

Improving Cement Sheet Contraction and Strength Retrogression of Oil Well Using Local Materials (Silica Flour, Egg Shell, Periwinkel Shell, Palm Kernel Fibre Aggregate and Saw Dust)

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doi: <https://doi.org/10.37745/04964>

Published November 11, 2025

Citation: Teminusi Sylvester Anirejuoritse, Uti Lawrence Oghenebrume (2025) Improving Cement Sheet Contraction and Strength Retrogression of Oil Well Using Local Materials (Silica Flour, Egg Shell, Periwinkel Shell, Palm Kernel Fibre Aggregate and Saw Dust), *British Journal of Multidisciplinary and Advanced Studies*,6(6),1-17

Abstract: *This study presents findings from experiments assessing the feasibility of utilizing egg shell powder, sourced from the egg shell, periwinkle, palm kernel fibre and saw dust, for improving cement sheet contraction. Cement slurries serve critical functions, such as facilitating zonal isolation, safeguarding the casing against corrosion, absorbing shock loads encountered during deeper drilling, and preventing blowouts by rapidly establishing a seal. The effectiveness and successful execution of cementing operations heavily rely on specific properties of the slurry, which can be enhanced through the incorporation of various additives. This study focuses on examining the impact of various local additives, including Palm kernel fibre aggregates and Silica sand, on specific properties of cement slurry. The conducted tests revealed that the cement samples mixed with local additives exhibited compressive strengths that ranged from a minimum of 3,359 psi to 11,759 psi, in contrast to the plain class G slurry, which registered an unsuitable strength of 1,600 psi. Additionally, the density measurements were found to be acceptable, falling between 15.3 and 16 ppg. However, the rheological properties and fluid loss characteristics were assessed to be either standard or subpar when compared to the benchmarks established by the American Society for Testing and Materials (ASTM). Upon concluding the experiment, a noticeable difference was noted between the results of the neat class G slurry and those of the additive-mix slurries. Consequently, it was determined that the neat slurry sample served effectively as a fluid loss agent, while all samples, with the exception of the plain slurry, demonstrated satisfactory compressive strengths. Additionally, the palm fibre alone showed sufficient rheological properties; however, with the sole exception of the plain slurry, none of the samples proved to be effective fluid loss agents.*

Keywords: Eggshell, Silica, Palm Kernel, Saw dust, Fibre

INTRODUCTION

Cement serves as the binding agent, a crucial component in construction that facilitates the adherence, setting, and hardening of materials for effective binding (Salehand Eskander, 2020; Glavind, 2009). In its powdered state, it is comprised of a mixture of limestone and clay, combined with sandstones and water (Glavind, 2009). The strength of cement is attained through a chemical reaction with water (Glavind, 2009). It has been observed that Portland pozzolana cement with a grade of 53 possesses a specific gravity of 3.15, which is utilized for creating eggshell concrete (Glavind, 2009). Various tests

conducted on cement include determining specific gravity via Le-Chatelier's principle, assessing fineness through sieve analysis (utilizing a 90 μ sieve), and measuring initial and final setting times with Vicat's apparatus (Glavind, 2009). The strength of cement fundamentally relies on a combination of various materials, egg shell, periwinkle, palm kernel fibre and saw dust, and water. The extensive usage of concrete has led to a depletion of natural resources, and no alternative material fulfills the role of this essential component. Consequently, to meet industrial demands, it is necessary to fully or partially substitute these materials. According to (Prusty and Patro, 2015), agricultural wastes in the form of aggregate in concrete and mortar composites can benefit society towards achieving a sustainable environment and circular economic. Currently, concrete is widely utilized in the construction of large structures such as buildings and bridges. At this time, the construction industry is actively seeking effective and precise ways to utilize waste products that could significantly reduce cement consumption and, ultimately, lower the production costs of concrete (Chinnaraju, et al., 2010). The evolution of crude oil production has significantly advanced since its inception, with the oil and gas sector devising and executing innovative strategies aimed at enhancing production efficiency while simultaneously minimizing the risk of failures at the lowest possible costs. The issue of "Hole Wall Integrity Sustenance" has been addressed through the installation of casing, resulting in an impressive increase of at least 47% in the success rate of these "Casing operations," attributed to the use of cementing techniques (Chong, et al. 2020; Eyankware, et al., 2021). Oil well cementing refers to the technique of injecting cement slurry into the annular space between the casing and the formation wall. The process of cementing an oil well is a crucial aspect of oil drilling operations. At its core, cementing involves creating aqueous cement slurries, displacing them between the casing and the geological formations adjacent to the wellbore, and allowing them to set, which facilitates effective bonding and sealing capabilities (Vasudevan1., et al. 2020; Tan et al., 2018). The overall quality and efficiency of the oil well are significantly influenced by the design of the cement and the method employed during the cementing process (Ishak et al., 2020). The significance of high-quality and efficient cementing cannot be overstated, as it is crucial for maintaining the integrity of the well throughout its lifecycle. Cement is favored as the primary material due to its superior attributes, including the ability to achieve high compressive strength and low permeability, its global availability, cost-effectiveness, and the ease with which it can be modified through the incorporation of additives. These characteristics make it preferable over other technically viable alternatives, such as Epoxy and Polymer elastomers. Pumping cement slurry during drilling operations serves several essential purposes, including but not limited to the following key functions: preventing the migration of fluids between different formations or to the surface, as these fluids can travel through the space between the casing and the formation, ensuring a strong bond between the casing and the surrounding formation, shielding the casing from corrosion that may be induced by formation fluids, and effectively sealing off problematic zones.

Several scholars have carried out strength of cement based on what it makes up. In the research conducted by Afolayan, (2017), concrete is widely utilized across a variety of structural applications. Cement, being the main ingredient of concrete, has seen a surge in demand that has consequently driven up its costs. To alleviate this economic challenge, it is crucial to investigate alternative materials that promote waste management in an environmentally friendly way. This study aims to utilize eggshell powder as a partial substitute for cement. The ratios of eggshell powder are established at 5%, 10%, and 15% of the cement's total weight. The experimental findings reveal that the addition of eggshell powder influences the mechanical characteristics of the concrete; in particular, the split tensile strength decreases with the introduction of eggshell powder, while both compressive and flexural strengths can increase by as much as 15%. In study, Asman, et al., (2017), carried out an experimental analysis to assess how fly ash influences the strength development of mortar, as well as to identify the optimal amount of fly ash to incorporate into mortar mixtures. Their findings indicated that the ideal percentage of fly ash should be 40% of the cement content. Mortar that included a 40% fly ash replacement exhibited a 14% enhancement in compressive strength when compared to ordinary Portland cement (OPC) mortar after

a 90-day curing period. Furthermore, an approximate increase of 8% in tensile strength was also observed.

An eggshell is composed of 94% calcium carbonate (CaCO_3), 1% calcium phosphate ($\text{Ca}_3(\text{PO}_4)_2$), 1% magnesium carbonate (MgCO), and 4% organic matter (Oliveira, et al., 2013; Laca, et al., 2019), which can serve as a substitute for limestone (Shiferaw, et al., 2019). The use of blended cement offers multiple benefits for the environment, economy, and advancements in technology ((Shiferaw, et al., 2019). The chemical makeup of eggshell powder (ESP) closely resembles that of limestone (Chandrasekaran, et al., 2018). Limestone powder functions as a filler in the production of cement, concrete, and bricks (Bonavetti. et al. 2003; Pliya and Cree, 2025; Algin and Turgut, 2008). Substituting cement with ESP enhances the hydration process and provides early strength gains, thereby improving tensile, compressive, and flexural strength (Hamada, et al., 2020; Lothenbach, et al., 2011). The. Consequently, the exploration of reusing ESP in concrete emerged as a viable alternative to direct landfill disposal (Gabol, et al., 2019; Ujim, et al., 2017). Since 1999, ESP has served as a calcium source for the synthesis of calcium phosphates; however, research on its influence on concrete properties remains sparse (Ujim, et al., 2017). A comprehensive investigation was conducted regarding the repurposing of solid waste in construction materials [19]. Annually, the total amount of eggshell waste reaches 10 billion (Ujim, et al., 2017; Faridi and Arabhosseini, 2018). By integrating solid waste into construction practices, a more sustainable environment and building approach can be achieved (Tao, and Huiqing, 2009). The specific objectives of this study are: i) to obtain, prepare, and integrate local additives including Silica flour, Palm kernel fibre aggregates, and Sawdust; ii) to assess the properties of the modified cement after the incorporation of these additives; and iii) to analyze the outcomes in line with API standards

METHODOLOGY

In this study, analyses were conducted under controlled laboratory conditions. To enhance elaboration and facilitate comparative assessments, additional additives—namely, egg shell, snail shell, periwinkle shell, and sawdust—will undergo the same procedural treatment. The samples were procured from a local market, while key materials such as silica sand and Class G cement were sourced from a nearby oil and gas well servicing company, WEAfri Well Services, despite challenges in acquisition. The larger particle samples were individually crushed and ground into a powdered state after being thoroughly dried, followed by sieving with standard ASTM sieves. Conversely, the snail shell and periwinkle shell were sun-dried for a duration of 14 days, after which they were granulated using a ball mill equipped with 20 steel balls, operating at a speed of 2000 revolutions per hour. The resulting granulated particles were subsequently sieved through a 100-micron mesh sieve. All processed sample additives were then stored in airtight

Sample Processing

As outlined in the preceding discussion, this investigation was carried out in a controlled laboratory environment. To improve comprehension and enable comparative evaluation, additional additives—namely egg shell, snail shell, periwinkle shell, and sawdust—will be subjected to the same experimental methodology. The samples were obtained from a local market, while critical materials like silica sand and Class G cement were sourced from WEAfri Well Services, a nearby oil and gas well servicing company. The larger particle samples were meticulously dried before being individually crushed and ground into a fine powder, which was then sieved using standard ASTM sieves. In contrast, the snail shell and periwinkle shell underwent sun-drying for 14 days before being processed into granules with a ball mill, featuring 20 steel balls and operating at a speed of 2000 RPM. Following this, the granulated substances were passed through a 100-micron mesh. All processed additives were stored in airtight containers to maintain their integrity.

Cement Slurry Preparation

The preparation of the cement slurry was conducted utilizing a "Warning blender" (four quartz blender) in accordance with the guidelines specified by A.P.I. The following steps were executed during the slurry preparation procedure: First, 350ml of water (44% B.W.O.C) was accurately measured using a measuring cylinder and subsequently transferred into the mixer, which was securely connected to a suitable power source. The mixer was then operated at a low speed of $4000\text{rpm} \pm 200\text{rpm}$, and within 15 seconds, a 792g blend of cement and additives was introduced without any spillage. Following this, the mixer was adjusted to a high speed of $12000\text{rpm} \pm 500\text{rpm}$ for a duration of 35 seconds, thereby finalizing the slurry preparation. This method was replicated for each of the six additives: palm kernel fibre, silica sand, snail shell, egg shell, periwinkle shell, and sawdust.

Determination of cement slurry properties

Determination of Cement Slurry Volume

For every cement slurry sample comprising of an additive, their generated volume were measured post-preparation. The entirety of the prepared slurry was poured into a measuring cylinder and the readings were recorded.

Determination of Cement Slurry Density

The following outlines the methodology utilized for determining the density of cement slurry: initially, the cement slurry underwent conditioning in an atmospheric consistometer to prepare it for subsequent testing. Once conditioned, the slurry was transferred into the cup of a pressurized mud balance. After pouring, the valve located on the lid was activated, and the lid was then pressed onto the cement-filled cup to remove any excess slurry and trapped air. With the lid securely fastened, a piston pump containing the slurry was employed to apply pressure to the cup. Finally, density measurements were recorded, including values in pounds per gallon, pounds per cubic foot, psi per 1000 feet, and specific gravity readings.

Determination of Cement Slurry Rheological Properties

The procedure for determining the rheological properties of the cement slurry consists of the following steps:

Initially, the cement slurry sample was conditioned in an atmospheric consistometer for an additional 20 minutes after it had reached the desired test temperature, ensuring it was adequately prepared for the analysis.

Next, the slurry sample was introduced into the cup of a 115-volt motor-driven viscometer, filled to the specified mark with minimal delay. Subsequently, the cup was positioned on a tripod, and the viscometer sleeve was immersed in the slurry until it reached the designated mark. The viscometer was then activated at a speed of 300 rpm, and allowed to operate for 15 seconds prior to recording the first reading. Following this, the speed was sequentially decreased to 200 rpm, 100 rpm, 60 rpm, 30 rpm, and finally 3 rpm, with a 15-second pause between each speed change to take the corresponding readings.

Determination of Cement Slurry Compressive Strength

The evaluation of the compressive strength of the sample slurry was conducted using the following methodology:

First, the sample slurry was poured into pre-lubricated cubic molds with dimensions of $2 \times 2 \times 2$ inches

to ensure easy removal of the cement after setting. To remove any air bubbles trapped within the mixture, a spatula was utilized in a dipping motion. Subsequently, the molds were allowed to remain undisturbed for a duration of 48 to 72 hours to ensure adequate setting before they were extracted. After extraction, the sample cubes were systematically placed on the lower holder of the Carver Compression Testing Machine, Model 3851-0.

The lever was then operated in an upward motion to secure the specimen, thereby applying the necessary load and pressure. This process continued until the first crack was detected to document the initial/crack pressure, and further proceeded until complete failure occurred to ascertain the final/collapse pressure.

Determination of Cement Slurry Fluid Loss

The free fluid test was performed with fresh slurry that had not been subjected to any previous evaluations. The procedure involved several steps: First, the filter press designated for the test was pressurized to 100 psi to enable a portion of the fluid to flow through the testing apparatus. The holding cup was then filled with slurry to three-quarters of its total capacity. Next, the O-Ring was lubricated and correctly positioned. The filter paper was dampened and properly arranged. Afterward, the cup unit was securely tightened, and the cartridge was fastened, allowing the integrated pin to puncture it. This puncture released the CO_2 , which acted as the displacing agent. Once the pressure was released and the cup compartment was detached, the filter cake was removed, and its thickness was measured using a vernier caliper.

Results

The outcomes of the various tests conducted on the cement slurry samples, each incorporating a unique additive, have been documented as presented in the following section.

Cement Slurry Volume Result

Table 1 to 12, illustrates the volumes produced from the formulation of cement slurry corresponding to each additive utilized.

Table 1: Cement slurry volume result

Slurry components (Cement, additives, and water)	Generated slurry volume (ml)
792g of class G cement + 350ml of water	600
752.4g of cement + 39.6g of palm kernel fibre aggregate + 350ml of water	600
633.6g of cement + 158.4g of silica sand + 350ml of water	600
633.6g of cement + 158.4g of egg shell + 350ml of water	600
633.6g of cement + 158.4g of snail shell + 350ml of water	600
633.6g of cement + 158.4g of periwinkle shell + 350ml of water	600
752.4g of cement + 39.6g of saw dust + 350ml of water	600

Cement Slurry Density Results

The density results for the cement slurry samples are shown in Table 2

Table 2: Cement Slurry Density Result

SAMPLE TYPE	DENSITY (ppg)	DENSITY (lb/cuft)	DENSITY (Psi/1000ft)	SPECIFIC GRAVITY
2Plain slurry (Control)	15.5	116	801	1.36
Cement + Palm kernel fibre aggregates	15.4	115	800	1.85
Cement + Silica sand	15.85	119	820.5	1.90
Cement + Egg shell	15.3	114.5	800	1.84
Cement + Snail shell	15.5	116	1000	1.86
Cement + Periwinkle shell	16	119.5	830.1	1.92
Cement + saw dust	15.5	116	810	1.86

Cement Slurry Rheological Properties Results

The results of the rheological test carried out on the slurry samples are shown in Tables 3, 4, 5, 6, 7, 8, and 9, respectively:

Table 3: Plain slurry (Control) rheological readings

RHEOLOGICAL READINGS	600 RPM	300 RPM	200 RPM	100 RPM	6 RPM	3 RPM
DIAL DOWN	97	64	50	42	23	142
DIAL UP	92	61	52	41	19	14

Table 4: Palm kernel fibre aggregate slurry rheological readings

RHEOLOGICAL READINGS	600 RPM	300 RPM	200 RPM	100 RPM	30 RPM	6 RPM	3 RPM
DIAL DOWN	68	56	843	30	28	23	18
DIAL UP	47	40	30	24	24	19	18

Table 5: Silica sand slurry rheological readings

RHEOLOGICAL READINGS	300 RPM	200 RPM	100 RPM	60 RPM	30 RPM	6 RPM	3 RPM
DIAL DOWN	93	91	78	77	74	38	27
DIAL UP	99	92	78	72	60	36	27

Table 6: Egg shell slurry rheological readings

RHEOLOGICAL READINGS	300 RPM	200 RPM	100 RPM	60 RPM	30 RPM	6 RPM	3 RPM
DIAL DOWN	138	137	124	112	113	54	40
DIAL UP	148	124	114	115	89	34	40

Table 7: Periwinkle shell slurry rheological readings

RHEOLOGICAL READINGS	300 RPM	200 RPM	100 RPM	60 RPM	30 RPM	6 RPM	3 RPM
DIAL DOWN	113	105	93	89	82	42	31
DIAL UP	114	100	90	83	75	36	31

The rheological properties of periwinkle shell slurry are predominantly examined within the framework of drilling fluids and cement slurries, serving as an additive to enhance characteristics such as fluid loss

control, pH levels, and overall strength. Typically, rheological assessments encompass the measurement of viscosity, gel strength, and yield point through the use of a viscometer across a range of shear rates, enabling an evaluation of the slurry's flow behavior under various conditions. Findings indicate a decrease in both viscosity and gel strength when compared to conventional additives.

Table 8: Saw dust slurry rheological readings

RHEOLOGICAL READINGS	300 RPM	200 RPM	100 RPM	60 RPM	30 RPM	6 RPM	3 RPM
DIAL DOWN	310	224	138	95	57	32	24
DIAL UP	245	182	110	75	50	25	24

Table 9: Snail shell slurry rheological readings

RHEOLOGICAL READINGS	300RPM	200RPM	100RPM	6RPM
DIAL DOWN	164	149	127	46
DIAL UP	165	149	128	42

Slurries made from snail shells display characteristics of non-Newtonian fluids. The rheological properties, such as viscosity, gel strength, and yield point, have been found to rise with increasing concentrations of snail shell powder. This behavior, characterized by shear-thinning, makes them ideal for uses in drilling muds and other composite materials. To quantify these properties, researchers employ a rotary viscometer, which allows them to record dial readings at different revolutions per minute (rpm). This process aids in analyzing particle interactions and enhancing processing efficiency, a methodology also observed in studies focused on various mineral slurries and suspensions.

Cement Slurry Compressive Strength Results

The results of the compressive strength tests are represented in the Table 10.

Table 10: Compressive Strength Results

TEST SAMPLE ADDITIVES	FIRST TEST (Metric tons)		SECOND TEST (Metric tons)		AVERAGE READING (Metric tons)	
	CRACK	COLLAPSE	CRACK	COLLAPSE	CRACK	COLLAPSE
PLAIN CEMENT (Control)	3.9	4.4	3.9	4.4	3.9	4.4
P.K.F.A	7.5	8.5	7.5	8.5	7.5	8.5
SILICA SAND	4	6.2	6	7	5	6.6
EGG SHELL	4	8.5	6	8.2	5	8.35
SNAIL SHELL	5	8.5	5.5	8	5.25	8.25
PERIWINKLE SHELL	5.5	6	4.5	6.2	5	6.1
SAW DUST	1	7.5	2	7.5	1.5	7.5

Cement Slurry Fluid Loss Test Results

The results for the fluid loss test carried out on the slurry are as shown in the Table 11 below:

Table 11: Fluid loss test results

SLURRY ADDITIVES	FLUID LOSS (ml/30mins)	FILTER CAKE THICKNESS (mm)
Plain slurry (Control)	1.4	0.45
Palm kernel fibre aggregates	65	21.1
Silica sand	<65	<21.1
Egg shell	<65	<21.1
Snail shell	<65	<21.1
Periwinkle shell	<65	<21.1
Saw dust	~65	~21.1

The result in Table 11, showed that there was a difference in thickness of the filter cake of the cement slurry due to the difference in fluid loss. The measured thickness ranges from 0.45 to 21.2 mm. Further deduction from Table 11, revealed that Palm kernel fibre aggregate has the filter cake thickness of 21.1 mm

Calculations

I. Plastic Viscosity = (Reading at 600rpm – Reading at 300rpm)

For plain slurry;

$$\text{Plastic viscosity} = (62.5 - 41.5)1.5 = (21)1.5 = 31.5$$

For silica sand;

$$\text{Plastic viscosity} = (96 - 78)1.5 = (18)1.5 = 27\text{cp}$$

For palm kernel fibre;

$$\text{Plastic viscosity} = (57.5 - 36.5)1.5 = (21)1.5 = 31.5\text{cp}$$

For Egg shell;

$$\text{Plastic viscosity} = (143 - 119)1.5 = (24)1.5 = 36\text{cp}$$

For Snail shell;

$$\text{Plastic viscosity} = (164.5 - 127.5)1.5 = (37)1.5 = 55.5\text{cp}$$

For Periwinkle shell;

$$\text{Plastic viscosity} = (113.6 - 91.5)1.5 = (22.1)1.5 = 33\text{cp}$$

For Saw dust;

$$\text{Plastic viscosity} = (277.5 - 124)1.5 = (153.5)1.5 = 230.26\text{cp}$$

II. Yield point = Reading at 300rpm – Plastic viscosity

For plain slurry;

$$\text{Yield point} = 41.5 - 31.5 = 10\text{lb}/100\text{sqft}$$

For silica sand;

$$\text{Yield point} = 78 - 27 = 51\text{lb}/100\text{sqft}$$

For palm kernel fibre;

$$\text{Yield point} = 36.5 - 31.5 = 5\text{lb}/100\text{sqft}$$

For Egg shell;

$$\text{Yield point} = 119 - 36 = 83\text{lb}/100\text{sqft}$$

For Snail shell;

$$\text{Yield point} = 127.5 - 55.5 = 72\text{lb}/100\text{sqft}$$

For Periwinkle shell;

$$\text{Yield point} = 91.5 - 33 = 58.5\text{lb}/100\text{sqft}$$

For saw dust;

$$\text{Yield point} = 124 - 230 = -106\text{lb}/100\text{sqft}$$

II. Apparent viscosity = Reading at 600rpm/2

For plain slurry;

Apparent viscosity = $62.5/2 = 31.25\text{cp}$

For Silica sand;

Apparent viscosity = $96/2 = 48\text{cp}$

For Palm kernel fibre;

Apparent viscosity = $57.5/2 = 28.75\text{cp}$

For Egg shell;

Apparent viscosity = $143/2 = 71.5\text{cp}$

For Snail shell;

Apparent viscosity = $164.5/2 = 82.25\text{cp}$

For Periwinkle shell;

Apparent viscosity = $113.5/2 = 56.75\text{cp}$

For Saw dust;

Apparent viscosity = $277.5/2 = 138.75\text{cp}$

The above calculations for the plastic viscosity, yield point and apparent viscosity are represented in the Table 12:

Table 12: Results for Plastic viscosity, Apparent Viscosity and Yield Point.

SAMPLE TYPE	PLASTIC VISCOSITY (cp)	YIELD POINT (lb/100sqft)	APPARENT VISCOSITY (cp)
Plain Slurry (Control)	31.5	10	31.25
Cement+Palm Kernel Fibre Aggregate	31.5	5	28.75
Cement+Silica Sand	27	51	48
Cement+Egg Shell	36	83	71.5
Cement+Snail Shell	55.5	72	82.25
Cement+Periwinkle Shell	33	58.5	56.75
Cement+Saw Dust	230	-106	138.75

DISCUSSION

Evaluation of the cement slurry volume

The analysis of the slurry produced after preparation revealed that all samples containing the test additives resulted in a slurry volume of 600ml. According to API Specifications, a combination of 350ml (349.8 g) of water (44% B.O.C) and a total of 792 g of Cement and additive (comprising 633.6g of Class G Cement and 158.4g of additive) was utilized for the Silica, egg shell, snail shell, and periwinkle shell samples. However, this formulation did not extend to the palm kernel fibre aggregates and the Saw dust additive mixture, as the initial 4:1 ratio of solid components failed to produce a slurry yield when subjected to the high-speed mixer.

Following extensive observation, the 792 g formulation was revised to incorporate a cement-additive ratio of 19:1 (comprising 95% or 752.4 g of Class G Cement and 5% or 39.6 g of additives), resulting in a successful slurry yield. It was observed that silica sand, eggshell, snail shell, and periwinkle shell conformed to the API specifications for standard laboratory cement slurry preparation. However, the palm fibre aggregates and sawdust exhibited an increased capacity for solvent absorption, necessitating

adjustments to either the mix water or the solute ratio to create an effective test sample slurry. For the plain slurry, a straightforward combination of 792 g of Class G cement and 350 ml of water was utilized.

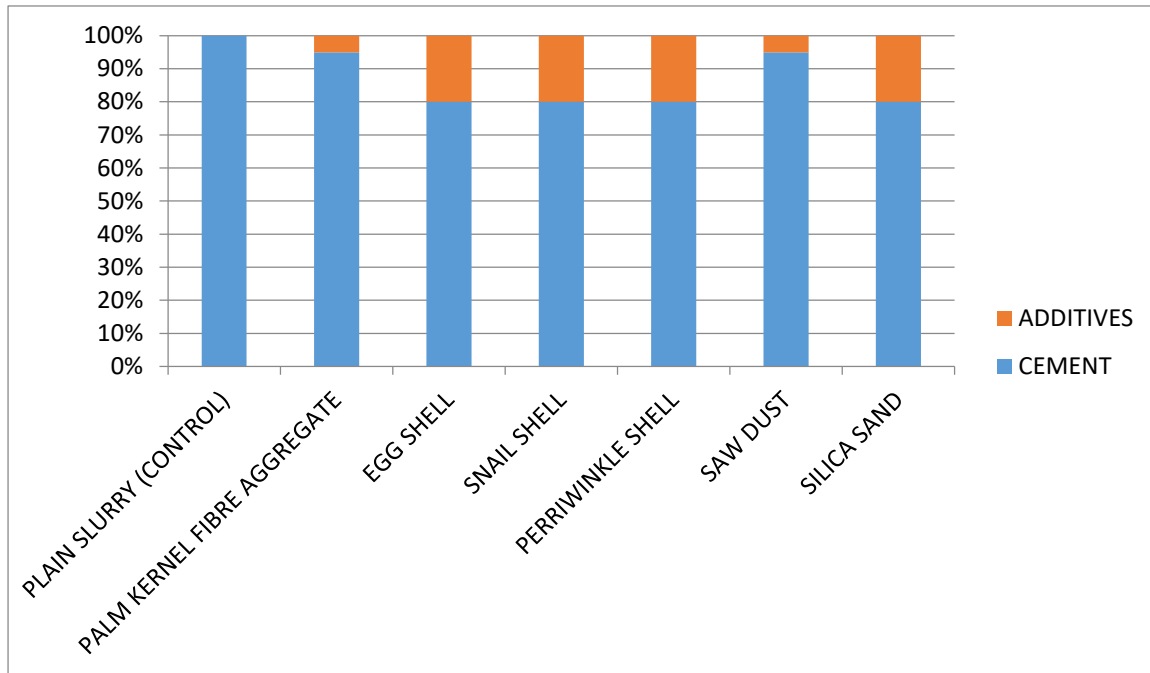


Fig. 1: Graphical illustration of different cement-mix for each sample slurry

An Analysis of the Density of the Obtained Cement Slurry

According to the laboratory analysis results presented in Table 3, the slurry samples exhibit specific weights ranging from 15.3 to 16 ppg, closely aligning with the standard value of 15.85 ppg and consistently falling within the acceptable tolerance range of 14.7 to 16 ppg. The specific gravities recorded for Plain Slurry, P.K.F.A, Egg Shell, snail shell, periwinkle shell, silica sand, and sawdust were 1.36, 1.85, 1.84, 1.86, 1.92, 1.90, and 1.86, respectively, as illustrated in Fig. 2. However, these measurements are considerably lower than the API specification of 3.15. The lower specific gravity values observed in the test samples, in comparison to the API standard, may compromise the quality and integrity of the cement sheath, indicating that a strengthening agent might be necessary.

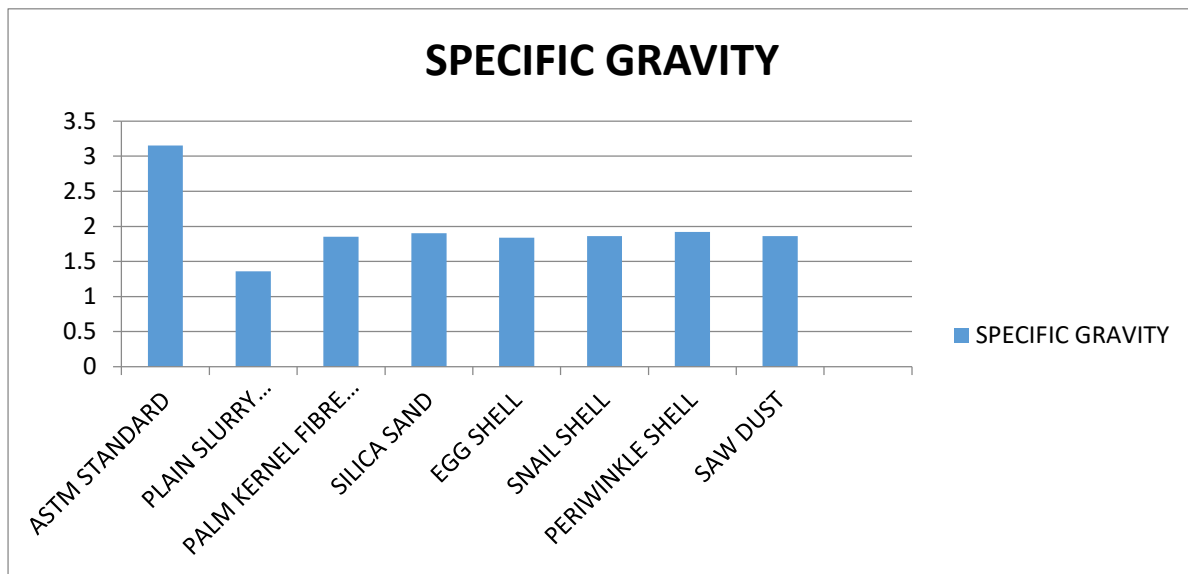


Fig. 2: Graph of Specific Gravity

Evaluation of the acquired rheological characteristics

Table 13 presents the viscometer measurements for the evaluated slurries, encompassing both unmodified and additive-enhanced samples, alongside their respective viscosities and yield points. These parameters are influenced by the slurries' rheological characteristics, which are distinctly represented by the dial ratios. In addition, a trend can be observed in Tables 13 and 14 that demonstrates the relationship between dial ratio variations and the different viscometer speeds employed during the analysis of the sample slurries.

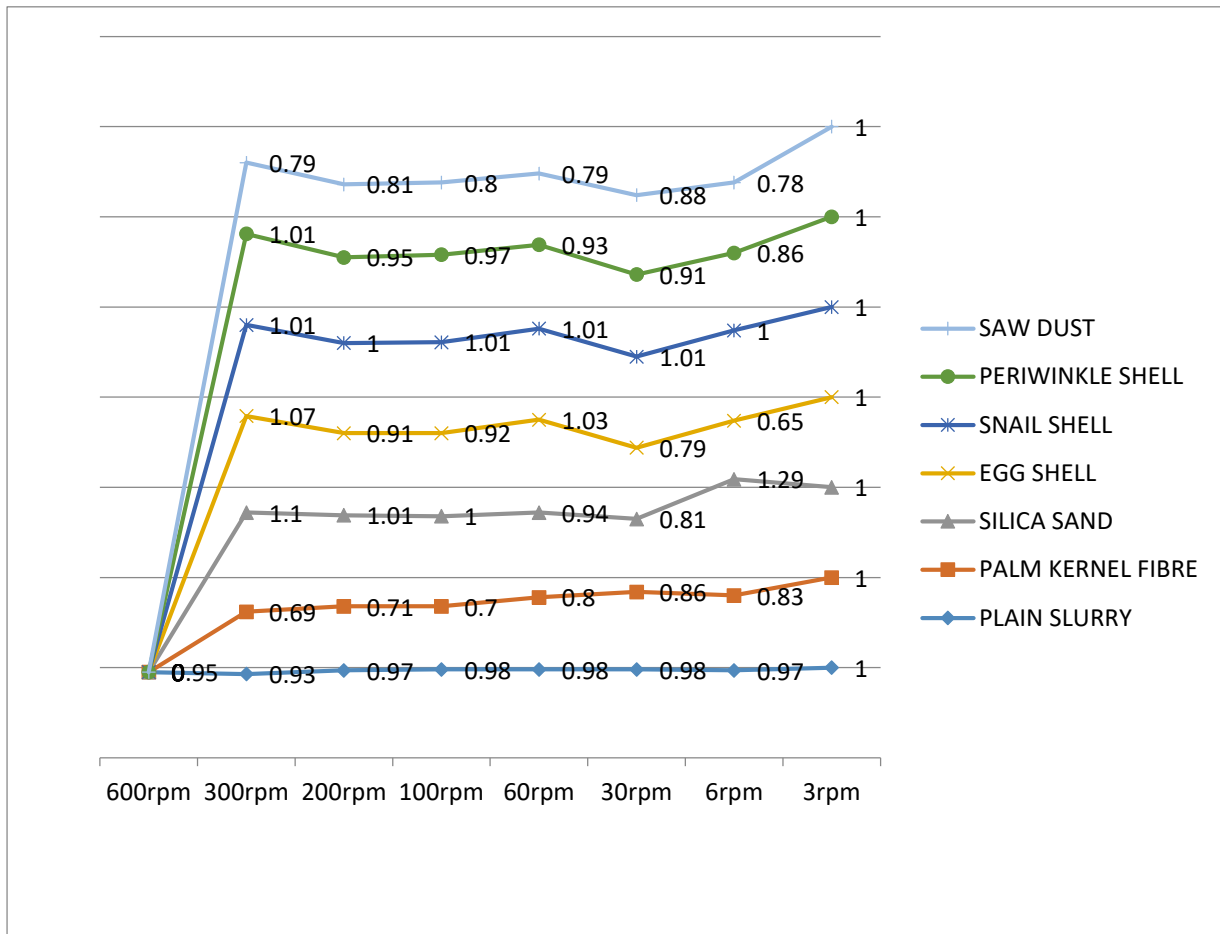


Fig. 3: 4.3:-Test Slurry Dial ratio Trend

Analysis of Tables 1, 2, 3, 5, 6, 7, and 9 indicated that the dial ratios of the viscometer outputs for the test slurries, the plain slurry, and snail shell exhibited minimal variation. This suggests that the viscometer readings for these additives demonstrate a greater level of consistency.

Table 13: Table of test slurry viscometer readings

SAMPLE TYPE	DIAL SPEED (rpm)	DIAL UP	DIAL DOWN	DIAL RATIO	APPARENT VISCOSITY	PLASTIC VISCOSITY	YIELD POINT
Plain slurry (Control)	600	92	97	0.95	31.25	31.5	10
	300	61	64	0.93			
	200	52	50	0.97			
	100	41	42	0.98			
	6	19	23	0.97			
	3	14	14	1.00			
Palm kernel fibre aggregate	300	47	68	0.69	28.75	31.5	5
	200	40	56	0.71			
	100	30	43	0.70			
	60	24	30	0.8			
	30	24	28	0.86			
	6	19	23	0.83			

	3	18	18	1.00			
Silica sand	300	99	93	1.10	48	27	51
	200	92	91	1.01			
	100	78	78	1.00			
	60	72	77	0.94			
	30	60	74	0.81			
	6	36	28	1.29			
	3	27	27	1.00			
Egg shell	300	148	138	1.07	71.5	36	83
	200	124	137	0.91			
	100	114	124	0.92			
	60	115	112	1.03			
	30	89	113	0.79			
	6	34	54	0.65			
	3	40	40	1.00			
Snail shell	300	165	164	1.01	82.25	55.5	72
	200	149	149	1.00			
	100	128	127	1.01			
	6	42	42	1.00			
Periwinkle shell	300	114	113	1.01	56.75	33	58.5
	200	100	105	0.95			
	100	90	93	0.97			
	60	83	89	0.93			
	30	75	82	0.91			
	6	36	42	0.86			
	3	31	31	1.00			
Saw dust	300	245	310	0.79	138.75	230.25	-106
	200	182	224	0.821			
	100	110	138	0.80			
	60	75	95	0.79			
	30	50	57	0.88			
	6	25	32	0.78			
	3	24	24	1.00			

The aforementioned ranges are designed to guarantee that cement slurries possess appropriate flow characteristics for successful placement and zonal isolation during well cementing activities. However, as indicated in Table 13, with the sole exception of the slurry utilizing palm kernel fibre aggregate, none of the other additive combinations met the API specifications for all three tests (plastic viscosity, yield point, and apparent viscosity). This suggests that the slurry incorporating palm fibre aggregate will demonstrate effective flow, whereas the mixtures containing eggshell, snail shell, and silica, which fall short in one of the three essential properties, will exhibit reduced flow efficiency. Furthermore, the sawdust mixture, which deviates significantly from the required ranges for plastic viscosity, yield point, and apparent viscosity, is not advisable for use.

Evaluation of the determined compressive strength

The findings from the compressive strength test are presented in Table 9.

Table 14: Minimum Standard Compressive Strength against resultant test fracture capacities.

TEST SLURRY SAMPLES	MINIMUM COMPRESSIVE STRENGTH (Psi)	COMPRESSIVE STRENGTH (MPa)	COMPRESSIVE STRENGTH (Metric Tons)
API STANDARD VALUES	3000	20.7	1.34
Palm Kernel Fibre + Cement	16,679	115.09	7.45
Silica Sand + Cement	11,200	77.28	5
Egg Shell + Cement	11,200	77.28	5
Snail Shell + Cement	11,759	77.28	5
Periwinkle Shell + Cement	3,359	81.14	5.25
Saw dust + Cement	11,200	77.28	5

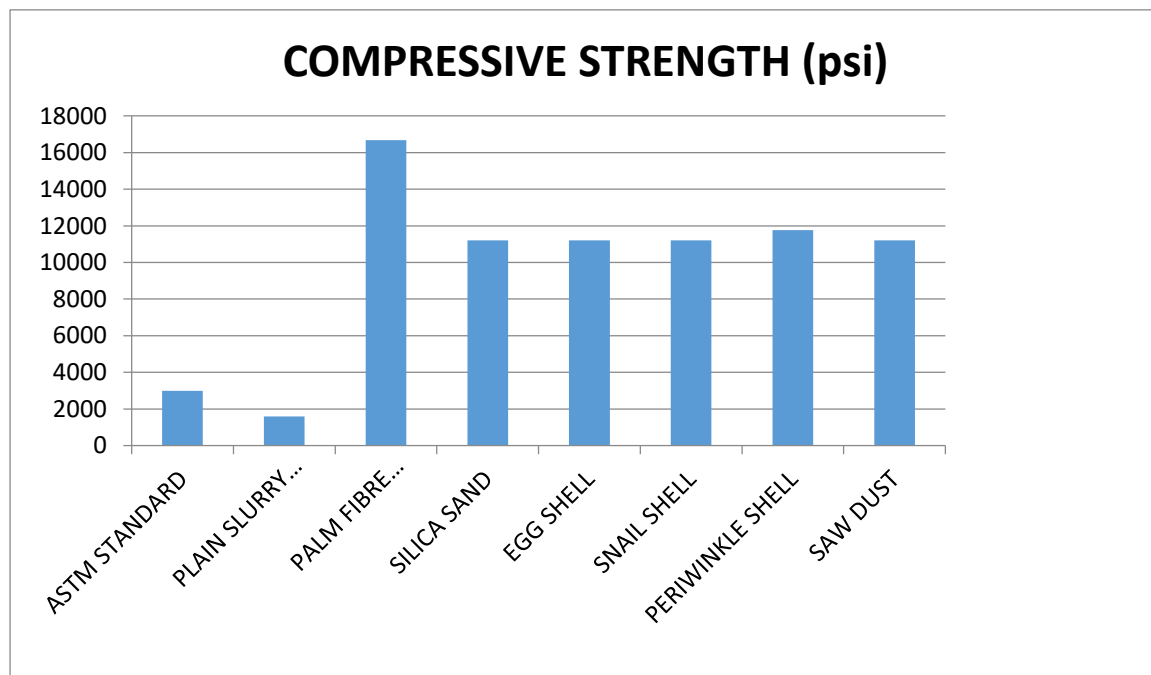


Fig. 4: Test slurry Compressive Strength

Figure 4 presents a bar chart illustrating the compressive strengths of the sample slurries. Analyzing the data from Figures 1 through 4, it is evident that the tested slurries possess adequate compressive strength to endure cement collapse pressure, as they surpass the minimum slurry compressive strength stipulated by ASTM Standards, with the exception of the plain slurry.

Evaluation of the fluid loss results obtained.

The fluid loss results obtained for the palm kernel fibre aggregate revealed that the slurry in question demonstrated a significant fluid loss of 65ml over 30 minutes, surpassing the ASTM limit of

‘50ml/30mins or less.’ This indicates that palm fibre is not an effective fluid loss control agent. Furthermore, the resultant filter cake significantly exceeds the ASTM specification range of 1.6 to 3.2mm, attributable to the excessive fluid loss. After thoroughly examining the compressive strength data presented in Table 9, considering the mixing ratios utilized in the slurry formulation, and acknowledging the pending evaluations of other samples, it is posited that the sawdust is likely to exhibit a fluid loss value near 65ml, while the additional test additives are expected to produce fluid loss values below 65ml.

CONCLUSION

To satisfy the ever-growing infrastructure demands of society, the use of cement has surged dramatically. This rapid adoption of cement within the construction sector has led to a considerable depletion of essential resources such as sand and coarse aggregates. Moreover, cement is susceptible to various challenges, including natural disasters, supply shortages, and gas leaks, all of which contribute to its deterioration. The examination of the slurry generated post-preparation indicated that every sample incorporating the test additives yielded a slurry volume of 600ml. Furthermore, the fluid loss measurements for the palm kernel fibre aggregate disclosed that the slurry exhibited a notable fluid loss of 65ml within a span of 30 minutes, exceeding the ASTM threshold of '50ml/30mins or less.' This finding suggests that palm fibre does not serve as an efficient fluid loss control agent. Following a thorough evaluation of the results obtained from the analysis of specific properties of the cement slurry formulated with local additives, including palm kernel fibre Aggregates and Silica Sand, it was determined, in accordance with API and ASTM standards, that Palm fibre serves effectively as a bonding agent. Additionally, all of the tested additives demonstrate suitability as weighting agents and can adequately endure collapse pressures in low to medium pressure environments. It is noteworthy that, aside from sawdust, these additives exhibit medium to high flow efficiency attributed to their viscosity and yield points.

Recommendation

In light of the findings from this research and in accordance with the standards set forth by the American Petroleum Institute, as well as acknowledging the present limitations, it is advisable to conduct additional analyses and experiments under varied conditions. The test results indicate that the local additives, when used in slurry formation, demonstrate a yield that could be enhanced through modifications or by blending with established standard additives, potentially yielding superior outcomes. Therefore, it is suggested that further experiments be undertaken to substantiate the assertions made in the discussion section of this study across different conditions. Moreover, it would be prudent to investigate other local materials, as this could lead to the discovery of a readily available substitute for standard additives at a reduced cost.

REFERENCES

- Afolayan J O (2017). Experimental Investigation of the Effect of Partial Replacement of Cement with Eggshell Ash on the Rheological Properties of Concrete” International Journal of Engineering and Applied Sciences (IJEAS),1:(12).
- Asman Afizah S N Salinah Dullah , Janice Lynn Ayog, Adriana Amaludin¹, Hassanel Amaludin, C. H. Lim , and Aslina Baharum (2017). Mechanical Properties of Concrete Using Eggshell Ash and Rice Husk Ash As Partial Replacement Of Cement” MATEC Web of Conferences 103, 01002 (2017) DOI: 10.1051/mateconf/ 201710301002 ISCEE 2016
- Al-Zahrani, M.A., Nasi-El-Din, H.A. (2012). The effect of fluid loss additives on cement slurry performance.

- Al-Yami, A. S., Nasr-El-Din H. A., AlHumaidi A. (2009). An Innovative Cement Formula to Prevent Gas Migration Problems in HPHT Wells. Presented at SPE International Symposium on Oilfield Chemistry held in The Woodlands, Texas, U.S.A. SPE 120885
- API RT 10B (1997). *Recommended practice for testing well cements*.
- Arinkoola, A. O., Salam, K. K., Alagbe, S. O., Afolayan, A. S., Salawudeen, T. O., Jimoh, M. O., Duru, I. U., Hammed, O. J. and Adeosun, T. A. 2021. Influence of Metakaolin and nano-clay on compressive strength and thickening time of class G oil well cement. *Songklanakarin. J. Sci. Technol.* 43 (1), 118–126
- American Petroleum Institute (1992). API specifications for oil well cement and cement additives. New York NY.
- American Petroleum Institute (2005). *Specification for cement and materials for well cementing* (23rd edition). Washington DC: API, p. 271
- Algin, H.M., Turgut, P. (2008). Cotton and limestone powder wastes as brick material, *Constr. Build. Mater.* 22 (6): 1074–1080.
- ASTM (2000). *C150-97a, Standard specification for Portland cement*. West Conshohocken, Pennsylvania: ASTM International.
- Attah, I. C., Etim, R.K. and Ekpo, D. U. (2018). Behaviour of periwinkle shell ash blended cement concrete in sulphuric acid environment. *Nigerian Journal of Technology*. Vol. 37, No. 2, pp.315–321.
- BS EN 197 – 1- 2009. *Cement Composition, Specification and Conformity Criteria for Common cements*. London, British Standard Institution.
- B2onavetti, V. et al. (2003). Limestone filler cement in low w/c concrete: a rational use of energy, *Cem. Concr. Res.* 33 (6):865–871.
- Calosa, W. (2010). Well Integrity Issues in Malacca Strait Contract Area. Paper Presented at the SPE Oil and Gas India Conference and Exhibition. Mumbai, India.
- Chandrasekaran, V., Vasanth, M., Thirunavukkarasu, S. (2018). Experimental investigation of partial replacement of cement with glass powder and eggshell powder ash in concrete, *Civ. Eng. Res. J.* 5:1–9.
- Chinnaraju K, Subramanian K and Senthil Kumar S. R. R. (2010). *Structural Concrete*, Thomas Telford, 1464- 4177.
- Chong, B.W., Rokiah, O., Ramadhansyah, P.J., Doh, S.I., Li, X. (2020). Properties of concrete with eggshell powder: A review, *Physics and Chemistry of the Earth*, doi: <https://doi.org/10.1016/j.pce.2020.102951>
- Eyankware, M. O., Ogwah, C. Ike, J.C. (2021). A synoptic review of mineralogical and chemical characteristics of clays in the southern part of Nigeria. *Research in Ecology*, DOI: <https://doi.org/10.30564/re.v3i2.3057>.
- Faridi, H., Arabhosseini, A. (2018). Application of eggshell wastes as valuable and utilizable products: a review, *Res. Agric. Eng.* 64 (2) (2018) 104–114.
- Gabol, N.A. et al., (2019). Analysis of eggshell powder as a partial replacing material in concrete, *Int. J. Mod. Res. Eng. Manag.* 2: 9.
- Glavind, M. (2009). Sustainability of cement, concrete and cement replacement materials in construction. in *Sustainability of construction materials*, Elsevier, 120–147.
- Hamada, H.M. et al., (2020). The present state of the use of eggshell powder in concrete: a review, *J. Build. Eng.* 32: 101583.
- Hruthik T., Bharath K., Kumar S., Chandana A., Yashwanth Y. (2022). Experimental Investigation of Egg Shell Powder as Partial Replacement with Cement in Concrete. *Turkish Journal of Computer and Mathematics Education*, 13(03); 1313- 1323
- Ishak, M. Y, Zamani, M. N. (2020). Eggshell as the partial replacement of Portland cement in the production of concrete IOP Conf. Series: Materials Science and Engineering 849; 01203.

- Laca, A., Laca, A., Díaz, M. (2019). Eggshell waste as catalyst: a review, *J. Environ. Manag.* 197 (2017) 351–359. [11] N. Shiferaw, et al., Effect of eggshell powder on the hydration of cement paste, *Materials* 12 (15):2483.
- Lothenbach, B., Scrivener, K., Hooton, R. (2011). Supplementary cementitious materials, *Cem. Concr. Res.* 41 (12) (2011) 1244–1256.
- Mtallib M. O. A., Rabi A. (2009). Effect of Eggshells Ash on the Setting Time of Cement. *Nigerian Journal of Technology*, 28(2): 29-38.
- Oliveira, D., Benelli, P., Amante, E. (2013). A literature review on adding value to solid residues: egg shells, *J. Clean. Prod.* 46 (2013) 42–47.
- Saleh, H.M., Eskander, S.B. (2020). Innovative cement-based materials for environmental protection and restoration. in *New materials in civil engineering*, Elsevier, pp. 613–641.
- Sathanantham T., Dinesh N., Ramesh Kumar R., Arunachalam., Chandra Sekar., Gowtham P. (2014), Partially Replacement of Fine Aggregate by Rice Husk and Eggshell in Concrete. *International Journal of Innovative research and studies*, 3(1): 444-460.
- Shiferaw, N. et al., (2019). Effect of eggshell powder on the hydration of cement paste, *Materials* 12 (15) (2019) 2483.
- Parthasarathi N. (2017). Experimental Study on Partial Replacement of Cement with Egg Shell Powder and Silica Fume, *10(2): 442 – 449*.
- Pliya, P., Cree, D. (2015). Limestone derived eggshell powder as a replacement in Portland cement mortar, *Constr. Build. Mater.* 95:1–9.
- Tao, X., Huiqing, P.(2009). Formation cause, composition analysis and comprehensive utilization of rare earth solid wastes, *J. rare earths* 27 (6): 1096–1102.
- Tan YY, Doh SI, Chin SC. (2018). Eggshell as a partial cement replacement in concrete development. *Magazine of Concrete Research*, 2018 70(13):662670
- Ujin, F., Ali, K.S., Hanur Harith, Z.Y. (2017). The effect of eggshells ash on the compressive strength of concrete. in *Key Engineering Materials*, Trans Tech Publ.,2017.
- Vasudevan1, G, Wei, S. C. (2020). Utilization of Eggshell Powder (ESP) as Partial Replacement of Cement Incorporating Superplasticizer, *IOP Conference Series: Materials Science Engineering* 840, 012016