strength testing machine of 2000N capacity
- Concrete Vibrator
- Straight edge and tamping rod (standard)
- Shovels
- Scoops
- Hand gloves
- Bristle Brush

For the purpose of this research, aggregate, which most of it passed through sieve No4 (0.187") (4.75mm), is generally considered as fine aggregate. In contrast, anything retained is generally considered coarse aggregate, of which these criteria were met by the aggregate used.

Methods

- They generated input data to be fed into the A^{+} Eigen computer application software. The data generated include the following.
- Target strength = 48
- Type of concrete = RCC
- Grade of concrete = M40
- Shape aggregate = Angular
- Slump = 110mm
- Water cement ratio = 0.46
- Exposure condition = Moderate
- Placement of concrete = By Hand
- Supervision = Good
- Fine aggregate zone = Zone 3
- Coarse aggregate size = 20mm (3/4")
- Standard deviation = 5Mpa
- The specific gravity of fine aggregate = 2.44
- The specific gravity of coarse = 2.54
- The specific gravity of cement = 3.24

Lubrication of Mould

The molds were lubricated adequately enough in readiness to receive fresh concrete to allow and facilitate easy removal of hardened concrete.

Batching of Concrete

The concrete was batched based on the outcome of the A^{+} Eigen application software that is, by weight, by putting all the ingredients together.

Trial Mix Schedule of Materials

Batching Method:	Weight
Mix Ratio:	1:1.38:2.68
Aggregate Sizes:	20mm/10mm
Cement:	Dangote Cement
Water-Cement Ratio (WCR):	0.46
Slump:	110mm
Total Mix:	9 molds of concrete + 1 cylindrical mold
	= 2650.7 + 30,375 = 79,261.68gkm^{3}

<u>Proportions</u>

Cement	=	15664.36kg
Fine	=	21616.82kg
Coarse	=	41980.49kg

Water-Cement Ratio = 0.46
Water Required = 7.205.61kg

Coarse

Aggregate variations:

50/50	=	20.990245kg/20.990245kg
60/40	=	25.188292kg/16.792196kg
TMIA Slump	=	110mm (60/40)
TMIB Slump	=	48.0mm at (70/30) coarse aggregate
TMIC Slump	=	58.0mm at (50/50) coarse aggregate
TM2 Slump	=	80mm at a mix ratio of 1:1.65:2.92

Mixing and Hydration

These materials were mixed thoroughly using the manual shovel method. At first, the River sand was mixed thoroughly with the cement until it formed a homogenous mix, then the coarse aggregate was introduced into it until the three components formed another homogenous mix which was neither fine aggregate nor coarse aggregate, before the introduction of water. Mixing continued until all the components of the mix were complete.

Casting of Fresh Concrete into Moulds

Ensuring a homogenous mix of the components, the fresh concrete was cast into a 15x15x15cm^3 mold and vibrated for 2 minutes. Nine (9) concrete cubes were cast and left to hold until 24hrs.

Demolding and Curing of Concrete Cubes

The hardened concrete was removed from the molds after 24hrs and then transferred into the curing tank filled with fresh tap water for curing.

Testing of Compressive Strength of Cube

The compressive strength of the cube thus formed was tested for compressive strength in 7, 14 and 28 days using three cubes for test for each day, respectively, to have an average record for each day tested. The results are displayed in Chapter 4 of this research.

RESULTS AND DISCUSSION

Result as Displayed By A$^+$ Eigen Application Software

Cement	=	498kg/m^3
Fine Aggregate	=	687.24kg/m^3
Coarse Aggregate	=	1334.64kg/m^3
Water	=	211kg/m^3
Water Cement Ratio	=	0.42

Which gives a mix ratio of;
Cement 1: FA1.38: CA2.68: W/C 0.42

Table 1: Specific Gravity of Coarse Aggregate

S/N	SAMPLE NO	1	2	3
a.	Mass of Empty Pyconometer M_1 (gr)	610	618	618
b.	Mass of Pyconometer + Soil M_2 (gr)	1076	1072	1316
c.	(b – a)	466	454	698
d.	Mass of Pyconometer + Soil + Water M_3 (gr)	1798	1794	1932
e.	(d – b)	722	722	616
f.	Mass of Pyconometer + Water M_4 (gr)	1516	1514	1514
g.	(f – a) (gr)	906	896	896
h.	Specific Gravity (SG) $= \frac{M_2 - M_1}{(M_4-M_1) - (M_3-M_2)} = \frac{c}{g-e}$	2.53	2.61	2.49
	Average	**2.54**		

SOURCE: (Laboratory Work, 2022)

Table 2: Specific Gravity of Fine Aggregate

S/N	SAMPLE NO	1	2	3
a.	Mass of Empty Pyconometer M_1 (gr)	132	140	110
b.	Mass of Pyconometer + Soil M_2 (gr)	216	236	236
c.	(b – a)	84	96	126
d.	Mass of Pyconometer + Soil + Water M_3 (gr)	496	506	498
e.	(d – b)	280	270	232
f.	Mass of Pyconometer + Water M_4 (gr)	440	446	418
g.	(f – a) (gr)	308	306	308
h.	Specific Gravity (SG) $= \frac{M_2 - M_1}{(M_4-M_1) - (M_3-M_2)} = \frac{c}{g-e}$	3.00	2.66	1.66
	Average	**2.44**		

SOURCE: (Laboratory Work, 2022)

Table 3: Specific Gravity of Cement

S/N	DATA COLLECTION	SAMPLE NUMBER		
		1	**2**	**3**
1.	Weight of empty bottle (W_1) (grm)	136	136	136
2.	Weight of bottle + sample (W_2) (grm)	146	146	146
3.	Weight of bottle +sample + liquid (W_3) (grm)	382	382	382
4.	Weight of bottle + Test liquid (W_4) (grm)	376	376	376
5.	Weight of bottle + water (W_5) (grm)	448	448	448
Calculations				
6.	Specific gravity (Gs) of test liquid $= \frac{W_4 - W_1}{W_5 - W_1}$	0.78	0.78	0.78
7.	Specific gravity Gs of cement Gs $= \frac{W_2 - W_1}{(W_2-W_1) - (W_3-W_4) \times (6)}$	3.21	3.21	3.21
8.	Average Specific Gravity (Gs) of the cement	**3.21**		

SOURCE: (Laboratory Work, 2022)

Table 4: 7-day Compressive Strength

Cube Number	SET 1		
	TM 1C C40 (50/50) 1	TM 1C C40 (50/50) 3	TM 1C C40 (50/50) 5
Weight of Cube (grm)	7980	7970	7982
Density of Cube g/cm^3	2.36	2.36	2.36
Gauge Reading at Failure (KN)	839.65	808.47	951.94
Area of Cube (cm^2)	225	225	225
Compressive Strength F/A (N/mm^2)	37.32	35.93	42.31
Average Compressive Strength (N/mm^2)	38.52		

SOURCE: (Laboratory Work, 2022)

Table 5: 14-day Compressive Strength

Cube Number	SET 1		
	TMIC (50/50) C40 2	TMIC (50/50) C40 4	TMIC (50/50) C40 6
Weight of Cube (grm)	7976	7934	7942
Density of Cube g/cm^3	2.36	2.35	2.35
Gauge Reading at Failure (KN)	805.62	780.86	1140.10
Area of Cube (cm^2)	225	225	225
Compressive Strength F/A (N/mm^2)	35.81	34.70	50.67
Average Compressive Strength (N/mm^2)	40.39		

SOURCE: (Laboratory Work, 2022)

Table 6: 28-day Compressive Strength

Cube Number	SET 1		
	TM 1C C40 (50/50) 7	TM 1C C40 (50/50) 8	TM 1C C40 (50/50) 9
Weight of Cube (grm)	7990	7994	7994
Density of Cube g/cm^3	2.37	2.37	2.37
Gauge Reading at Failure (KN)	1133.90	952.98	1130.80
Area of Cube (cm^2)	225	225	225
Compressive Strength F/A (N/mm^2)	50.40	42.35	50.27
Average Compressive Strength (N/mm^2)	47.67		

SOURCE: (Laboratory Work, 2022)

Table 7: 7-day Compressive Strength

Cube Number	SET 1		
	TM 1A (60/40) 1	TM 1A (60/40) 2	TM 1A (60/40) 3
Weight of Cube (grm)	79348	7914	7844
Density of Cube g/cm^3	2.35	2.34	2.32
Gauge Reading at Failure (KN)	978.73	962.67	878.39
Area of Cube (cm^2)	225	225	225
Compressive Strength F/A (N/mm^2)	43.49	42.79	39.04
Average Compressive Strength (N/mm^2)	41.77		

SOURCE: (Laboratory Work, 2022)

Table 8: 14-day Compressive Strength

Cube Number	SET 1		
	TM I C40 (60/40) 3	TM I C40 (60/40) 4	TM I C40 (60/40) 6
Weight of Cube (grm)	7950	7974	7882
Density of Cube g/cm^3	2.36	2.36	2.34
Gauge Reading at Failure (KN)	1053.6	1133.4	1059.9
Area of Cube (cm^2)	225	225	225
Compressive Strength F/A (N/mm^2)	46.83	50.37	47.11
Average Compressive Strength (N/mm^2)	48.10		

SOURCE: (Laboratory Work, 2022)

Table 9: 28-day Compressive Strength

Cube Number	SET 1		
	TMI 60/40 C40 7	TMI 60/40 C40 8	TMI 60/40 C40 9
Weight of Cube (grm)	7926	8030	7960
Density of Cube g/cm^3	2.35	2.38	2.36
Gauge Reading at Failure (KN)	1138.00	1159.40	1135.70
Area of Cube (cm^2)	225	225	225
Compressive Strength F/A (N/mm^2)	50.58	51.53	50.48
Average Compressive Strength (N/mm^2)	50.86		

SOURCE: (Laboratory Work, 2022)

DISCUSSION

From the table of results so far, it is deduced that at barely 7 days, the characteristic strength of the cube was 38.52N/mm^2 of the targeted strength, which is 79.83%, while at 14 days to strength test, 40.39N/mm^2 of the targeted strength was achieved which is 83.70% of the targeted strength. On the 28th-day compressive strength test of the concrete cube, 47.67N/mm^2 of the targeted strength was reached, about 99% of the targeted strength of 48.25N/mm^2. However, when the proportion of the coarse aggregate was substituted and varied by 60% (20mm) and 40% (10m^2), the result never the less gave an upsurge of up to 50.86N/mm^2 on the 28th day, which shows about 1.1% increase in the strength capability as compared to when an average aggregate of single aggregate was to be used for the mix

CONCLUSION

Based on the result, it is concluded that the application software used for the design is of proven integrity and dependable because the concrete cube strength at 28 days was 99% of the targeted strength. It also shows a 1.1% increase in the strength capability compared to when an average aggregate of a single aggregate is to be used.

RECOMMENDATIONS

Therefore, it is recommended based on the above facts as shown from the results.

i. An optimization procedure should be arrived at before finally using the application software.
ii. It is also recommended that the best proportion of coarse aggregate most suitable for the mix design be investigated practically in the laboratory to select the optimum proportion.
iii. All modeling outcomes should be tested practically before adoption and acceptance for use.

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