COMPRESSIVE STRENGTH OF CONCRETE WITH PARTIAL REPLACEMENT OF AGGREGATES WITH GRANITE POWDER AND COCKLE SHELL

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Abstract: Construction materials are being exploited by mankind posing a risk of their sustainability. On the other hand, many industries are producing waste by-products and their safe disposal is a major challenge to engineers and environmentalists. Identifying waste materials that resemble in properties with some ingredient of concrete can solve this problem to some extent. The aim of this study is to determine the feasibility of utilising two industrial by-products as a replacement of both fine aggregate and coarse aggregate. Granite powder and cockle shell are adopted as partial replacements to fine and coarse aggregate respectively. It is concluded from the study that maximum strength is attained with a combination of granite powder and cockle shell at 20% and 15% partial replacements of fine and coarse aggregate respectively for M30 grade Concrete. The compressive strength for 28 days at these combinations is 43.7 MPa which is 43.75% higher than that of conventional concrete.

Keywords: *Sustainability, non-renewable, industrial wastes, cockle shell, granite powder.*

1.0 Introduction

About 70% of concrete is aggregate which a stressed natural resource. On the other hand, rapid industrialisation is leading to the problem of safe waste disposal. Identifying wastes that have properties close to that of conventional aggregates and establishing their feasibility for partial use in concrete is the need of the hour.

The present study is aimed at developing a concrete using the granite scrap, an industrial waste of Quarries as a partial replacement material for the fine aggregate and cockle shell, a waste by-product of fisheries industry, as partial replacement of course aggregate. This not only reduces the cost of construction but also helps in overcoming the environmental problems of the region associated with disposal of granite powder and cockle shell.

2.0 Literature Review

The global consumption of natural river sand is very high due to its extensive use in concrete. In particular, the demand for natural river sand is quite high in developed countries owing to infrastructural growth. The non-availability of sufficient quantity of ordinary river sand for making cement concrete is affecting the growth of construction industry in many parts of the country. Recently, Tamil Nadu government (India) has imposed restrictions on sand removal from the river beds due to its undesirable impact on the environment. On the other hand, the granite waste generated by the industry has accumulated over the years. Only insignificant quantity has been utilised and the rest has been dumped unscrupulously resulting in pollution problems. With the enormous increase in the quantity of waste needing disposal, acute shortage of dumping sites, a sharp increase in the transportation and dumping costs, there is a need for effective utilisation of this waste.

A part of the research towards producing a new concrete material stems out from two factors presented by two different industries in Malaysia. They are the growing needs for construction trade and the by-product of cockle shell trade. The continuously growing construction industry is a threat to the sustainability of natural aggregates in the future. This would increase the cost of concrete material. This fact has been addressed by researchers who highlighted that the natural resources decrease while the demand for aggregate to be used in concrete production increases (Hanifi *et al.* 2007; Alshahwany, 2011). Anticipating this issue, various types of waste materials such as oil palm shell, (Mannan and Ganapathy, 2004) periwinkle shell (Falade *et al*. 2010), recycled coarse aggregate (Wai *et al*. 2012) and others have been investigated for their potential to be used as partial coarse aggregate replacement material in concrete production. However, these concretes have low workability because of the size, shape and texture of the shells used (Muthusamy and Sabri, 2012).

The availability of cockles, marine bivalve mollusks (which is an important protein source in the South East Asian region) is one of the factors that boosts the cockle trade in Malaysia. It has been highlighted by Awang-Hazmi (2007), Peng-Lim (2011) and Boey *et al*. (2011) that active cockle trade has led towards the generation of an abundant waste shell. The shells that are dumped and left untreated caused an unpleasant smell and disturbing view to the surroundings. Mohammad *et al*. (2012) conducted studies on the decomposition of calcium carbonate in cockle shell. He also opined that the rapid increase in cockles production (evident from the increase in the retail value of cockles by 33.53% in a year) is expected to increase the availability of cockle shell as waste in near future and will, in turn, pose a negative impact on the nearby area. This has led towards the effort of integrating this waste cockle shell as one of the mixing ingredients in concrete production thus opening a new horizon in agro-concrete research and simultaneously offering alternatives to preserve natural coarse aggregate for the use of future generation. Success in incorporating this material as a partial coarse aggregate replacement in the concrete making would contribute towards the reduction in the quantities of cockle shell ending up as waste. The crushed seashells as a coarse aggregate replacement produced low strength and lightweight concrete that is more suitable for low strength application such as concrete paver (Dahunsi, 2003, Boutouil *et al*., 2013). Nor Hazurina *et al*. (2013) conducted an experimental study on cockle shell ash as partial replacement for cement and as filler in concrete. The study determined the chemical composition of cockle shell ash using Fluorescence X-ray analysis. The observation on the morphology structure based on SEM analysis was also performed. The next phase involved in determining the properties such as compressive strength, tensile, modulus of elasticity, water permeability and porosity of concrete made from mixture of cockle shell ash of 5%, 10%, 15%, 25%, 50% and compared to normal concrete cured in ordinary water at the 7, 28, 90 days and up to 120 days for water permeability test. It was concluded from the study that inclusion of 5% and 10% of cockle shell ash in concrete resulted in relatively compacted morphology structure thus affecting the strength, modulus of elasticity, permeability and porosity of the concrete. A recent study by Cuadrado-Rica *et al*. (2015) concluded that the use of crushed queen scallop shells as the aggregate replacement could decrease the mechanical properties and increase the porosity because of an increase of entrapped air in concrete. Uncrushed cockle shells could replace aggregate partially up to 20% with an increase in compressive strength than normal concrete.

Felixkala and Partheeban (2010) examined the possibility of using granite powder as replacement of sand along with partial replacement of cement with fly ash, silica fume and blast furnace slag. They reported that granite powder of marginal quantity as a partial replacement to sand had a beneficial effect on the mechanical properties such as compressive strength, split tensile strength and modulus of elasticity. They also reported that the values of plastic and drying shrinkage of concrete with granite powder were less than those of normal concrete specimens. Oyekan *et al*. (2008) studied the performance of hollow sandcrete blocks containing cement, sharp sand and granite fines in varying propositions to determine their structural and hydrothermal properties. The percentage of granite fines by volume of the total fine aggregate was varied in steps of 5% to a maximum of 30%. Results of the tests indicated that the inclusion of granite fines in the sand-cement matrix has a very significant effect on the compressive strength of sandcrete blocks. It was also, observed that for both mix propositions, 15% granite fines content was the optimum value for improved structural performance. Shahul Hameed and Sekar (2009), Bahar (2010), Shahul Hameed *et al*. (2010), Bouziani *et al.* (2011) and Shirulea *et al*. (2012) investigated the usage of quarry rock dust and marble sludge powder as possible substitutes for natural sand in concrete. They also carried out durability studies on green concrete and compared with that of natural sand concrete. They found that the compressive, split tensile strength and the durability concrete was good when the fine aggregate was replaced with 50% marble sludge powder and 50% quarry rock dust (green concrete).The resistance of concrete to sulphate attack was enhanced greatly. Kanmalai Williams *et al*. (2008) examined the performance of concrete made with granite powder as fine aggregate. Sand was replaced with granite powder in steps of 0%, 25%, 50%, 75% and 100% and cement was replaced with silica fume (7.5%), fly ash (10%) and slag (10%). 1% superplasticizer was added to improve the workability. The effects of curing temperature at 32^0C on 1, 7, 14, 28, 56 and 90 days compressive strength, split tensile strength, modulus of elasticity, drying shrinkage and water penetration depth were found. Results indicated that the increase in the proportions of granite powder resulted in a decrease in the compressive strength of concrete. The highest compressive strength was achieved in samples containing 25% granite powder concrete, which was 47.35 kPa after 90 days of curing.

From the review of the literature, it can be observed that cockle shell can be used as partial replacement of coarse aggregate and granite powder can be used as partial replacement of fine aggregate. However, little work is done on concretes with both aggregates replaced by cockle shell and granite powder. The present paper investigates the performance of concrete mix in terms of compressive strength upon addition of cockle shell and granite powder as partial replacements to coarse aggregate and fine aggregates respectively.

3.0 Experimental Investigation

3.1. Materials

All relevant tests on Cement, fine aggregate, Course aggregate, cockle shell and granite powder are conducted to ensure their suitability for use in structural concrete.

a) Cement

The most commonly available Portland cement of 53 - grade was used for the investigation. Cement was bought from the same source throughout the research work. While storing cement, all possible contacts with moisture were avoided. The properties of cement used in this study are as follows.

Cement grade	43 grade OPC	(Conforming to IS: 8112 – 1989)
Fineness	6.8 %	(IS: 4031 – 1996 (Part 1))
Specific gravity	3.12	(IS: 4031 – 1988 (Part 11))
Standard Consistency	25 %	(IS: 4031 – 1996 (Part 4))
Initial setting time	82 minutes.	(IS: 4031 – 1988 (Part 5))
Final Setting time	525 minutes	(IS: 4031 – 1988 (Part 5))
Soundness	2 mm	(IS: 4031 – 1996 (Part 3))

b) Coarse Aggregate

Hard broken granite stones were used as a coarse aggregate in concrete. The size of the coarse aggregate used in the investigation was 10 mm and 20 mm. The properties of coarse aggregate used in this study are as follows.

Fineness Modulus	7.89	(IS: 383 – 1970)
Specific gravity	2.72 (20 mm)	(IS: 2386 – 1963 (Part 3))
	2.78 (10mm)	(IS: 2386 – 1963 (Part 3))
Water Absorption Value	0.3 %	(IS: 2386 – 1963 (Part 3))
Free surface moisture	NIL	
Flakiness index	11 %	(IS: 2386 – 1963 (Part 1))
Elongation index	13 %	(IS: 2386 – 1963 (Part 1))
Aggregate Crushing Value	18 %	(IS: 9376 – 1979)
Aggregate Impact Value	12 %	(IS: 9377 – 1979)
Aggregate Abrasion Value	15 %	(IS: 10070 – 1982)

c) Fine Aggregate

In the present work, the concrete mixes were prepared using locally available river sand. The properties of fine aggregate used in this study are as follows.

Fineness modulus	2.65	(IS: 383 – 1970)
Specific gravity	2.78	(IS: 2386 – 1963 (Part 3))
Water Absorption	NIL	(IS: 2386 – 1963 (Part 3))
Free surface moisture	NIL	
Zone of Sand	II	(IS: 2386 – 1963 (Part 1))

d) Granite Powder

Granite belongs to igneous rock family. Granite powder obtained from the polishing units was procured and its properties were determined. Table 1 (a) gives the properties of granite powder while Table 1 (b) gives chemical composition of granite powder.

Table 1 (a): Properties of granite powder

Property	Granite Method	Test Method
Specific gravity	2.59	IS 2386 – 1963 (Part 3)
Bulk relative density (kg/m3)	1790	IS 2386 – 1963 (Part 3)
Absorption (%)	1.3	IS 2386 – 1963 (Part 3)
Moisture content (%)	Nil	IS 2386 – 1963 (Part 3)
Fine particles less than 0.075mm (%)	13	IS 2386 – 1963 (Part 1)
Sieve analysis	Zone II	IS 383 – 1970

Table 1 (b): Constituents of Granite Powder

Constituent	% present in Granite Powder
Alumina (Al_2O_3)	14.42
Magnesium oxide (MgO)	0.71
Calcium oxide (CaO)	1.82
K_2O	4.12
Na_2O_3.	3.69
Silica (SiO_2)	72.04
Fe_2O_3	1.22

e) Cockle Shell

It is a waste material from fishing industry used as a partial replacement for coarse aggregate in concrete. Figures 1 and 2 show cockle shell and granite powder dumped as waste on National Highways around Visakhapatnam (India). The properties of cockle shell used in this study are as follows.

Specific gravity	2.43	(IS: 2386 – 1963 (Part 3))
Water Absorption Value	0.1 %	(IS: 2386 – 1963 (Part 3))
Free surface moisture	NIL	
Aggregate Crushing Value	48.7 %	(IS: 9376 – 1979)
Aggregate Impact Value	52.8 %	(IS: 9377 – 1979)
Aggregate Abrasion Value	15.8 %	(IS: 10070 – 1982)

f) Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction (hydration) with cement. In general, potable water (such as pipe water) suitable for drinking is used for mixing concrete. Impurities in the water may affect setting time, strength, shrinkage of concrete or promote corrosion of reinforcement. The Local drinking water is used in the present work.

Figure 1: Cockle shell (a waste from fishing industry)

Figure 2: Granite powder disposed on the National Highway near Bhogapuram (Visakhapatnam, India)

3.2. Methodology and Experimental Programme

The methodology adopted for this study is explained below.

1. Mix of G25 grade was designed as per IS: 10262 – 2009 and 150 mm^3 concrete cube specimens were caste.
2. 0 to 25% fine aggregate was replaced with granite powder at increments of 5% and mix with maximum 28 days compressive strength is determined.
3. 0 to 25% coarse aggregate was replaced with granite powder at increments of 5% and mix with maximum 28 days compressive strength is determined.
4. The optimum percentages of cockle shell and granite powder for maximum strength are determined individually.
5. Finally specimens were caste by fixing optimum granite powder percentage and varying cockle shell (5 to 25%) and mix with maximum 28 days compressive strength is determined.
6. Specimens were also caste by fixing optimum cockle shell percentage and varying granite powder (5 to 25%) and mix with maximum 28 days compressive strength is determined.
7. The combination for arriving at absolute maximum strength was determined.

The sample preparation and compressive strength testing procedures are explained in the following sections.

3.2.1 Sample Preparation (In Accordance with IS: 1199 – 1959)

Concrete cube mould of 15 cm x 15 cm x 15 cm is cleaned thoroughly to remove any residual concrete and dust. Then they are greased all along their inner sides. Concrete is mixed uniformly on an impervious layer and filled in three layers. Each layer is compacted carefully either by tamping rod or by vibration. After compaction, top layer of the surface of concrete is brought to finished level by using a trowel. Three cube specimens are caste for each mix. The cubes were demoulded after 24 hours and immersed in water for curing. Figure 3 shows all the ingredients of concrete including granite powder and cockle shell ready for mixing.

Figure 3: Ingredients of concrete including cockle shell and granite powder

3.2.2 Compressive Strength of Cubes – Testing Procedure

The concrete cube specimens are tested as per the specifications of IS: 516 – 1959. Concrete cube moulds are tested in Compression testing machine of 3000 kN capacity.

4.0 Results and Discussion

4.1 Compressive Strength of Concrete with Varying Percentage of Granite Powder

The compressive strength of concrete for different percentages of granite powder replacement is presented in Table 2, Figure 4(a) and Figure 4(b). From Table 2, Figure 4(a) and Figure 4(b), it can observed that the strength of concrete increases with increase in percentage of granite powder up to certain extent and then decreases. The percentage at which maximum value of compressive strength is obtained is at 15%.

Table 2: Compressive strength of concrete with different percentage of granite Powder

Percentage of granite powder	*Compressive Strength (MPa)*
0	30.4
5	28.6
10	32.3
15	33.9
20	30.0
25	28.8

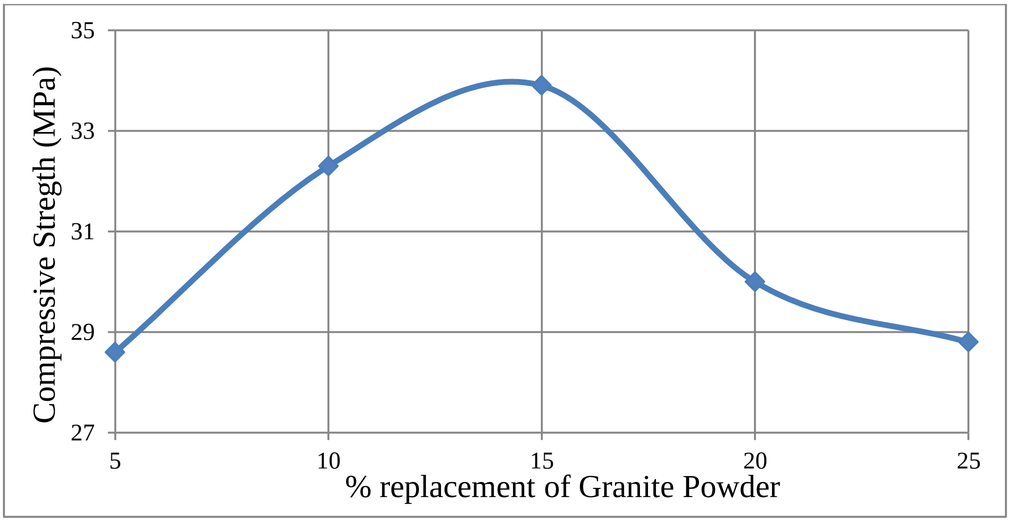

Figure 4 (a): Compressive strength of concrete at different percentage of granite powder

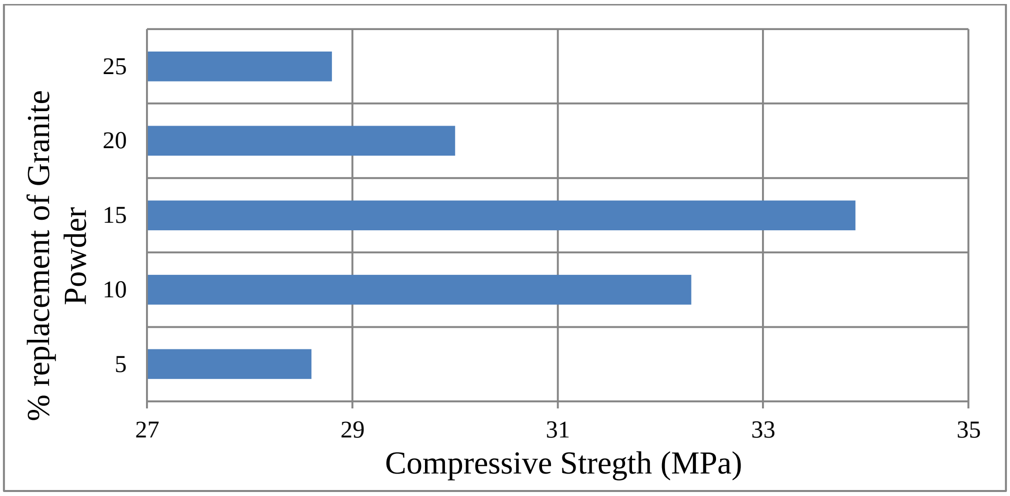

Figure 4 (b): Compressive strength of concrete at different percentage of granite powder

4.2 Compressive Strength of Concrete with Varying Percentage of Cockle Shell

The compressive strength of concrete for different percentages of cockle shell replacement is presented in Table 3, Figure 5 (a) and Figure 5 (b). It is found that strength of concrete increases with increase in the percentage of cockle shell up to 10% and then decreases. However the strength of replaced concrete is marginally less than conventional concrete. The percentage at which maximum strength is obtained is at 10%.

Table 3: Compressive strength of concrete with different percentage of cockle shell

Percentage of cockle shell	*Compressive strength (MPa)*
0	30.4
5	28.0
10	28.4
15	27.1
20	26.0
25	24.6

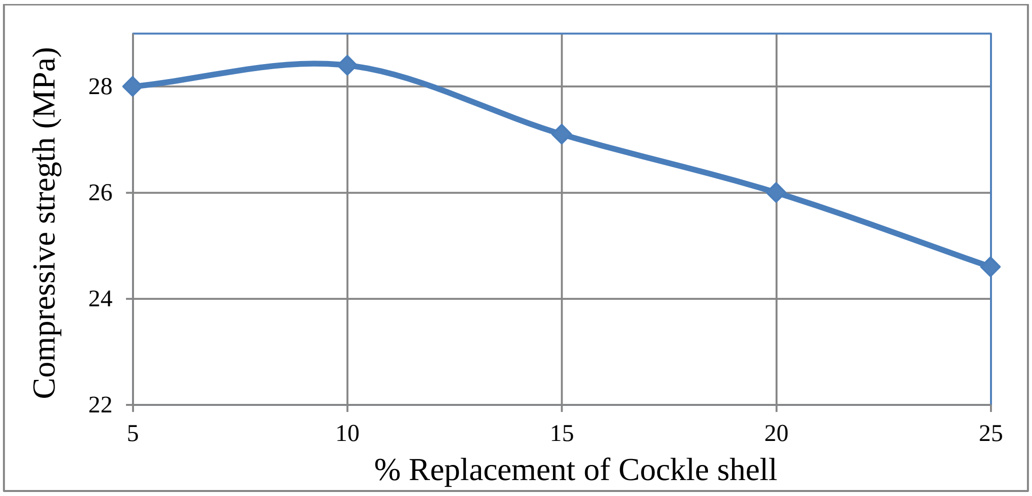

Figure 5 (a): Compressive strength of concrete at different percentage of cockle shell

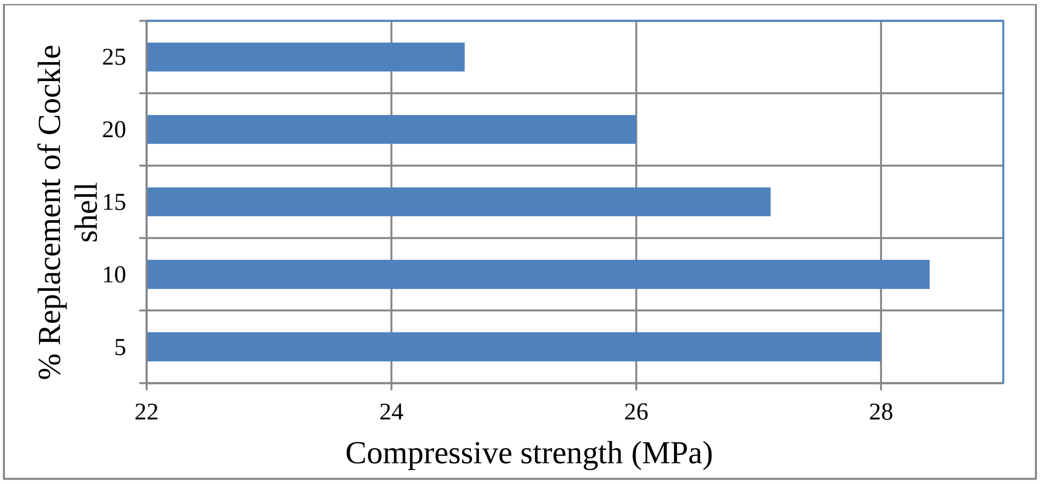

Figure 5 (b): Compressive strength of concrete at different percentage of cockle shell

4.3 Compressive Strength of Concrete with Constant Granite Powder (5%) And Varying Cockle Shell

The strengths obtained by fixing granite powder at 5% and varying cockle shell percentage are shown in Table 4, Figure 6 (a) and Figure 6 (b). It can be observed that these strengths are less than that of conventional Concrete.

Table 4: Strength of Concrete (with 5% granite powder and varying cockle shell %)

Percentage of cockle shell	*Compressive strength (MPa)*
5	28.4
10	29.5
15	28.0
20	27.3
25	25.7

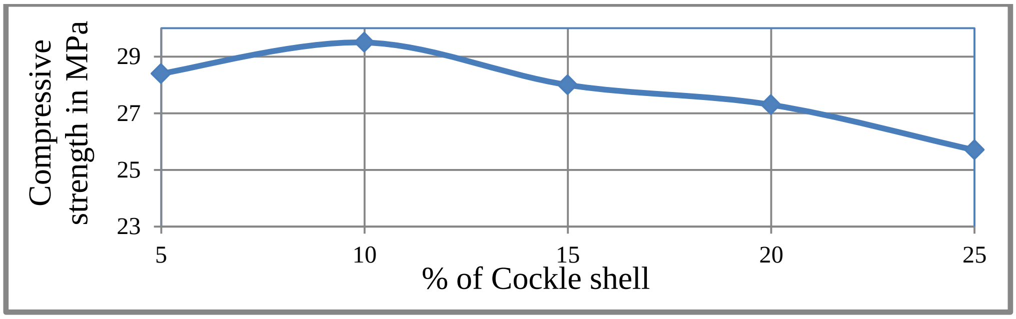

Figure 6 (a): Compressive strength of concrete with different percentage of cockle shell (granite powder 5% fixed)

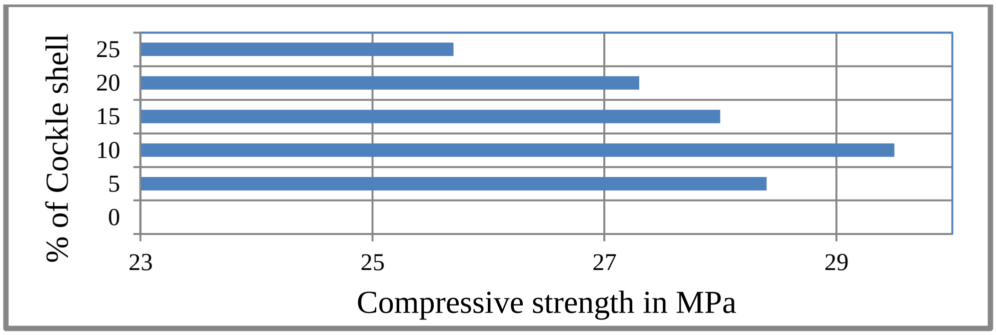

Figure 6 (b): Compressive strength of concrete with different percentages of cockle shell (granite powder 5% fixed)

4.4 Compressive Strength of Concrete with Constant Granite Powder (10%) And Varying Cockle Shell

The compressive strengths obtained by fixing granite powder at 10% and varying cockle shell percentage from 5 to 25 are presented in Table 5, Figure 7 (a) and Figure 7 (b). It can be observed that there is an increase in strength compared to that of conventional concrete at 10% and 25% of cockle shell. The maximum value is obtained at 10% cockle shell and 10% granite powder which is 20.4% higher than conventional concrete.

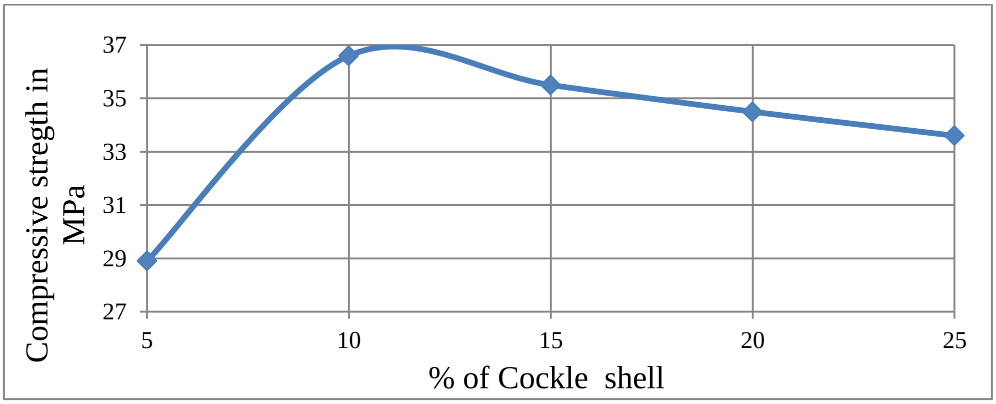

Figure 7 (a): Compressive strength of concrete with varying percentage of cockle shell (granite powder 10% fixed)

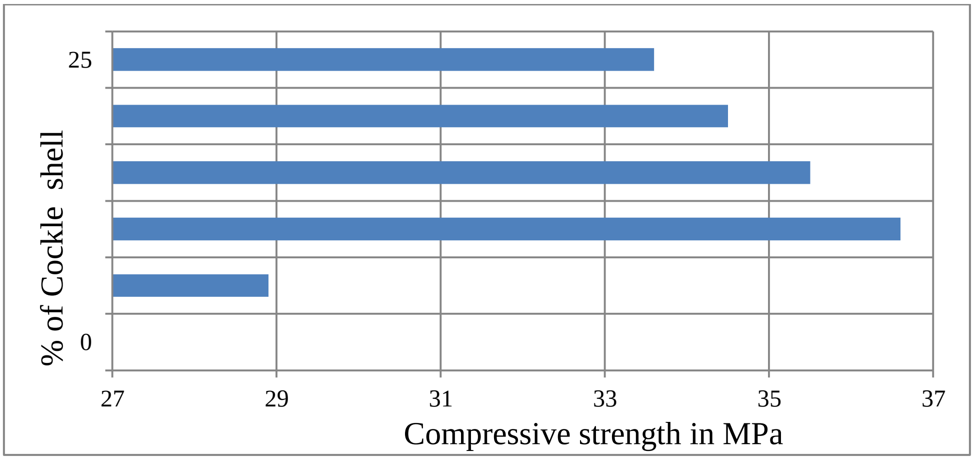

Figure 7 (b): Compressive strength of concrete with varying percentage of cockle shell (granite powder 10% fixed)

Table 5: Compressive strength of concrete (10% granite powder fixed and cockle shell varying)

Percentage of cockle shell	*Compressive strength (MPa)*
5	28.9
10	36.6
15	35.5
20	34.5
25	33.6

4.5 *Compressive Strength of Concrete with Constant Granite Powder (15%) And Varying Cockle Shell.*

The strengths obtained with a constant Granite powder at 15% and varying cockle shell are shown in Table 6 and Figure 8 (a) and Figure 8 (b). It can be observed from Table 6, Figure 8 (a) and Figure 8 (b) that there is an increase in strength with respect to the conventional concrete from 5% to 25% of cockle shell. The maximum compressive strength is attained at 25% cockle shell and 15% granite powder.

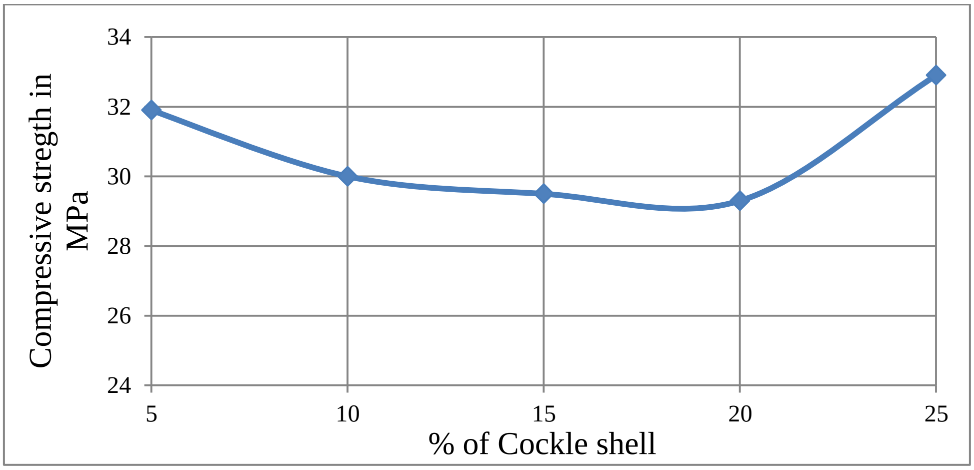

Figure 8 (a): Compressive Strength of concrete with different percentage of cockle shell (granite powder 15% fixed)

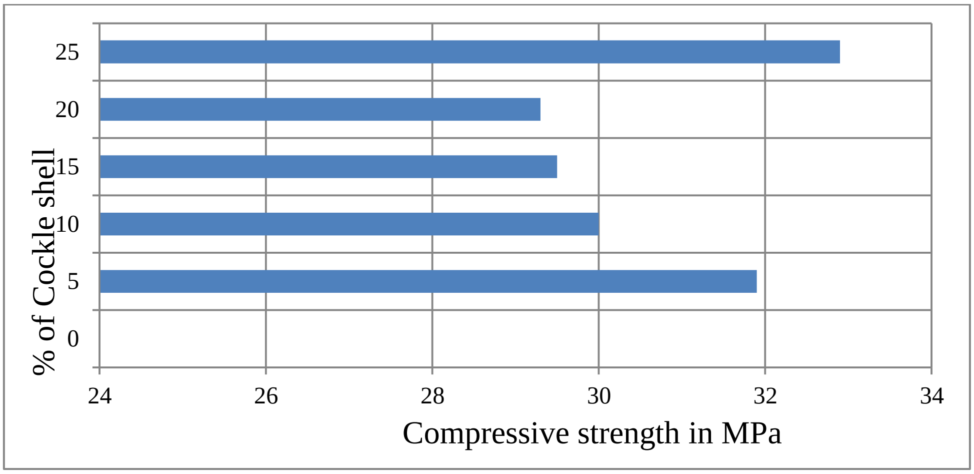

Figure 8 (b): Compressive strength of concrete with different percentage of cockle shell (granite powder 15% fixed)

Table 6: Compressive strength of concrete (15% granite powder fixed with varying Cockle shell)

Percentage of cockle shell	*Compressive strength (MPa)*
5	31.9
10	30.0
15	29.5
20	29.3
25	32.9

4.6 Compressive Strength of Concrete with Constant Granite Powder (20%) And Varying Cockle Shell.

The strengths obtained by fixing Granite powder at 20% and varying cockle shell is shown in Table 7, Figure 9 (a) and Figure 9 (b). It is observed that from Table 7, Figure 9 (a) and Figure 9 (b) that there is an increase in strength compared to the conventional concrete at 10% and 15% of cockle shell. The maximum value is obtained at 15% cockle shell and 20% granite powder. This is the maximum strength obtained than all other combinations which is 43.75% greater than conventional concrete.

Table 7: Compressive strength of concrete (20% granite powder fixed and cockle shell varying)

Percentage of cockle shell	*Compressive Strength (MPa)*
5	30.0
10	42.0
15	43.7
20	28.7
25	25.4

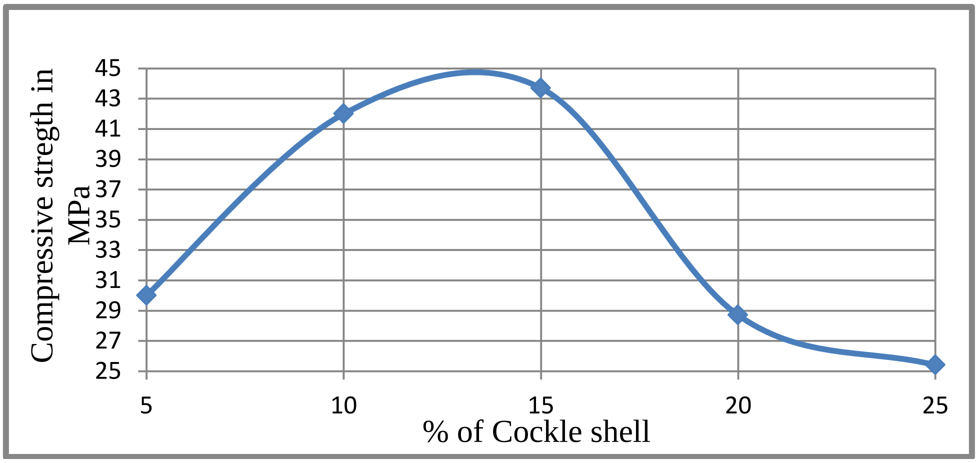

Figure 9 (a): Compressive strength of concrete with different percentage of cockle shell (granite powder 20% fixed)

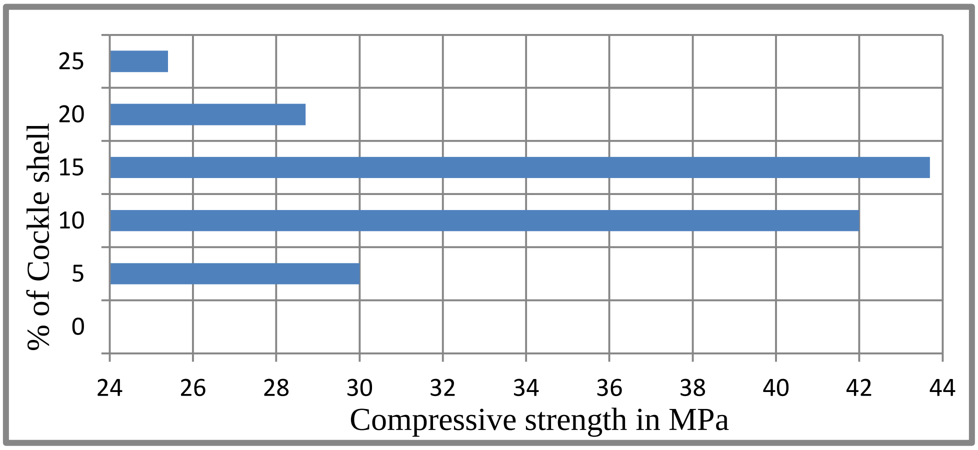

Figure 9 (b): Compressive strength of concrete with different percentage of cockle shell (granite powder 20% fixed)

4.7 Compressive Strength of Concrete with Constant Granite Powder (25%) And Varying Cockle Shell

The compressive strengths obtained by fixing granite powder (25%) and varying cockle shell are shown in Table 8, Figure 10 (a) and Figure 10 (b). However these strengths are less than that of the conventional concrete.

Table 8: Compressive strength of concrete (25% granite powder fixed and cockle shell varying)

Percentage of cockle shell	*Compressive Strength (MPa)*
5	30.2
10	28.6
15	27.1
20	27.0
25	27.1

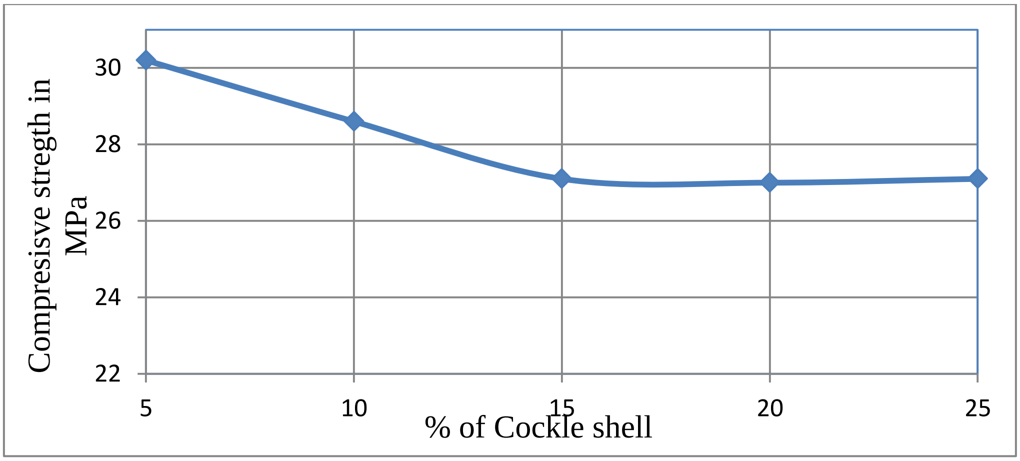

Figure 10 (a): Compressive strength of concrete with different percentage of cockle shell (granite powder 25% fixed)

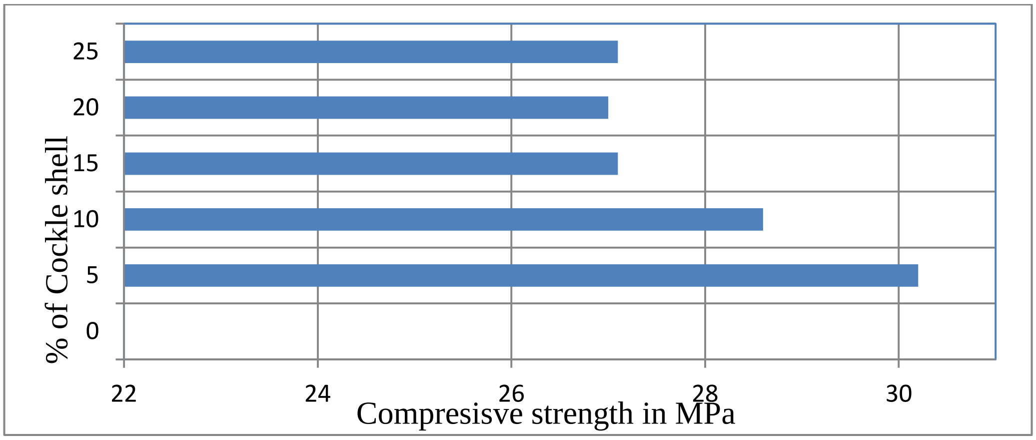

Figure 10 (b): Compressive strength of concrete at different percentage of cockle shell (granite powder 25% fixed)

4.8 Consolidated Results of Compressive Strength of Concrete with Cockle and Granite Powder

Table 9, Figure 11 (a) and Figure 11 (b) present the consolidated compressive strength results of concrete with fixed granite powder and varying cockle shell percentage. The possible reason for enhanced strength of concrete due to partial replacement of course aggregate in concrete with Cockle shell may be the calcium rich nature of cockle shell. The other ingredient that is partially replaced with fine aggregate is granite powder which is very fine in nature. It may have contributed to the strength by filling the voids left by fine aggregate and cement mortar mix there by increasing the density and hence compressive strength of concrete

Table 9: Compressive Strength of Concrete with granite powder and cockle shell (MPa)

Granite powder percentage	*Cockle shell percentage*					
	0	*5*	*10*	*15*	*20*	*25*
0	30.4	28	28.4	27.1	26	24.6
5	28.6	28.4	29.5	28	27.3	25.7
10	32.3	28.9	36.6	35.5	34.4	33.6
15	33.9	31.9	30	29.5	29.3	32.9
20	30	30	42	43.7	28.7	25.4
25	28.8	30.2	28.6	27.1	27	27.1

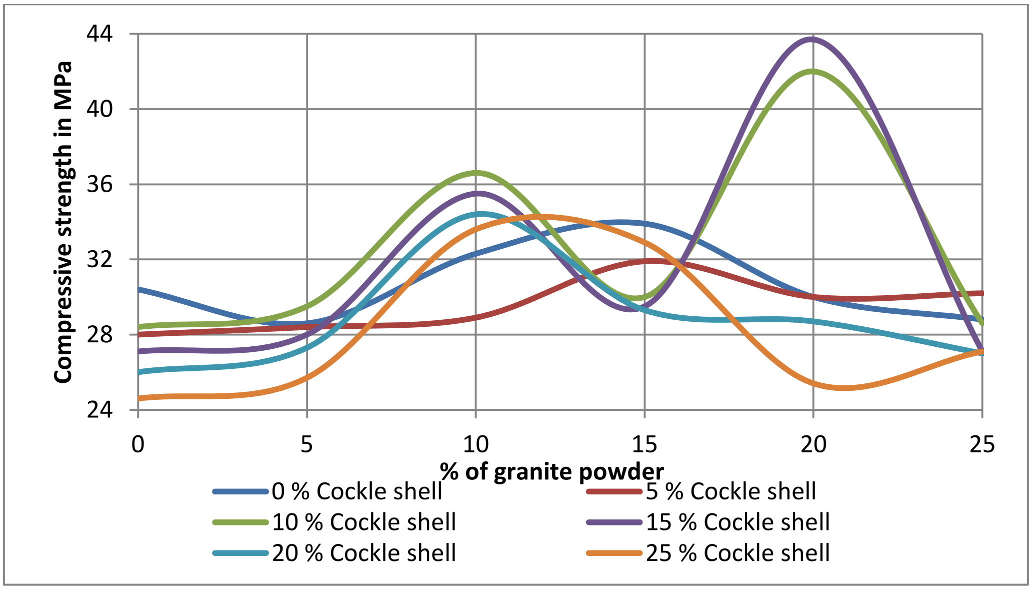

Figure 11 (a): Compressive strengths of concrete with fixed granite powder replacement

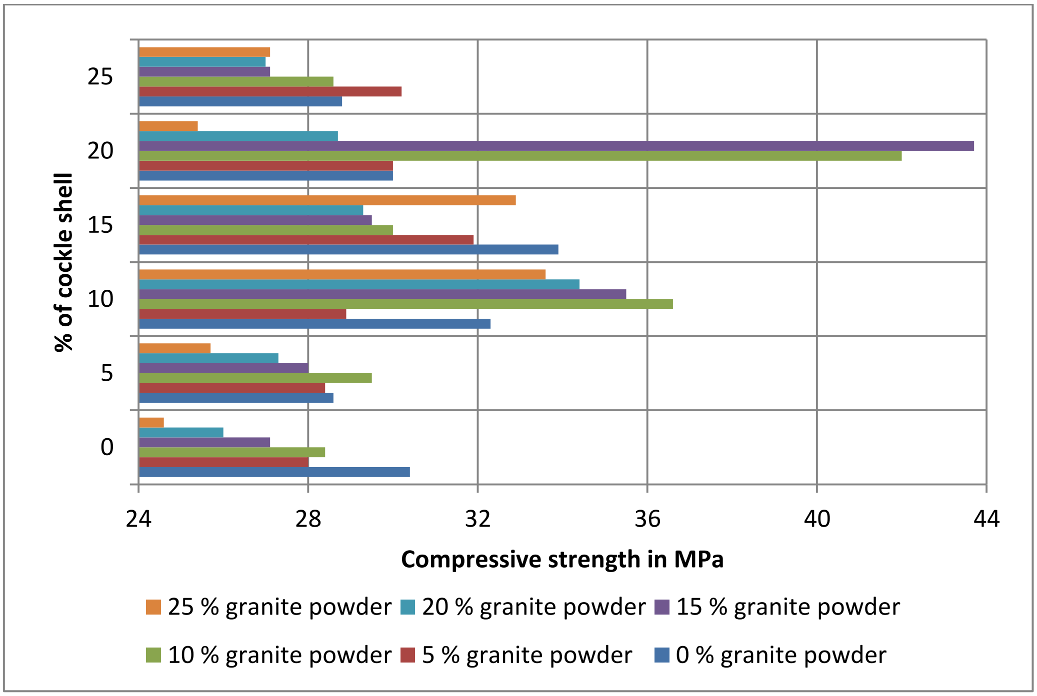

Figure 11 (b): Compressive strengths of concrete with fixed granite powder replacement

5.0 Conclusions

As per the literature available, studies conducted earlier demonstrated the feasibility of partially replacing fine aggregate with granite powder and coarse aggregate with cockle shell individually. This study presents an experimental study on simultaneous use of both cockle shell and granite powder as a partial replacement of coarse and fine aggregates respectively.

1. A maximum compressive strength of 33.9 MPa is observed for 15% replacement of fine aggregate with granite powder. The possible reason for this increase may be the C-S-H gel that may have formed due to the high percentage of Silica in granite powder reacting with $Ca(OH)_2$ (a byproduct of cement hydration reaction).

2. From the test results, it can be observed that partial replacement of coarse aggregate with cockle shell decreased the compressive strength of concrete. The possible reason may be the very high crushing and impact value of cockle shell.

3. The maximum compressive strength of concrete is observed when cockle shell and granite powder are partially replaced with 15% of coarse aggregate and 20% fine aggregate respectively. The compressive strength for this mix is observed to be 43.7 MPa while that of conventional concrete is observed to be 30 MPa. The possible reason for this phenomenon may be due to the C-S-H gel (formed due to high silica content in granite powder) enhancing the properties of cockle shell by forming a layer over it.

Although further studies like XRD and SEM are necessary to ascertain the reasons for increase in compressive strength of concrete due to combined replacement of fine and coarse aggregates with granite powder and cockle shell, the study demonstrates a clear feasibility of adopting these wastes in concrete at least for non-structural applications. The study is expected to go a long way in solving the problem of cockle shell and granite powder disposal while partially solving the problem of sustainability of aggregate which is a stressed natural resource.

References

Alshahwany R.B.A (2011) Effect of partial replacement of sand with limestone filler on some properties of normal concrete. *Al Rafidain Engineering Journal.* Vol. 19 (3), 37-48.

Boey P.L., Maniam G.P., Hamid S.A. (2011) Performance of calcium oxide as a heterogeneous catalyst in biodiesel production: a review Chem. Eng. J., 168, pp. 15–22

Awang-Hazmi A.J., Zuki A.B.Z, Noordin M.M., Jalia A. and Norimah Y. (2007) Mineral composition of the cockle (Anadara granosa) shells of West Coast of Peninsular Malaysia and it's potential as biomaterial for use in bone repair. *Journal of Animal Veterinary Advances.* Vol. 6, 591-594.

Bahar D. (2010) The effect of the using waste marble dust as fine sand on the mechanical properties of the concrete. *International Journal of the Physical Sciences.* Vol. 5 (9), 1372-1380.

Boutouil N., Sebaibi L., Baraud Leleyter F. (2013) Valorization of seashell by products in pervious concrete pavers. *Construction and Building Materials.* Vol. 49, 151–160.

Bouziani T., Benmounah A., Bederina M. and Lamara M. (2011) Effect of Marble powder on the properties of Self-Compacting Sand Concrete. *The Open Construction and Building Technology Journal*. Vol. 5, 25-29.

Cuadrado-Rica H, Sebaibi N, Boutouil M and Boudart B (2015) Properties of ordinary concretes incorporating crushed queen scallop shells. *Materials and Structures*. April 2015 (Online), 1-12.

Dahunsi B.I.O (2003), Properties of periwinkle-granite concrete *Journal of Civil Engineering.* Vol. 8, 27–35.

Mohammad D.M., Yusup S. and Maitra S. (2012) Decomposition study of calcium carbonate in cockle shell. *Journal of Engineering Science and Technology*. Vol. 7 (1), 1-10.

Falade F., Ikponmwosa E.E. and Ojediran N.I. (2010) Behaviour of lightweight concrete containing periwinkle shell at elevated temperature. *Journal of Engineering Science and Technology*. Vol. 5 (4). 379 - 390.

Felixkala T. and Partheeban P. (2010) Granite Powder Concrete. *Indian Journal of Science and Technology.* Vol 3 (3), 311-317.

Hanifi B., Hasan K. and Salih Y. (2007) Influence of marble and limestone dusts as additives on some mechanical properties of concrete. *Academic Journals*. Vol. 2 (9), 372-379.

IS : 383 : 1970, Specifications for coarse and fine aggregates from natural sources for concrete, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 2386 : 1963 (Part 1), Methods of test for aggregates for concrete : Particle size and shape, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 2386 : 1963 (Part 3), Methods of test for aggregates for concrete : Specific gravity, density, voids, absorption and bulking, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 4031 : 1996 (Part 1), Methods of physical tests for hydraulic cement : Determination of fineness by dry sieving, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 4031 : 1996 (Part 3), Methods of physical tests for hydraulic cement : Determination of soundness, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 4031 : 1996 (Part 4), Methods of physical tests for hydraulic cement : Determination of consistency of standard cement paste, *Bureau of Indian Standards,* Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 4031 : 1988 (Part 5), Methods of physical tests for hydraulic cement : Determination of initial and final setting time, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 4031 : 1988 (Part 11), Methods of Physical Tests for Hydraulic Cement : Determination of Density, *Bureau of Indian Standards,* Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 8112 – 1989, Specifications for 43 grade ordinary Portland cement, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 516 : 1959, Indian code for method of tests for concrete, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 10070 : 1982, Specification for machine for Abrasion Testing of Coarse Aggregates, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 10262 : 2009, Concrete mix proportioning – Guidelines, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 9376 : 1979, Specification for apparatus for Aggregate crushing Value, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 9377 : 1979, Specification for apparatus for Aggregate Impact Value, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

IS : 1199 : 1959, Methods of sampling and analysis of concrete, *Bureau of Indian Standards*, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110002.

Kanmalai Williams C., Partheeban P. and Felix Kala T. (2008) Mechanical Properties of High Performance Concrete Incorporating Granite Powder as Fine Aggregate. *International Journal on Design and Manufacturing Technologies.* Vol. 2 (1), 67-73.

Nor Hazurina O., Badorul H.A.B., Mashitah M.D. and Megat A.M.J. (2013) Cockle shell ash replacement for cement and filler in concrete. *Malaysian Journal of Civil Engineering.* Vol. 25 (2), 201-211.

Mannan M.A and Ganapathy C. (2004) Concrete from an agricultural waste-oil palm shell (OPS). *Building and Environment*. Vol. 39, 441-448.

Muthusamy K. and Sabri N.A. (2012) Cockle shell: a potential partial coarse aggregate replacement in concrete. *International Journal of Science, Environment and Technology*, Vol. 1, 260–267.

Oyekan G.L. and Kamiyo O.M. (2008) Effects of granite fines on the structural and hygrothermal properties of sandcrete blocks. *Nigeria journal of Engineering and Applied sciences*. Vol. 3 (3), 735-741.

Peng-Lim B., Gaanty P.M., Shafida A.H, Dafaalla M.H.A. (2011) Utilization of waste cockle shell (Anadara granosa) in biodiesel production from palm olein: Optimization using response surface methodology. *Fuel.* Vol. 90, 2353-2358.

Shahul Hameed M and Sekar A.S.S (2009) Properties of Green Concrete Containing Quarry Rock Dust and Marble Sludge Powder as Fine Aggregate. *ARPN Journal of Engineering and Applied Sciences.* Vol. 4 (4), 83-89.

Shahul Hameed M, Sekar A.S.S and Saraswathi V (2010) Chloride Penetration Study on Self-Compacting Green Concrete Using Crusher Rock Dust and Marble Sludge Powder as Fine Aggregate. *NDT.net*, Vol. 2, 1-10.

Shirulea P A, Ataur R. and Rakesh D.G. (2012) Partial Replacement of Cement with Marble Dust Powder. *International Journal of Advanced Engineering Research and Studies.* Vol. 1, 175-177.

Wai H.K., Ramli M., Kenn J.K., and Suleiman M.Z. (2012) Influence of the amount of recycled coarse aggregate in concrete design and durability properties. *Construction and Building Materials*, Vol. 26, 565-573.