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PROGRAM: BACHELOR OF SCIENCE IN QUANTITY SURVEYING

TOPIC: INVESTIGATING THE EFFECT OF SELECTED VOLUME BATCHING MEANS ON THE MECHANICAL PROPERTIES OF CONCRETE

BY

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JANUARY, 2022

DECLARATION

I, Nankya Nassozi Primerose declare that the information presented in this research report is my original work and it has not been presented anywhere else in any academic institution.

Sign: .... Date: 08/02/2022

APPROVAL

This is to approve that this research work is the student's original work, has been carried out under my supervision and is ready for submission.

Signature: .... Date: ...14/02/2022.....................

ENG. PAMELA ACHIENG

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DEDICATION

I dedicate this report to my family for their endless and selfless support throughout this project.

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ABSTRACT

Batching of concrete materials can be done either by volume or by mass. However, in many developing countries inclusive of Uganda, many researchers have reported that volume batching is the most commonly used method during concrete production with means such as gauge boxes, wheelbarrows, and half-cut jerrycans, among others being used despite the vast caution against it.

This research investigated the effect of volume batching means on the mechanical properties of concrete and thereafter, the most effective means were recommended. The mechanical properties of concrete studied included workability, compressive strength, and flexural strength. The volume batching means studied were the gauge box, wheelbarrow, and half-cut 20litre jerrycan.

Concrete produced using all the volume batching means was mixed using the same water-cement ratio of 0.60. Concrete samples that were cast for the study were; cube samples of 150x150mm and beams of size 150x150mm and length of 400mm for each. The tests that were carried out during the study were the slump test, compressive strength test and flexural strength test.

It was found that indeed, the means used during volume batching does have an effect on the mechanical properties of concrete. All mechanical properties of concrete investigated varied with the volume batching means used during production.

Results from all the investigations made showed that the concrete batched by the gauge box had the best mechanical properties, followed by the wheelbarrow with moderate quality, and then the concrete batched by the half-cut jerrycan had the worst mechanical properties.

It was therefore recommended that in case volume batching is employed during concrete production, the gauge box should be used. The wheelbarrow can be used as an alternative but it should be limited to minor concrete works. The half-cut jerrycan on the other hand, should be highly discouraged.

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

H – Height

L – Length

mm - millimetres

W – Width

CHAPTER ONE: INTRODUCTION

1.1 Background

Concrete is the most common building material used for structural elements in the construction industry (Hidayat et al, 2015). It is used as a material in structural elements of most buildings of the world; and most building failures including collapse are associated with failure of concrete either as produced or as assembled. The variations in the mechanical properties of concrete are as a result of several factors that may include the differences in the quality of materials, variation in the mix- proportions, and the production processes used which include batching, mixing, compaction, and curing (Owicho, 2016).

Among the various factors that affect the mechanical properties of concrete, this study is intended to assess the batching factor. The method of batching used in concrete production has been found to affect the mechanical properties of the resultant concrete since it affects the proportions of materials used during the production. During batching of materials for concrete, two methods can be used that is: volume batching and batching by weight (Bob Reed, 2012). Olusola et al (2012) discovered that if weight batching is used using well calibrated equipment, then a high degree of uniformity in the fresh and hardened properties of concrete can easily be achieved. However, when volume batching is used possible errors can lead to variation in the amount of aggregate (both coarse and fine). These errors can eventually result into variations in the mechanical properties of concrete when compared with the prescribed properties. It is for this reason that various scholars and engineers have continuously reiterated that volume batching is not recommended especially for structural elements. Unfortunately, even with the vast caution, volume batching is still very much used on construction sites especially in developing countries since it is easier, simpler and faster as compared to batching by mass (Neville and Brooks, 1987, and Olusola et al, 2012).

In countries such as Ghana, majority of the constructors (77.9%) in the construction industry were found to prefer volume batching means. The scholars further found out that only 7.36% of the constructors especially in the informal construction industry used gauge boxes in batching coarse and fine aggregates. Others were found to use wheelbarrows, head pans and other tools Hedidor and Bondinuba (2018). This appears to be the same case on many construction projects in the private and informal sector of the construction industry in Uganda, where tools like wheelbarrows, and half-cut jerry cans are being used extensively. In the meantime, the effect of these volume batching means onto the mechanical properties of concrete has, so far, not yet been established hence prompting the current researcher to delve into the proposed study.

1.2 Problem Statement

The utilisation of concrete as a building material in the construction industry is rapidly increasing in developing countries, such as Uganda, as the industry keeps on growing. The batching of materials during concrete production in the industry, however, has been reported to be largely done by volume rather than by weight. This is because it is easier, simpler and faster when compared to batching by mass (Olusola et al, 2012).Where batching by volume is carried out in concrete production, however, a prefabricated gauge box ought to be employed to ensure that accurate amounts of materials (cement, sand and course aggregates) are used for each batch (Chudley & Greeno, 2004).

Unfortunately, this idea appears not to be strictly adhered to by various building contractors in the Ugandan construction industry especially in the informal sector. This, in a way, is evidenced by the conclusions reached by some of the earlier researchers on the issue (Hedidor and Bondinuba, 2018 & Olusola et al, 2012). Their respective researches designated that such volume-batching means were very widely used in developing countries despite the alleged irregularities such as risk of failure of built structures and associated losses.

Distressingly, there appears to be very scanty researched data on the issue and solutions to the predicament, and yet it is feared that if nothing systematic is done to present empirical information and solutions to the problem, the aforesaid losses and worries will continue to manifest. Therefore, the proposed study shall be timely to reduce such unfortunate incidents and to improve the value offered by the Ugandan construction industry.

1.3 Objectives of the Study

1.3.1 Main objective

To investigate the effect of selected volume batching means on the mechanical properties of concrete.

1.3.2 Specific objectives

1. To investigate the effect of the selected volume batching means on the workability of concrete
2. To compare the effect of the selected volume batching means on the compressive strength of fresh concrete
3. To determine the effect of volume batching means on the flexural strength of hardened concrete
4. To establish the optimum volume batching means for preparation of concrete

1.3.3 Research questions

1. How do the selected volume batching means affect the workability of fresh concrete?
2. Is there a significant difference in the compressive strength of hardened concrete produced using different volume batching means?
3. What is the effect of the selected volume batching means on the flexural strength of hardened concrete?
4. What are the optimum batching means for preparation of concrete?

1.4 Significance

a) The construction industry will benefit in that the best practice of batching materials for concrete by volume shall be determined after the study.
b) Investors will henceforth get accrued value from their financial inputs.
c) The research community shall also be able to base on this study to do further research.

1.5 Scope of the Study

1.5.1 Content Scope

The research study concentrated on finding out whether volume batching means used have an effect on the mechanical properties of concrete produced.

The mechanical properties of concrete studied included workability, compressive strength and flexural strength.

1.5.2 Time Scope

The study took a period of 7 months (July 2021 - January, 2022).

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter is intended to clearly show a detailed review of literature related to the study and thereafter, the link between volume batching and the mechanical properties of concrete is explained.

2.2 Review of Related Literature

Just like all materials, the performance of concrete is determined by its microstructure. Its microstructure is determined by its composition, its curing conditions, and also by the mixing method and mixer conditions used to process the concrete (Joshua et al, 2018). In concrete production, after materials have been organized on the construction site, batching is usually the first on-site activity, which implies that it is the first activity in the control of the quality of concrete (Joshua et al, 2018).

2.2.1 Understanding Batching of Concrete

Batching of concrete according to Patel (2018) is the process in which the quantity or proportion of materials (cement, sand, aggregates and water) is measured and used to prepare the concrete mix. To make good quality concrete, the proportions of all materials should be measured properly and accurately and thus can only be done through batching.

Proper batching of concrete improves the workability of fresh concrete, increases the speed of construction and minimizes wastage of materials thus reducing extra costs. Proper batching also helps in the production of concrete of the required strength hence increasing the structural integrity of concrete structures (Patel, 2018).

Batching of concrete directly affects the strength of concrete for example, an increase in the cement content in the mix and the use of well graded aggregate results in increased strength of the resultant concrete (Hassoun and Al-Manaseer, 2015).

Batching of concrete can be done in two ways that is; volume batching and weight batching (batching by mass).

Weight batching

In this method, materials are measured and proportioned on the basis of weight. It is the more accurate and recommended method especially for large structures.

During weight batching, predetermined weights are measured for the materials. For example, to prepare 1:1:2 concrete mix, the proportions for the materials shall be 50kg of cement, 50kg of fine aggregate and 100kg of coarse aggregate (Anujopu, 2018).

British standards accept volume batching only in mass concrete (<15 MPa) and batching by weight for normal and higher strength concrete. Structural concrete like in storeyed buildings requires at least a normal strength concrete (>20 MPa) recommended to be batched by weight. However, despite being the more accurate and recommended method, weight batching is not widely used especially in developing countries due to the high costs associated with it in terms of highly skilled labor required to do it, and the equipment required which are not readily available (Olusola et al, 2012).

Volume batching

This is a method of batching in which the measurement of proportions for materials is done by volume. Volume batching is not a good method for measuring materials, it is not recommended for the case of reinforced structures, and should therefore be used for minor concrete works (Suryakanta, 2014). Despite the fact that it is not recommended, volume batching is still very widely used especially in developing countries since it is cheaper and easier to do, given the shortage of skilled labor. Designs batched by volume have been identified as the most commonly used method in concrete production in Nigeria and most developing nations, especially by medium to small scale construction firms due to the very high cost of employing batching plants (Joshua et al, 2018).

Chudley and Greeno (2004) advises that if volume batching is to be employed, then a gauge box ought to be used to measure the materials in order to guarantee a high level of accuracy, such that the strength of the resultant concrete is not compromised. Bob Reed (2012) also reiterates that in case volume batching is employed, containers of known volume must be used.

However, volume batching of fine and coarse aggregates on numerous sites especially in developing countries is being done using other means aside gauge boxes. These include but are not limited to; wheelbarrows, and half-cut jerry cans (Hedidor and Bondinuba, 2018).

2.2.2 Understanding Mechanical Properties of Concrete and their Relationship with Batching

The mechanical properties of concrete to be studied include workability, compressive strength and flexural strength.

Workability of concrete

Workability of concrete is a property of freshly mixed concrete that determines the ease and homogeneity with which it can be mixed, placed, and finished (Mishra, 2016).

American Society for Testing and Materials (ASTM) defines workability as a property of concrete determining the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity.

Workability of concrete is affected by various factors such as water:cement ratio, shape and size of aggregates, mix proportions of concrete (batching), use of admixtures among others. The mix proportions (batching) of concrete which is the main focus of the study affects workability of concrete since it affects the ratio of fine aggregates, coarse aggregates and cement.the more cement added to the mix, concrete becomes richer and aggregates have enough lubrication for easy mobility and thus better workability. If low quantity of cement is added, mobility of aggregates is restrained hence leading to unworkable concrete being produced (Mishra, 2015).

Neville & Brooks (2010) also reported that the aggregate/cement ratio directly affects the workability of concrete. Therefore, the effect of various batching means on the workability of concrete ought to be ascertained in order to advise on which means to use hence making the proposed study timely.

Strength of concrete

The strength of concrete can be classified into various categories namely; compressive strength, tensile strength, flexural strength, shear strength, and bond strength among others (Shraddhu, 2021). However, this study is meant to concentrate on compressive strength and flexural strength of concrete because they are widely accepted measures of assessing the performance of concrete and they determine how well concrete can withstand loads that affect its size (Ready_Mix_Concrete, 2002).

Generally, the strength of concrete is affected by various factors which include but are not limited to type of cement, amount and quality of cement, proportions of water, handing and placement methods, mixing/richness of mix, curing, temperature in the environment, proportions of materials (aggregate-cement ratio), and effect of compaction (Shraddhu, 2020).

The aggregate-cement ratio/proportion of materials, which is a major factor that affects the strength of concrete is determined by the process of batching as described before. The main ingredients of concrete are cement, fine and coarse aggregate which should be measured carefully to fulfill standard criteria and in order to realize maximum strength of the concrete. For example, at constant cement content, the higher the amount of aggregate, the more the strength of concrete reduces (Patel, 2018).

Compressive strength of concrete is a measure of concrete's ability to resist loads which tend to compress it. Generally, it measures the ability of concrete to withstand loads that are meant to decrease its size. Compressive strength is the most common and well-accepted measurement of concrete strength used to assess the performance of a given concrete mixture. It is the criterion of quality of concrete and the other concrete stresses can be taken as a percentage of the compressive strength (Hassoun & Al-Manaseer, 2015).

The main importance of determining compressive strength of concrete on a site is to ensure that the concrete delivered on the site meets the requirements of the specified strength in the specifications given for the project.

Flexural strength of concrete, on the other hand is typically a measure of the tensile strength of an unreinforced concrete beam or slab to resist failure in bending (Damodar & Gupta, 2014). It mainly influences the deflection and cracking behavior of concrete structures. In normal circumstances, the flexural strength of concrete is usually 10-15% of the compressive strength but it varies depending on various factors (Lysett, 2019). Bazant and Novak (2001) concluded that the flexural strength of concrete structural elements decreases with increase in the size of the element and therefore, size of elements has to be considered while testing for the flexural strength of concrete. They therefore recommend that while testing for flexural strength, all specimens should essentially be of the same size in order to avoid compromising the results got. Flexural strength tests however, are not normally conducted for structural concrete. They are normally conducted for concrete pavements. Most engineers and construction companies find the use of compressive strength convenient and reliable for determining the quality of concrete as delivered on site.

Olusola et al (2012) discovered that weight batching should be employed during concrete production such that a high degree of uniformity in the fresh and hardened properties of concrete can easily be achieved. It was added that when volume batching is used, possible errors made in the proportioning of materials can lead to variation in the amount of aggregate (both coarse and fine). These errors can eventually result into variations in the mechanical properties of concrete when compared with the prescribed properties.

Unfortunately, even with the recommendations, volume batching is still very much used on construction sites especially in developing countries since it is easier, simpler and faster as compared to weight batching (Neville and Brooks, 1987).

Furthermore, the conventional gauge box as recommended by many previous scholars is not commonly employed on conctruction sites in developing countries. Instead, contractors were found to use alternatives such as wheelbarrows, head pans and other tools (Hedidor and Bondinuba, 2018).

In a nutshell, the means used during volume batching of materials for concrete quite possibly has an effect on the mechanical properties of concrete (Hedidor and Bondinuba, 2018 & Olusola et al, 2012). Alas, hardly any research has been made to verify whether the different means used in volume batching of concrete, aside from the gauge box have an effect on the mechanical properties of concrete hence making this study timely therefore.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter is comprised of the classification of the proposed research, the research strategy, the research design, data collection methods, data collection procedure, data analysis, and ethical considerations.

3.2 Classification of the Proposed Research

The proposed research is classified as quantitative research because it is intended to quantify the variation in a phenomenon (mechanical properties of concrete), information is to be gathered using quantitative variables hence yielding quantifiable results, and analysis is geared towards ascertaining the magnitude of the variation (Kumar, 2011).

3.3 Research Strategy

An experimental research strategy is to be applied in the proposed study since it is intended to involve empirical investigation under controlled conditions to determine the relationship between the defined variables (Saunders M., 2003).

3.4 Research Design

In this section the variables to be used in the proposed study are clearly defined. The proposed research is intended to study two variables that is; the independent and the dependent variable.

The independent variable is to be the selected volume batching means, and the dependent variable is to be the mechanical properties of the resultant concrete.

3.5 Data Collection

In this section, the method of data collection is to be described. The study is intended to be carried out using experiments on various samples of concrete whose production shall be done using the selected volume batching means. The selected volume batching means that were studied included the gauge box, a wheelbarrow, and a half-cut 20litre jerry can.

3.5.1 To compare the effect of the selected volume batching means on the workability of fresh concrete

Workability of concrete was determined using the slump test where fresh concrete was placed in a slump cone and then lifted. Thereafter, the resultant concrete slump was measured and compared with the original height of the cone. Concrete of class 20 was mixed using each selected batching means and then tested according to BS EN 12350-2:2019. 3 samples for each means were tested and then the average slump was recorded for each means.

Figure 1: Slump cone after being filled with concrete before lifting the cone to observe the concrete slump

3.5.2 To investigate the effect of the volume batching using a standard gauge box, a wheel barrow and half-cut jerrycan on the compressive strength of concrete

Batching of materials (cement, coarse and fine aggregate) was done using each of the selected volume batching means to produce Class 20 concrete cubes of 150mm x 150mm x 150mm which were the test samples. These samples were then dried carefully while curing them using standard means such that they could attain maximum strength. The samples were then tested after 7days curing, 14days curing and 21days curing using the compressive strength test. 3 cubes were tested on each test day for each selected volume batching means that is to say; the 7th day, 14th day, and the 21st day and then the average compressive strength was recorded. The tests were done according to BS EN 12390-3:2019.

3.5.3 To determine the effect of volume batching means on the flexural strength of hardened concrete

Flexural strength of concrete was tested using the flexural test which is also called the transverse beam test. The flexural test on concrete was conducted using the center point load test (ASTM C293). The test was carried out using a flexural test machine. Specimens were prepared using the selected volume batching methods. These specimens were C20 unreinforced concrete beams of size 100x100mm and length of 400mm. The specimens were then cured by dipping them in water for 21days. Testing of the specimens was done at the ages of 14 days and 21 days and it was done according to BS EN 12390-5:2019.

3.5.4 To establish the optimum volume batching means for preparation of concrete

The results got from the various tests on each volume batching means were compared using graphs and thereafter, the means were ranked and the optimum means were ascertained.

3.6 Data Analysis

Analysis of the obtained test results was carried out using Microsoft Excel using tables and graphs in order to effectively compare them. The respective conclusions and recommendations were then advanced.

3.7 Ethical Considerations

Ethics are moral choices that affect decisions, standards and behavior. The researcher therefore made sure that acceptable study processes and procedures were strictly followed and adhered to. Moreover, the data collected was the only one to be recorded, analysed and on the basis of which the conclusions were made. Lastly, where need be, the researcher asked for permission to use the College facilities in the laboratory.

CHAPTER FOUR: RESULTS AND ANALYSIS

4.1 Introduction

This chapter shows the results obtained from tests intended to study the selected mechanical properties (workability, compressive strength, and flexural strength). These results are tabulated accordingly for purposes of easier and better understanding of the data, as well as easier analysis. Afterwards, graphs are to be obtained from the tabulated results in order to easily to make comparisons and thereafter draw conclusions.

The tests that were carried out on the concrete included, compressive strength test, flexural strength test and workability test. The tests carried out for the samples were made on the 7, 14 and 21days mark. The workability, however, was done on the day the concrete was cast since it is performed on fresh concrete.

4.2 Presentation of Results, Analysis and Discussion

4.2.1 Effect of the selected volume batching means on the workability of fresh concrete

In order to ascertain the workability of concrete produced using the selected volume batching means, the slump test was carried out on concrete made by each volume batching means as shown below in figures 1, 2 and 3.

Figure 2: Slump obtained from concrete batched using a half-cut jerrycan

Figure 3: Slump obtained from concrete batched using a gauge box

Figure 4: Slump obtained from concrete batched using a wheelbarrow

From the figures above, it can be observed in figure 1 that the slump obtained from the concrete batched using the half-cut jerrycan collapsed. From figure 2, the slump obtained from the concrete batched using the gauge box remained a true slump and then finally from figure 3, the slump obtained from the concrete batched using the wheelbarrow was somewhat a shear slump.

Furthermore, the slumps were each measured, and the average slump for each volume batching means was recorded in millimeters. The following results shown in table 1 were obtained.

Table 1: Average slump height obtained from the selected volume batching means

Volume batching means	**Average slump**
Gauge box	75mm
Half-cut jerry can	110mm
Wheelbarrow	80mm

A bar graph as shown below was thereafter obtained from the tabulated results in order to show the variation of workability with the various volume batching means.

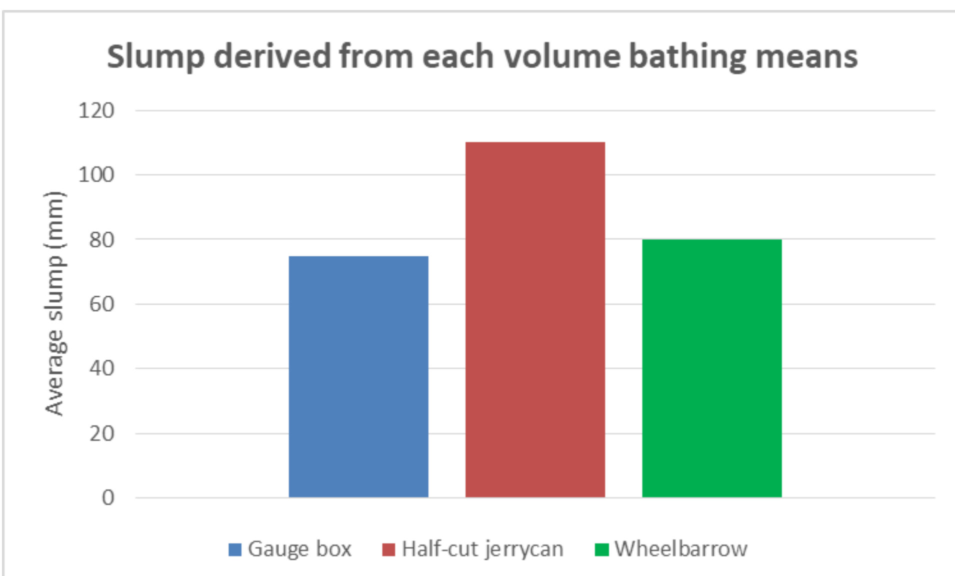

Figure 5: Comparison of workability of concrete produced using the selected volume batching means

From table 1 and figure 5 above, it can be observed that the concrete batched using the half-cut jerrycan had the highest workability with an average slump of 110mm, then the concrete batched using the wheelbarrow came in next with an average slump of 80mm, and then the concrete batched using the gauge box had the lowest workability with an average slump of 75mm.

It was observed that concrete batched using the gauge box and the wheelbarrow had medium workability with average slumps of 75mm and 80mm respectively. However, the concrete batched using the half-cut jerrycan had high workability since its average slump was 110mm (Backus, 2021).

The variation in workability of the concrete could have been brought about by the following.

1. Difference in the amount of cement put in the mix; since batching was done by use of volumes, there was a difference in the weight of cement put in each batch. For example, concrete batched by the gauge box had 21.5kg, wheelbarrow had 40.6kg, and then half-cut jerrycan had 14.4kg of cement.

2. Difference in the mix ratio arrived at after batching; in addition to the amount of cement added, the mix ratio arrived at could have also led to the variation in workability. This is because batching was done by volume and therefore, weights of the materials varied. For example, the wheelbarrow, used the most cement, but on addition of sand and aggregate, the ratio arrived at was 1:2.08:4.3; the half-cut jerrycan used the least cement but the resulting mix ratio was 1:2.23:4.8. Concrete batched using the gauge box resulted in the most favorable mix ratio of 1:2.05:4.08.

It was thereafter concluded that incase of volume batching, a wheelbarrow and a gauge box should be employed on sites since the resultant concrete can be manually placed and it can be mechanically vibrated. The concrete batched using a half-cut jerrycan, however, is not recommended since it does not respond well with vibration and therefore, it can easily undergo segregation, and thus eventually affecting the strength of the structure being constructed (Backus, 2021).

4.2.2 Effect of the volume batching using a standard gauge box, a wheel barrow and half-cut jerrycan on the compressive strength of concrete

The compressive strength test was performed over a period of 21 days (7, 14, and 21 days) in order to ascertain the compressive strength of cube samples cast using concrete whose materials were batched using the selected volume batching means. The results obtained on each test day are shown in tables 2, 3, and 4 below, as well as graphs obtained from each table in figures 6, 7, and 8 respectively. The results obtained on each test day were compared with the ideal situation as presented by Mishra (2020) which shows the ideal development trend of the compressive strength of concrete. The ideal compressive strength development over 21 days is shown in Table 2 below. Thereafter, the average compressive strength was recorded on each test day as shown in Table 5 and thereafter, a graph was derived from the table.

Table 2: Ideal compressive strength development in concrete over a period of 28 days Source: Mishra (2020)

AGE	**% OF 28**	**COMPRESSIVE STRENGTH (N/mm^2)**
1 day	16%	3.2
7 days	65%	13
14 days	90%	18
21 days	95%	19
28 days	100%	20

Test results

Table 3: Compressive strength of cube samples achieved after 7 days

Volume batching means	Cube sample	Date Cast	Date Tested	Age Days	Dimensions (mm) L	W	H	Mass (kg)	Density (kg/m^3)	Failure Load(kN)	Compressive Strength N/mm^2	Average compressive strength (N/mm2)
Wheelbarrow	1	20/12/21	27/12/21	7	150	150	150	8.6	2547.9	300	13.3	12.1
	2	20/12/21	27/12/21	7	150	150	150	8.11	2403.6	280	12.4	
	3	20/12/21	27/12/21	7	150	150	150	7.75	2295.1	240	10.7	
Gauge box	1	20/12/21	27/12/21	7	150	150	150	8.397	2488.0	320	14.2	13.3
	2	20/12/21	27/12/21	7	150	150	150	8.113	2403.9	280	12.4	
	3	20/12/21	27/12/21	7	150	150	150	8.809	2610.1	300	13.3	
Half-cut jerrycan	1	20/12/21	27/12/21	7	150	150	150	8.832	2618.7	200	8.9	8.0
	2	20/12/21	27/12/21	7	150	150	150	7.726	2289.2	160	7.1	
	3	20/12/21	27/12/21	7	150	150	150	8.363	2477.9	180	8.0	

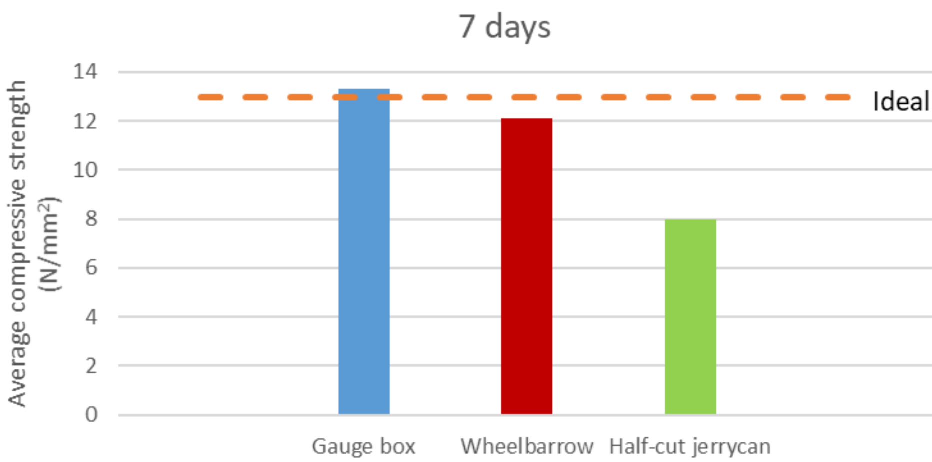

Figure 6: Comparison of compressive strength achieved after 7 days

From table 3 and figure 7 above, it is observed that after 7 days, the concrete batched using the gauge box had developed the highest average compressive strength of 13.3 N/mm^2. The concrete batched using the wheelbarrow then came in next having developed an average compressive strength of 12.1N/mm^2. The concrete batched using the half-cut jerrycan, however, had developed the lowest average compressive strength of 8N/mm^2.

However, in comparison with the ideal compressive strength that concrete should be able to achieve within a period of 7 days 13N/mm^2, it is observed from Figure 6 that only the concrete batched using the gauge box was able to attain compressive strength that surpassed the ideal strength.

It is also observed that the concrete batched using the wheelbarrow attained compressive strength that was almost reaching the ideal strength with a small difference of 0.9N/mm^2. The concrete batched using the half-cut jerrycan, however, attained an average compressive strength that was way below the ideal strength with a difference of 5N/mm^2.

Table 4: Compressive strength achieved by cube samples after 14 days

Volume batching means	Cube sample	Date Cast	Date Tested	Age Days	Dimensions (mm) L	W	H	Mass (kg)	Density (kg/m^3)	Failure Load(kN)	Compressive Strength (N/mm^2)	Average compressive strength (N/mm^2)
Wheelbarrow	1	20/12/21	03/01/22	14	150	150	150	8.783	2602.4	360	16.0	14.8
	2	20/12/21	03/01/22	14	150	150	150	8.224	2436.7	300	13.3	
	3	20/12/21	03/01/22	14	150	150	150	8.564	2537.5	340	15.1	
Gauge box	1	20/12/21	03/01/22	14	150	150	150	7.912	2344.3	340	15.1	17.2
	2	20/12/21	03/01/22	14	150	150	150	8.568	2538.7	440	19.6	
	3	20/12/21	03/01/22	14	150	150	150	8.516	2523.3	380	16.9	
Half-cut jerrycan	1	20/12/21	03/01/22	14	150	150	150	8.655	2564.4	280	12.4	11.0
	2	20/12/21	03/01/22	14	150	150	150	8.408	2491.3	220	9.8	
	3	20/12/21	03/01/22	14	150	150	150	8.465	2508.1	240	10.7	

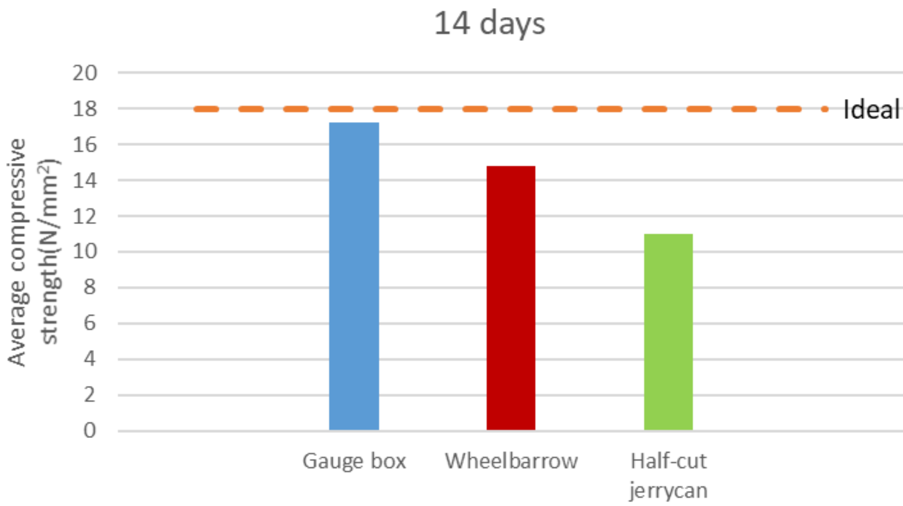

Figure 7: Comparison of compressive strength achieved after 14 days

From table 4 and figure 8, it is observed that after 14 days, the concrete batched using the gauge box had developed the highest average compressive strength of 17.2N/mm^2. The concrete batched using the wheelbarrow then came in next having developed an average compressive strength of 14.8N/mm^2. The concrete batched using the half-cut jerrycan had developed the lowest average compressive strength of 11N/mm^2.

However, in comparison with the ideal compressive strength that concrete should be able to achieve within a period of 14 days 18N/mm^2, it is observed from Figure 6 that none of the cube samples was able to attain compressive strength that surpassed the ideal strength.

It is further observed that the concrete batched using the gauge box attained compressive strength that was almost reaching the ideal strength with a small difference of 0.8N/mm^2.

The concrete batched using the wheelbarrow and the half-cut jerrycan, however, attained low average compressive strength in comparison with the ideal strength with differences of 3.2N/mm^2 and 7N/mm^2 respectively.

Table 5: Compressive strength after 21 days

Volume batching means	Cube sample	Date Cast	Date Tested	Age Days	Dimensions (mm) L	W	H	Mass (kg)	Density (kg/m^3)	Failure Load(kN)	Compressive Strength N/mm^2	Average compressive strength (N/mm2)
Wheelbarrow	1	20/12/21	10/01/21	21	150	150	150	8.164	2419.0	440	19.6	18.7
	2	20/12/21	10/01/21	21	150	150	150	8.219	2435.3	400	17.8	
	3	20/12/21	10/01/21	21	150	150	150	8.612	2551.7	420	18.7	
Gauge box	1	20/12/21	10/01/21	21	150	150	150	8.977	2659.9	420	18.7	19.6
	2	20/12/21	10/01/21	21	150	150	150	7.947	2354.7	440	19.6	
	3	20/12/21	10/01/21	21	150	150	150	8.517	2523.6	460	20.4	
Half-cut jerrycan	1	20/12/21	10/01/21	21	150	150	150	8.813	2611.3	280	12.4	13.6
	2	20/12/21	10/01/21	21	150	150	150	8.208	2432.0	340	15.1	
	3	20/12/21	10/01/21	21	150	150	150	8.056	2387.0	300	13.3	

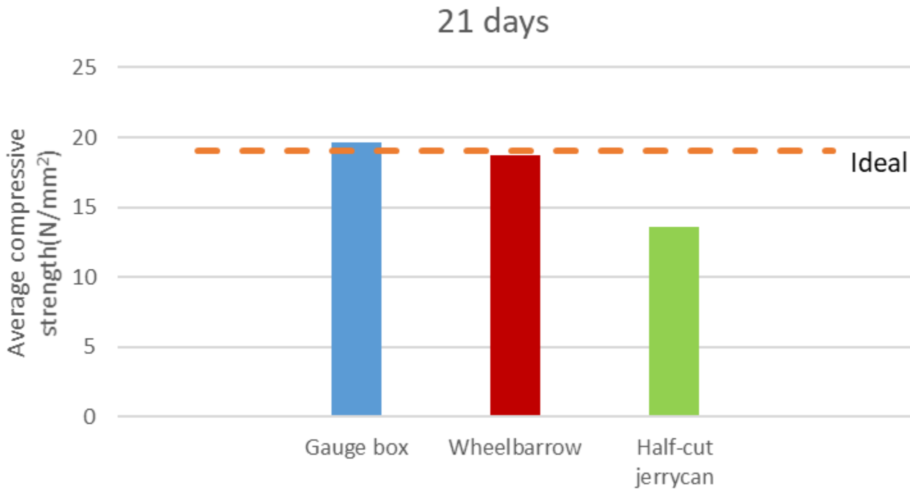

Figure 8: Comparison of compressive strength achieved after 21 days

From Table 4 and Figure 9, it is observed that after 21 days, the concrete batched using the gauge box had developed the highest average compressive strength of 20.6 N/mm^2. The concrete batched using the wheelbarrow then came in next having developed an average compressive strength of 19.6N/mm^2. The concrete batched using the half-cut jerrycan had developed the lowest average compressive strength of 13.6N/mm^2.

In comparison with the ideal compressive strength that concrete should be able to achieve within a period of 21 days of 19N/mm^2, it is further observed from Figure 8 that the concrete batched using the gauge box and that batched using the wheelbarrow were able to attain compressive strength that surpassed the ideal strength.

It is also observed that the concrete batched using the half-cut jerrycan attained an average compressive strength that was way below the ideal strength with a difference of 5.4N/mm^2.

Table 6: Compressive strength development in cube samples over a period of 21 days

Test day	**Average compressive strength (N/mm^2)**			
	Gauge box	**Wheelbarrow**	**Half-cut jerrycan**	**Ideal**
7	13.3	12.1	8.0	13
14	17.2	14.8	11	18
21	19.6	18.7	13.6	19

Figure 9: Compressive strength development trends for the selected volume batching means over a period of 21 days

From Figure 10 and Table 6 above, it is observed that generally, the compressive strengths increased progressively over the period of 21 days with increase in curing age for all the volume batching means used.

It is further observed that over the period of 21 days, the compressive strength of concrete batched using the gauge box increased at the highest rate, followed by the concrete batched using the wheelbarrow, and then the compressive strength of the concrete batched using the half-cut jerrycan increased at the lowest rate.

Additionally, in comparison with the ideal compressive strength development trend, concrete batched using the gauge box had the highest rate of development with some of the strengths even going higher than the ideal strengths.

Also, the concrete batched using the wheelbarrow had a satisfactory compressive strength development trend with the strength developed after 21 days being higher than the ideal strength. The compressive strength of concrete whose materials were batched using the half-cut jerrycan, however, had the lowest rate of development in comparison with the ideal development trend to an extent that its curve does not even reach within the range of the ideal development curve.

In general, the variation in compressive strength of the concrete could have been brought about by the following.

1. Difference in the weight of cement put in the mix; since batching was done by use of volumes, there was a difference in the weight of cement put in each batch and yet cement is responsible for the bond between the materials for concrete, which directly impacts strength. For example, concrete batched by the gauge box had 21.5kg, wheelbarrow had 40.6kg, and then half-cut jerrycan had 14.4kg of cement.

2. Difference in the mix ratio arrived at after batching; in addition to the amount of cement added, the mix ratio arrived at could have also led to the variation in compressive strength. This is because batching was done by volume and therefore, weights of the materials varied. For example, the wheelbarrow, used the most cement, but on addition of sand and aggregate, the ratio arrived at was 1:2.08:4.3; the half-cut jerrycan used the least cement but the resulting mix ratio was 1:2.23:4.8. Concrete batched using the gauge box resulted in the most favorable mix ratio of 1:2.05:4.08.

4.2.3 Effect of volume batching means on the flexural strength of hardened concrete

The flexural strength test was performed over a period of 21 days (14, and 21 days) in order to ascertain the flexural strength of beam samples cast using concrete whose materials were batched using the selected volume batching means. The test results for each test day were recorded and are presented in tables 7 and 8. Thereafter, the average flexural strength was recorded on each test day is shown in Table 9.

Table 7: Flexural strength after 14 days

Volume batching means	Beam sample	Date Cast	Date Tested	Age (Days	Dimensions (mm)			Mass (kg)	Density (kg/m^3)	Failure Load (kN)	Flexural Strength (N/mm^2)	Average flexural strength (N/mm^2)
					L	W	H					
Wheelbarrow	1	20-Dec-21	3-Jan-22	14	400	100	100	10.737	1342.1	26	10.4	9.6
	2	20-Dec-21	3-Jan-22	14	400	100	100	10.708	1338.5	22	8.8	
	3	20-Dec-21	3-Jan-22	14	400	100	100	10.698	1337.3	24	9.6	
Half-cut jerrycan	1	20-Dec-21	3-Jan-22	14	400	100	100	9.817	1227.1	20	8.0	7.7
	2	20-Dec-21	3-Jan-22	14	400	100	100	10.197	1274.6	21	8.4	
	3	20-Dec-21	3-Jan-22	14	400	100	100	9.735	1216.9	17	6.8	
Gauge box	1	20-Dec-21	3-Jan-22	14	400	100	100	10.035	1254.4	24	9.6	10.4
	2	20-Dec-21	3-Jan-22	14	400	100	100	9.896	1237.0	28	11.2	
	3	20-Dec-21	3-Jan-22	14	400	100	100	10.71	1338.8	26	10.4	

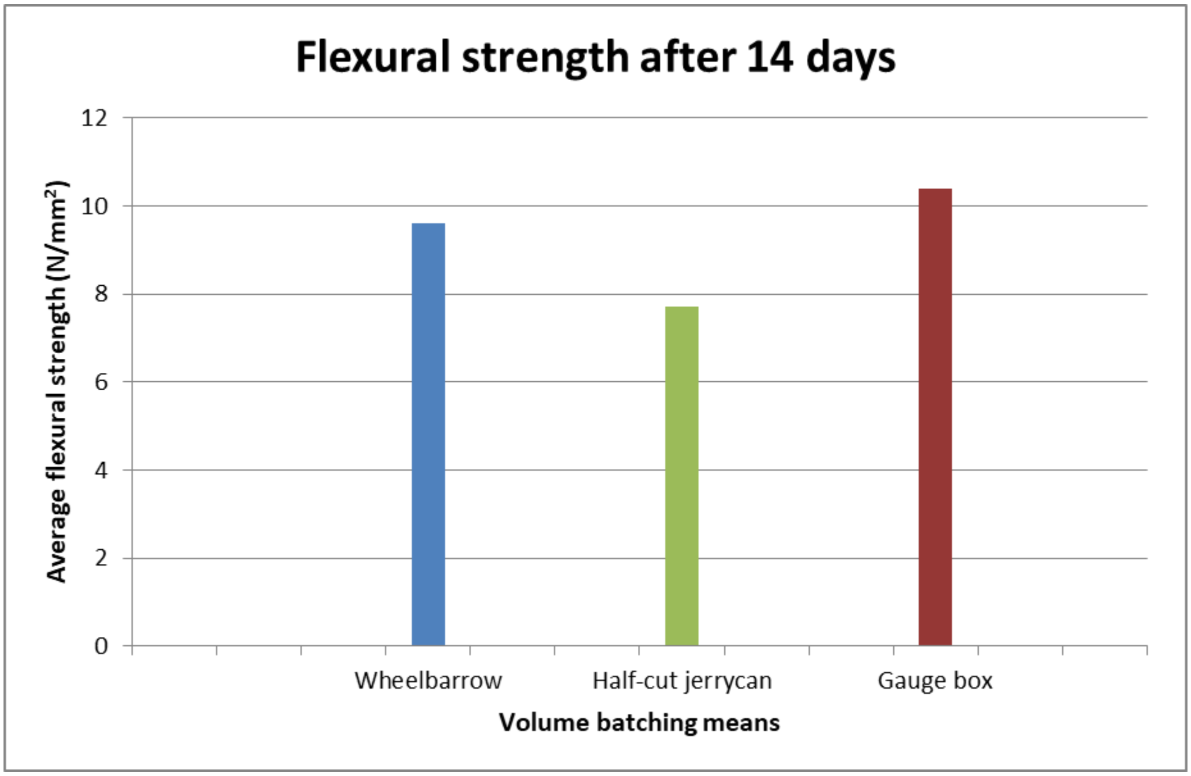

Figure 10: Flexural strength attained after 14 days

From Figure 11 and Table 7 above, it is observed that after a period of 14 days, the concrete batched using the gauge box had developed the highest average flexural strength of 10.4N/mm^2. The concrete batched using the wheelbarrow then came in next with an average flexural strength of 9.6N/mm^2.

The concrete batched using the half-cut jerrycan developed the lowest average flexural strength of 7.7N/mm^2.

Table 8: Flexural strength attained after 21 days

Volume batching means	Beam sample	Date Cast	Date Tested	Age Days	Dimensions (mm) L	W	H	Mass (kg)	Density (kg/m^3)	Failure Load (kN)	Flexural Strength (N/mm^2)	Average flexural strength (N/mm^2)
Wheelbarrow	1	20-Dec-21	10-Jan-22	21	400	100	100	10.868	1358.5	27	10.8	10.4
	2	20-Dec-21	10-Jan-22	21	400	100	100	11.139	1392.4	26	10.4	
	3	20-Dec-21	10-Jan-22	21	400	100	100	10.045	1255.6	25	10.0	
Half-cut jerrycan	1	20-Dec-21	10-Jan-22	21	400	100	100	9.855	1231.9	23	9.2	8.1
	2	20-Dec-21	10-Jan-22	21	400	100	100	10.263	1282.9	20	8.0	
	3	20-Dec-21	10-Jan-22	21	400	100	100	9.735	1216.9	18	7.2	
Gauge box	1	20-Dec-21	10-Jan-22	21	400	100	100	10.325	1290.6	28	11.2	11.3
	2	20-Dec-21	10-Jan-22	21	400	100	100	9.687	1210.9	30	12.0	
	3	20-Dec-21	10-Jan-22	21	400	100	100	11.054	1381.8	27	10.8	

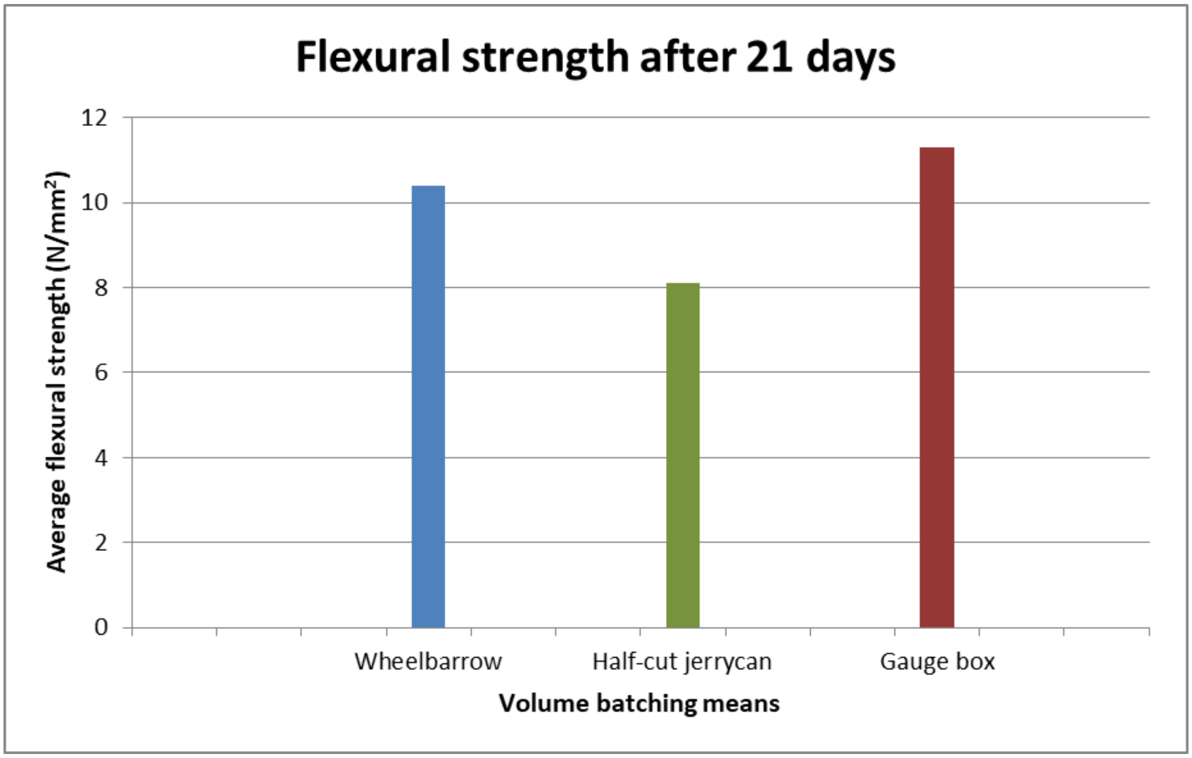

Figure 11: Flexural strength attained by the beam samples after 21 days

From Figure 12 and Table 8 above, it is observed that after a period of 21 days, the concrete batched using the gauge box had developed the highest average flexural strength of 11.3N/mm^2. The concrete batched using the wheelbarrow then came in next with an average flexural strength of 10.4N/mm^2.

It is further observed that the concrete batched using both the gauge box and the wheelbarrow developed flexural strength within the same range with a difference of only 0.9N/mm^2.

The concrete batched using the half-cut jerrycan developed the lowest average flexural strength of 8.1N/mm^2

Table 9: Comparison of flexural strength obtained from concrete samples over 21 days

Test day	Average flexural strength (N/mm^2)		
	Gauge box	Wheelbarrow	Half-cut jerrycan
14	10.4	9.6	7.7
21	11.3	10.4	8.1

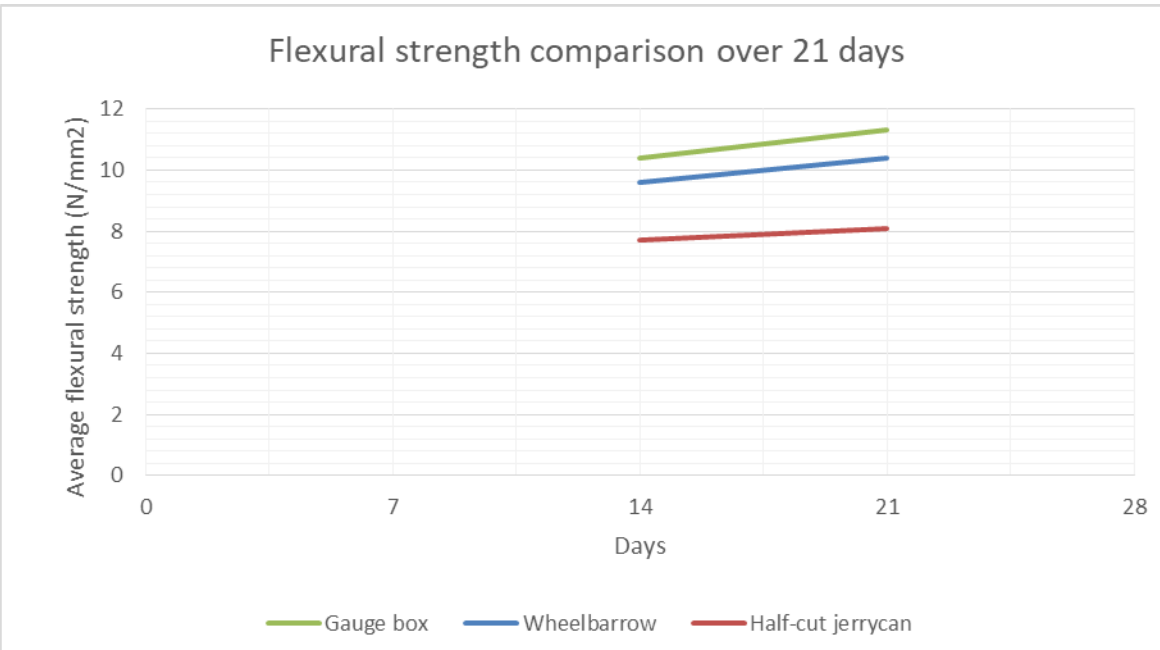

Figure 12: Flexural strength development trends over 21 days

From Figure 13 and Table 9 above, it is observed that flexural strength increased progressively over the period of 21 days with increase in curing age for all the volume batching means used.

It is further observed that over the period of 21 days, the flexural strength of concrete batched using the gauge box increased at the highest rate, followed by the concrete batched using the wheelbarrow, and then the flexural strength of the concrete batched using the half-cut jerrycan increased at the lowest rate.

Additionally, it is observed that the overall flexural strength development trend of the concrete batched using both the gauge box and the wheelbarrow were within a small range of each other.

In a nutshell, the variation in flexural strength of the concrete could have been brought about by the following.

1. Difference in the weight of cement put in the mix; since batching was done by use of volumes, there was a difference in the weight of cement put in each batch and yet cement is responsible for the bond between the materials for concrete, which directly impacts strength. For example, concrete batched by the gauge box had 21.5kg, wheelbarrow had 40.6kg, and then half-cut jerrycan had 14.4kg of cement.

2. Difference in the mix ratio arrived at after batching; in addition to the amount of cement added, the resultant mix ratio could have also led to the variation in flexural strength. This is because batching was done by volume and therefore, weights of the materials varied. For example, the wheelbarrow, used the most cement, but on addition of sand and aggregate, the resultant ratio was 1:2.08:4.3; the half-cut jerrycan used the least cement but the resulting mix ratio was 1:2.23:4.8. Concrete batched using the gauge box resulted in the most favorable mix ratio of 1:2.05:4.08.

4.2.4 Optimum volume batching means for preparation of concrete

Basing on the results obtained from the various tests done for workability, compressive strength and flexural strength, comparisons were made and thereafter, the volume batching means studied were ranked according to their level of concrete strength and costs incurred when each of the means is used.

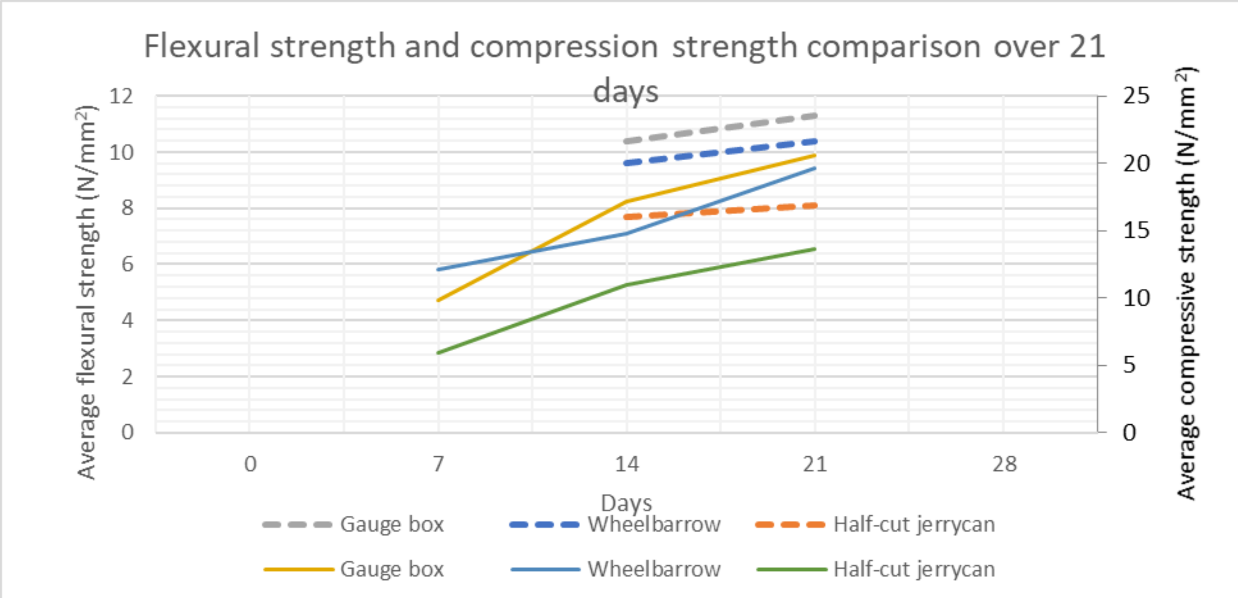

Figure 13: Compressive strength and flexural strength over 21 days

From the combined graph in figure 13 above, compressive strengths and flexural strengths of concrete over the period of 21 days were compared and then the volume batching means were ranked as shown in Table 10 below.

Table 10: Ranking of volume batching means according to their effectiveness

Rank	Volume batching means
1	Gauge box
2	Wheelbarrow
3	Half-cut jerrycan

From Table 10 above, it is observed that the gauge box came first. This is because the concrete batched using the gauge box had the best workability, it had the highest overall compressive strength, and it generally had the highest flexural strength. Therefore, the gauge box is the most effective volume batching means.

The wheelbarrow then came in second. This is because the concrete batched using the wheelbarrow had satisfactory workability, compressive strength and flexural strength. For this reason, in the absence of a gauge box, a wheelbarrow can be employed during volume batching but it should be restricted to minor concrete works.

The half-cut jerrycan then came in last. This is because concrete batched using the half-cut jerrycan had the worst workability; it also generally had the lowest compressive strength, and the lowest flexural strength. For this reason, the half-cut jerrycan should be highly discouraged as a means of batching.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the various studies and investigations made as well as comparisons and results obtained, the following conclusions were made.

1) The means used when volume batching is employed during preparation of concrete has an effect on the workability of concrete as follows.
   - When a gauge box is used, the concrete produced has the best workability shown by the true slump formed during the slump test.
   - When a wheelbarrow is used, the concrete produced has moderately good workability shown by the shear slump formed.
   - When a half-cut jerrycan is used, the concrete produced has the highest workability which is further shown by the collapse slump formed during the slump test.
2) Volume batching means have an effect on the compressive strength whereby the concrete produced using the gauge box has the highest compressive strength, concrete produced using a wheelbarrow is of moderate compressive strength, and the concrete produced using a half cut jerrycan has the lowest compressive strength.
3) The means employed during volume batching have an effect on the flexural strength of concrete whereby, the concrete produced using the gauge box has the highest flexural strength, concrete produced using a wheelbarrow has moderate flexural strength, and the concrete produced using a half cut jerrycan has the lowest flexural strength.
4) The gauge box is the best volume batching means, followed by the wheelbarrow and then lastly the half cut jerrycan. However, the use of half-cut jerrycan as a means of volume batching should be extremely discouraged.

The study was, nevertheless, not void to limitations. These included the following.

1) Only one mix design (C20) was studied. Therefore, further research should be carried out for other various mix designs.
2) The study focused on three volume batching means (gauge box, wheelbarrow, half-cut jerrycan) and yet there are other volume batching means employed during volume batching of concrete such as buckets, headpans, spades among others. Further research should be done in this regard as well.

3) Time constraint; due to the limited time availed for the projects, the researcher was able to carry out the study for 21 days and therefore, further research should be carried out to observe the properties of concrete at 28 days and more.

5.2 Recommendations

1) When using volume batching during preparation of concrete, the gauge box should be employed since it produces the best quality concrete in comparison to other volume batching means. This is mainly because it has a definite volume and therefore, it makes measurement of the proportions of materials for concrete easier and more accurate than the rest. It was also found to be the most cost-effective means.

2) In absence of a gauge box, a wheelbarrow can be employed particularly for minor concrete works since it produces somewhat good quality concrete. However, extra care needs to be taken during batching using a wheelbarrow because it doesn't really have a definite volume and therefore, only experienced people should be the ones to use it in order to ensure that somewhat accurate proportions are obtained.

3) The half-cut jerrycan as a volume batching means should be highly discouraged. This is because it produces concrete of very low strength and therefore, it is bound to endanger the quality of concrete produced in case it is used.

4) Further research should be done with variations in cement and aggregates in order to ascertain the actual ratios which can attain the ideal strength of concrete for each volume batching means. Such findings shall greatly benefit Uganda's construction industry since very many constructors actually employ volume batching during concrete production.

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APPENDICES

Appendix A - Photos of Equipment

Figure 14: Concrete cubes for testing *Source: (Mishra, 2020)*

Figure 15: Cube mold for making test samples *Source: (Mishra, 2020)*

Figure 16: Compression testing machine   Source: TeamCivil (March 6, 2017)

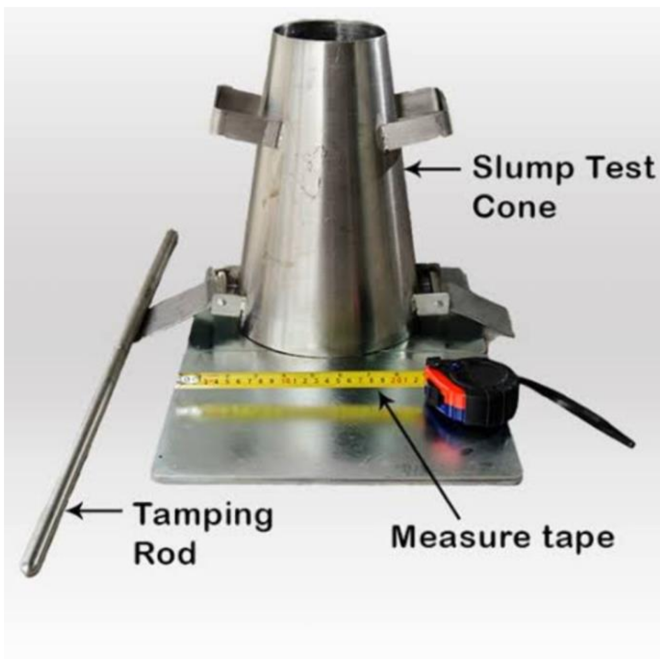

Figure 17: Slump cone test apparatus   Source: www.gharpedia.com

Figure 18: Flexural strength test machine *Source: www.matest.com*

Appendix B – Photos of Activities Undergone During the Research Study

Figure 19: Oiling the moulds that were used for casting the concrete samples

Figure 20: Volume batching using a gauge box

Figure 21: Volume batching using a half-cut jerrycan

Figure 22: Wheelbarrow

Figure 23: Concrete mixer


Figure 24: Casting of concrete samples


Figure 25: Removing samples from moulds

Figure 26: Curing using ponding

Figure 27: Flexural strength test


Figure 28: Compressive strength test

Appendix C – Project Program

YEAR 2021-2022

		JULY				AUGUST				SEPTMBER				OCTOBER				NOVEMBER				DECEMBER				JANUARY			
NO	**ACTIVITY**	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	Preparation																												
2	Proposal writing																												
3	Data collection																												
4	Data Analysis																												
5	Report Compilation																												
6	Report Submission																												
7	Final Presentation																												

Appendix D – Project Budget

Item	Description	Quantity	Rate	Amount
1	stationery	lumpsum		15,000
2	transport	lumpsum		100,000
3	printing	lumpsum		50,000
4	hiring equipment	per day	20,000	100,000
5	aggregates	Lumpsum		150,000
6	sand	lumpsum		70,000
7	cement	3	28,000	84,000
8	labour	per day	10,000	10,000
9	jerrycan	1	7,000	7,000
10	wheelbarrow	1		30,000
11	spade	1		10,000
12	gauge box	1		15,000
	TOTAL			641,000