e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

DESIGN AND DEVELOPMENT OF CONCRETE MIX DESIGN COMPUTER PACKAGES FOR LABORATORY AND SUSTAINABILITY RESEARCH WORKS

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ABSTRACT

In the production process of sustainable concretes of various grades, the most important stage is the estimation of the actual quantities of its ingredients; Water, Cement, Sand, Gravel and Sustainable additives or replacing materials (such as Fibres, Pozzolanic ashes etc.) The manual approach used to be time consuming. The research is aimed at developing Computer Aided packages to support the estimations. A manual approach of estimation was performed which was then used to formulate into Microsoft Excel. The packages are designed to allow Users easy handling of compressive, flexural and split tensile strengths of sustainable concretes tests. The packages are also made to suite all concrete standards (British standard, American standard and Indian standard). The packages are developed as a self-taught which simply directs the Users of each and next steps of actions. It has dynamic results presentation feature. Conclusively, the final results from both approaches were compared, the results were found to be similar, except that, results obtained from computer aided are found to be more precise, faster to perform and possibility of human error is neglected. Lastly the easy access to Microsoft excels in our computers nowadays. This make the software can be suitable for concrete laboratory users.

Keywords: Concrete, Sustainability, Compressive Strength, Flexural Strength, Split Tensile Strength, Microsoft Excel.

I. INTRODUCTION

One of the tedious and time consuming aspects of sustainable concrete production project is the determination of the exact amount of Cement, Sand, Gravels, Water and replaceable material that will be suitable for a specified concrete grade. The task is usually done manually, yet it is an unavoidable structural safety and economy.

Mehta and Monteiro (2006) and Goga et al. (2018) described concrete as the most widely used material in construction industries.

Concrete are been produce in grades depending on the water cement ratio and ingredients mix proportions such as; 1:3:6, 1:2:4, 1:1:2 e.t.c. whereas the first digit stands for Cement, second digit is for Sand and the last digit is for Gravels weights express in proportion. Concrete being the most utilized building construction material. This draws the attention of many researchers from various part of the World to take part in numbers of research works with aim of modifying and / or improving the concrete by deploying sustainability approaches. This is been achieved through incorporation of locally made materials, waste in form of fibres, waste containing pozzolanic, agricultural and industrial by products etc., hence the need for determining the proportional quantities is of paramount importance. This will enable maintaining of standard, repeatability in production and record keeping in terms of construction progress reporting.

Badewi (2009), Hota and Liang (2011), Ramadevi and Manju (2012), Saikia and Brito (2013) Ejeh, Abubakar, Ocholi & Nuruddeen (2014), Katzer (2016), Mohod (2015) etc. have made use of various recyclable wastes as alternative and cheaper construction materials with the aims of producing concrete with an improved qualities and to help in containment of waste management problems. As wastes production is increasing globally, more researches and facilities are needed to be put in place in order to encourage sustainability, hence this research fall will also contribute efficiently. It is manually tedious task for a concrete producer to bring out the separate quantities of cement, sand, gravels, additives, fillers, required for certain task (project) otherwise it takes them prolonged period of time before making it available.

Nowadays computer packages (software) are been developed to make difficult tasks possible for works to be effectively and accurately accomplished which enables professionals to carry out their various works with ease

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and confidence. Using computer software makes it possible for Civil engineers, Builders, Quantity surveyors technologist and students to be handling concrete production without difficulty and time saving. Therefore, the importance of computerised techniques to facilitate effective sustainable concrete mix design for both construction project and laboratory base research cannot be overemphasised.

Sustainability

The incorporation of materials (fibres, aggregates etc.) mostly from waste and local materials into concrete and other building construction is termed as sustainable or green engineering construction. Sustainable or "green" building codes and standards have been developed on a global basis to give guidance on how to enhance sustainability and minimize environmental impact. Examples of such code are; the Leadership in Energy and Environmental Design (LEED), Port Authority of New York and New Jersey (PANYNJ) environmental policy, Sustainable Building Guidelines (SBG), United Nations Environment Programme (UNEP) etc. all from which policies have been in great adoption within the construction industries in particular. The standards are guidelines to sustainable designing, building and operating more environmentally friendly construction materials and buildings.

ITU (2012) Concluded that; sustainable buildings are structures that are built in an environmentally responsible manner by maximizing use of materials, minimizing use of resources and ensuring the health and well-being of occupants and the surrounding built environment both today and for generations to come. On the other hand, plastic waste recycling can provide an opportunity to collect and dispose of plastic waste in the most environmental friendly way and it can be converted into a resource. In most of the situations, plastic waste recycling could also be economically viable, as it generates resources, which are in high demand (UNEP, 2009).

In this changing time, waste products might just be one of an infinite number of solutions for low cost housing (Ganiron Jr, 2014).

The extremely recalcitrant nature of solid waste coupled with the fast-pace disposable culture of today has led to a variety of different plastics becoming a major waste problem worldwide. In an attempt to address this waste problem, various recycling technologies have been developed. (Kenny, Runic, & O'Connor, 2011). Solid wastes product remains one of the major solid wastes even in developed countries like United State, Ireland etc. even though many approaches have been developed for reuse and recycling them.

Previous Works

Bree and Gallegher (2016) concluded that an approach that integrates a widely used of software suite for organizing and coding data in Microsoft Excel which does not require a deep knowledge of the software.

Rianmora and Raksiri (2022) developed a computer aided program which facilitates design of Aluminium Die-Casting Mold, which aids precession in production.

Iwayemia and Moruf (2019) state that different software have been developed nowadays which allows saving and retrieval of data in a computerized system.

Akinbohun, and Apeh (2019) In Nigeria, developed a Self-Reporting Electronic Voting System. The software has exhibits maximum accuracy and security protection against election malpractice when compared to ordinary paper balloting and older e-voting systems. Thus, the importance of software in solving problems and achieving maximum precision and security cannot be overemphasised.

II. METHODOLOGY

Materials

The materials used for this research are Microsoft Excel, Water, Cement, Sand and Gravel.

Method

In the experiment a typical concrete mix analysis was carried out using of manual approach. The results which adopted for the production of three cubes, the beams and three cylinders for compressive, flexural and split tensile strengths tests respectively, after which the mix analysis was adopted for the formulation into Microsoft Excel for development of software for Compressive strength, Flexural strength and Split tensile strength tests in laboratory or research works. The package is designed to evaluate weights of cement, fine aggregates, coarse aggregates, water and fillers / additives for sustainability research on compressive strength tests, flexural

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strength tests and split tensile strength tests. The package was test-run and the results obtained compared with those generated from the manual approach. Observation and contributions were made also security and protections were then provided.

Lastly, the weights of replaceable material are calculated by subtracting its percentages from the original weight of ingredient to be replaces at various selected percentages (Say; 0.00%, 0.5.00%, 1.00%, 1.50% and 2.00%) or as deem suitable for a research. Similar approaches were conducted in the case of Flexural and Split tensile strength tests.

III. WORKING PRINCIPLE

The modus operandi of the software is similar for all the three tests (compressive, flexural and tensile strength tests). The package contains three separate workbooks one for each tests. The first worksheet named 'Home' introduces the title, sponsor and developer organizations. At the same time displays the type of test to be performed, either compressive, flexural or split tensile. Tagged as "for Compressive Strength Test Mix" clicking on it will lead you the second worksheet which shows varieties of analysis you can perform under the compressive strength test, either replacement of cement or sand or gravels. Clicking on the desired test analysis to be conducted will directly take you to third worksheet. This part is foolproof designed as it notifies you what to do next, each time you moves your cursor on any label in the worksheet. The whole workbook is inter-linked using hyperlink commands such as; "Home" (see figure 1) upon clicking on it, will take you back to first worksheet. Figure 2 contained options for the type of test to be performed. Figure 3 contained options of "Previous" which take you one step back and "Go to Summary" which take you to the forth worksheet containing the Summary of the analysis performed. The summary shows the following information; number of cubes, volume of concrete per cubes, total volume of concrete, total mix ratio, weight of individual cube, total weight of all cubes to be cast, percentage tolerance and weight of water required see figure 4, it also provides space for entering Technologist name and equipped with a real time (dynamic) date and time.

Figure 1: Home indicating Type of Test (Compressive Strength)

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Figure 2: Types of Replacement (either Cement, Sand or Gravel) to Perform

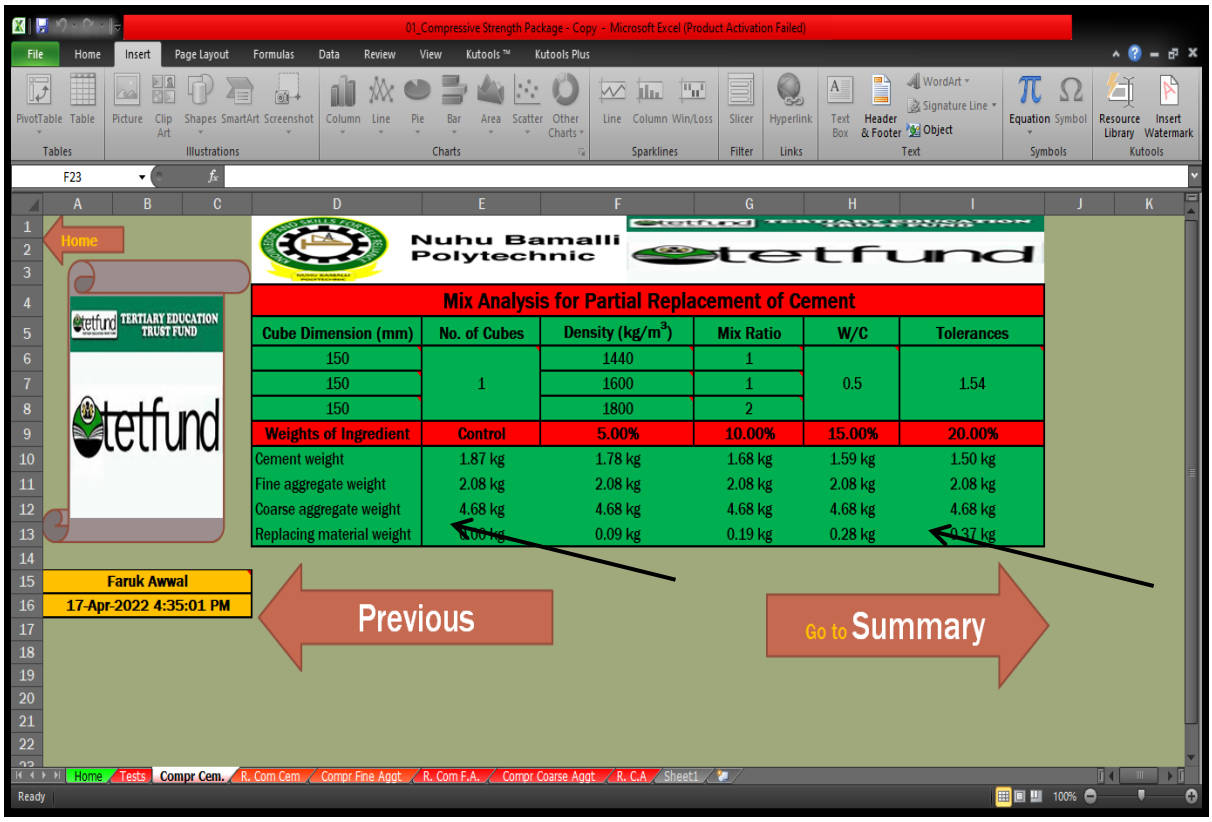

Figure 3: Working Page which allows Data entering and Analysis

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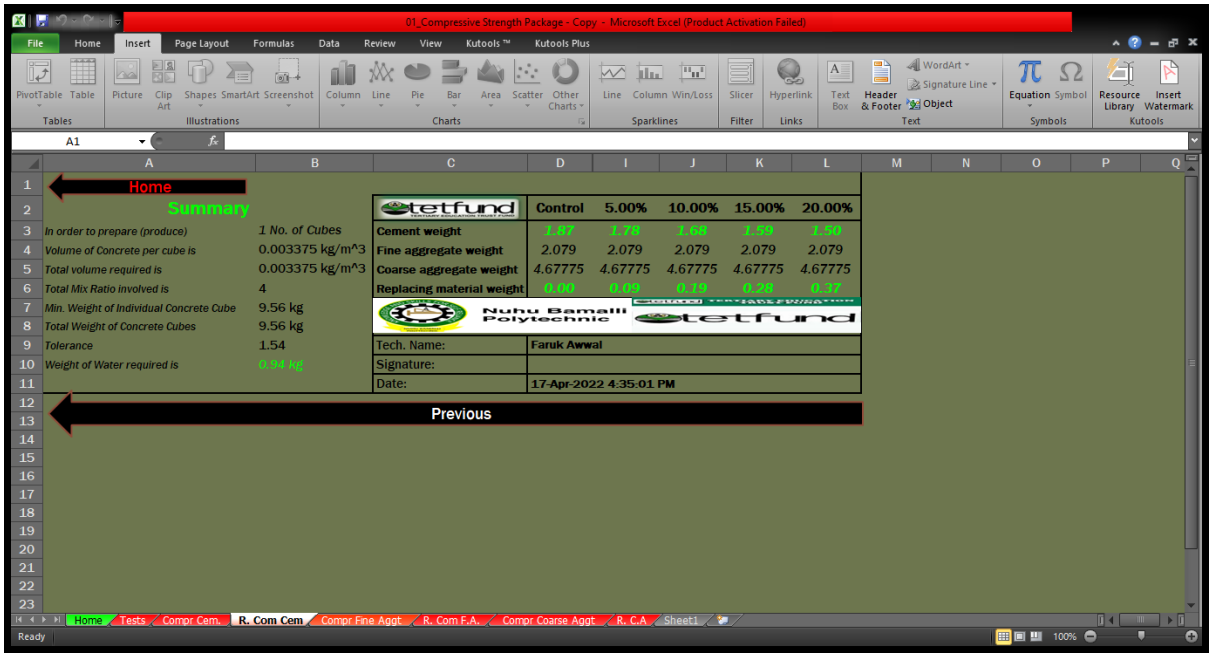

Figure 4: Summary of the Analysis

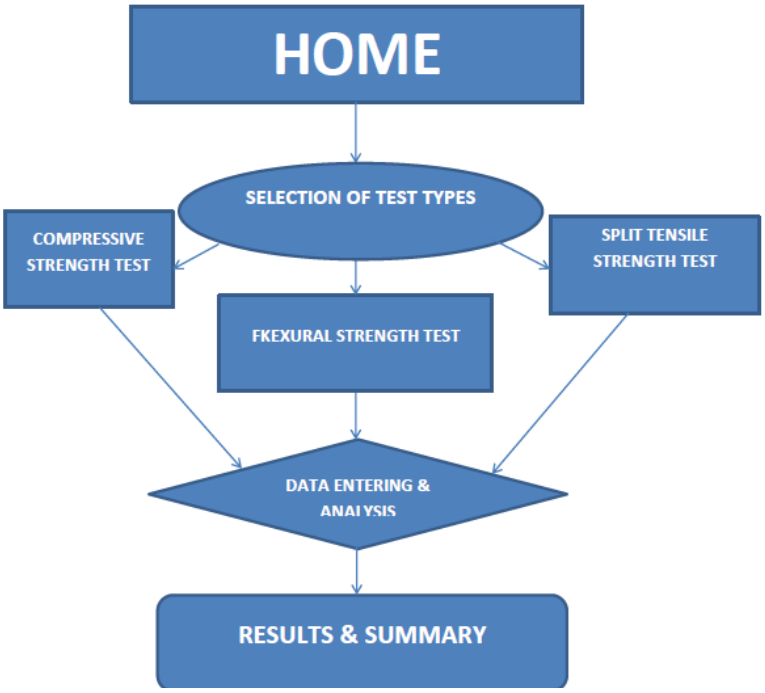

Figure 5: Concrete Constituents Estimation Procedure

Where figure 5 is showing the design model used to achieve the objectives of this paper. The system was designed to permit selection different types of test to be conducted, either compressive or flexural and split tensile tests. Lastly, the same approach is applied for the case of flexural strength and split tensile strength tests.

IV. RESULTS AND DISCUSSION

Manual Approach of Concrete Mix Analysis for 150×150×150mm (18 Cubes)

Concrete grade = M25, Water cement ratio = 0.5, Mix ratio = 1:1:2,

Concrete density, γ = 2400 kg/m^3, Density of Sand γ_s = 1600 kg/m^3

Density of Gravels, γ_{ag} = 1800 kg/m^3, Dry density, γ_d = 1.54 kg/m^3

Volume of Cube = 150mm × 150mm × 150mm = 0.003375 m^3

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Number of Concrete cubes (samples) to be cast = 18, Sum of Ratio = 1:1:2 = 4

Volume of Cement for 1 m^3 concrete Vc => $\frac{1}{4} \times 1.54 = 0.385\ m^3$

⇨ Vc for 18 Cubes = 0.003375×0.385×18 = 0.0234 m^3

⇨ Weight of Cement for 18 Cubes = 0.0234×1440 = 33.68 kg

Volume of Sand for 1 m^3 concrete Vs => $\frac{1}{4} \times 1.54 = 0.385\ m^3$

⇨ Vs for 18 Cubes = 0.003375×0.385×18 = 0.0234 m^3

⇨ Weight of Sand for 18 Cubes = 0.0234×1600 = 37.44 kg

Volume of Gravels for 1 m^3 concrete Vg => $\frac{2}{4} \times 1.54 = 0.77\ m^3$

⇨ Vg for 18 Cubes = 0.003375×0.77×18 = 0.0467775 m^3

⇨ Weight of Gravels for 18 Cubes = 0.18711×1800 = 84.20 kg

Table 1. Weights of Constituents for 18 Concrete Cubes Using Manual Approach

Constituents	Weights for Control (kg)	Weights for 0.5 % Fibre (kg)	Weights for 1.0 % Fibre (kg)	Weights for 1.5 % Fibre (kg)	Weights for 2.0 % Fibre (kg)
Cement	33.68	33.68	33.68	33.68	33.68
Fine aggregate	37.44	37.25	37.07	36.88	36.69
Coarse aggregates	84.20	84.20	84.20	84.20	84.20
Replaceable Material (say Fibre)	0.0	0.187	0.374	0.562	0.749

Table 2. Weights of Constituents for 18 Concrete Cubes Using Computer Aided Approach

Mix Analysis for Partial Replacement of Fine Aggregate					
Cube Dimension (mm)	No. of Cubes	Density (kg/m^3)	Mix Ratio	W/C	Tolerances
150	18	1440	1	0.5	1.54
150		1600	1		
150		1800	2		
Weights of Ingredient	Control	0.50%	1.00%	1.50%	2.00%
Cement weight	33.68 kg	33.68 kg	33.68 kg	33.68 kg	33.68 kg
Fine aggregate weight	37.42 kg	37.23 kg	37.05 kg	36.86 kg	36.67 kg
Coarse aggregate weight	84.20 kg	84.20 kg	84.20 kg	84.20 kg	84.20 kg
Replacing material weight	0.00 kg	0.19 kg	0.37 kg	0.56 kg	0.75 kg

It was observed that, the results obtained from both Manual and Computer Aided approaches are similar, even though, the results from computer aided approaches are more précised and rounded to two decimal points. Also the time taking for computer aided approach is much faster (2 minutes) than manual approach, which takes about 40 minutes per test (either; compressive test, flexural test and split tensile test).

V. CONCLUSION

- It is concluded that using the software makes the determination of quantities of concrete easy and faster than the manual method.
- The package is fool proof, which means concrete producers with little computer skill can perform the analysis, unlike the manual method.
- The availability and easy access to Microsoft Excel make it sustainable and adoptable in all computers and mobile phone users.
- The software is designed with colourful display, which makes it attractive hence users will not find it boring.
- The package is recommended for the estimate of materials in M10, M15, M20, M25 and M30 grades of concrete.

ACKNOWLEDGEMENTS

This is to express our deepest gratitude to the TETFUND for their financial supports and the Directorate of Technology Incubation, Innovation and Partnership (TIIP) Nuhu Bamalli Polytechnic, Zaria for their smooth facilitation, guidance and supervisions from the beginning to the finished of this work. Also special gratitude goes to Engr. Mohammed Maiwada Goga of Civil Engineering Department Nuhu Bamalli Polytechnic, Zaria, for his eminent contributions during the formulation and programming task.

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