Optimize mechanical properties of Oman cement using bio waste of sea shell

Ahmmed Saadi Ibrahim, Mazhar Ul-Islam,
Amani Samir Hilal Al Noobi,
Shorooq Hamood Mohammed Khalfan Al Abri and
Afrah Manaa Salaiman Mohamed Al Salmi

January 4, 2020

Optimize mechanical properties of Oman cement using bio waste of sea shell

Ahmmed Saadi Ibrahim, Mazhar Ul-Islam, Amani AL-Noobi , Shorooq AL-Abri , Afrah AL-Salmi

Chemical Engineering Department- Dhofar University,211, Oman

Email of corresponding author: ahmadsaadi47@yahoo.com

Abstract

This study is used to optimize the quality of Omani cement using sea shells as a bio waste to be employed as an active additives surrogate of fine aggregates. The starting of this work is to collect, clean, grind and burn the shells in the oven at a certain temperature 500 ºC. Then, prepared five samples of cement and add specific proportions of shell powder properties 0%, 3%, 5%, 6.5%, and 10% by weight of cement and mechanical properties were tested for the compressive force, split tensile strength and flexural strength for all the samples. The experimental results showed that 6.5% is the best sample. Employed numerical mathematical model for the estimate the maximum and minimum percentage of shell powder to increase strength of samples. The optimum of numerical model percentages of seashell powder 2.3%, 2.21% and 6.53% were the optimum in the compressive strength, split tensile strength and flexural strength respectively. It is appeared from this novel technique to apply the active interaction effects between experimental, numerical model and optimization make significantly promotes to reach high quality outcomes.

Keywords

Cement; Shell powder; Numerical technique; Optimization; Mechanical Properties

1.Introduction

Sea shells represent bio-waste that is considered hazardous material owing to the presence of high concentrations of calcium carbonate and metals oxides. These compositions of seashell are among the major causes of environmental pollution. The wastage of these sea shells is causing economic and environmental problems. This not only results in economic deprivation but also provide perfect habitat for the growing bugs and insects that consequently leads to serious health risks. Looking at the enormous total of money lost and the growing economic and environmental concerns, many research work aimed to evolve schemes for converting wastes to important bio products and thus providing healthy environmental and economic benefits.In 2003, a research group employed the ground shell between 5-20% by weight of cement [4] for enhancing the cement quality. Another research group concluded that by increasing the sea shell contents in cement up to 20% leads to increase in compressive strength of the cement [5]. The crushed seashells produced light weight and low strength concrete like concrete paver [6,7]. In 2013, a research group proved that the concentration of seashell above 15 % decreased the permeability and porosity of cement [8]. Furthermore, an increase in cement mechanical properties by adding sea shell has been proved by other researchers [9,10]. In 2015, A research group reported certain shells addition in high aggregates can lead to a reduction in the mechanical properties [11]. Adding slightly lower quantities of sea shell powder after physical and mechanical treatments to cement can produce higher cement and concrete of higher tensile strength and flexural strength [12, 13]. It has been established for literature review that sea shell addition can alter the physical and mechanical properties of cement, however a detailed study is required to optimize the added concentration. Besides sea shell some other bio-waste including palm kernel shell and cockle shell etc. have also been utilized in enhancing the cement quality [14-17]. Theaim of this work is to develop an optimization technique for finding the optimum quantities of sea shell to be used in enhancing the cement quality. The work will be carried in a parallel way via theatrically developing optimization standard and correlating it with experimental values.

2.Material and method

2.1 Mechanical treatment

The seashells are provided through the coasts of sultanate Oman then, mechanically treated with grinding to increase the surface area. Seashells are cleaned from dust and plankton attached to brush and water. The seashells are ready for grinding after drying. Then, cracking of shells using automatic soil compactor andgrinding the shells in the grinderas shown in Figure 1.

Figure 1:Automatic soil compactor machine

2.2 Heat and

We burned the shell powder in the oven at a temperature of 500 ºC for three hours to induce the breakdown of calcium carbonate into calcium oxide and carbon dioxide as seen in equation 1.

$$CaCO_3 \rightarrow CaO + CO_2 \qquad (1)$$

After the incineration, it was found that the calcium oxide ratio was low. We increased the time to burn to 24 hours and the analysis of atomic absorption column showed that calcium ratio increased to 58% as shown in Figure 2.

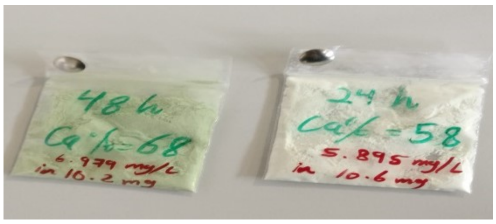

Figure 2: Percentage of calcium oxide.

After 48 hours of continuous burning process, calcium ratio reached 68%. Burning process continued until it reaches 96 consecutive hours in which the percentage of calcium rose to 90%.We started sampling by selecting the appropriate cube (10*10*10) cm. Then we started to make the mixture consisting of cement, sand, Aggregate and water with a steady rate 1;2;4. Then we made the calculations for the mixture components separately as shown in Figure 3 and Table 1.

Table 1: Composition of cement samples.

Compounds	Weight (Kg)
Cement	0.342
Sand	0.685
Aggregate	1.371
Water	1.54

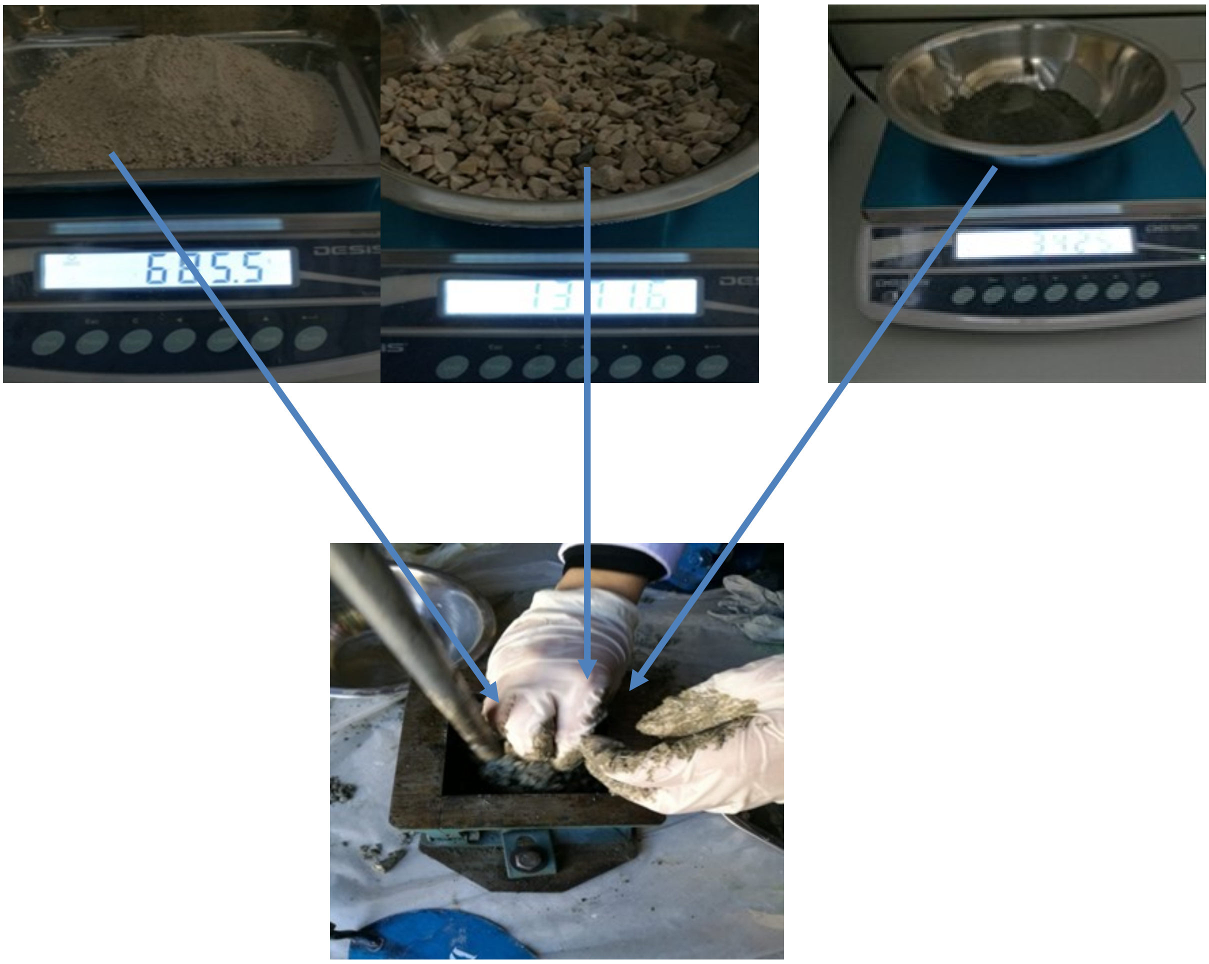

Figure 3: Prepare cement samples

Then we made five samples and add specific proportions of shell powder (0%, 3%, 5%, 6.5%, 10%) for each test of compressive strength, split tensile strength and flexural strength. Then we mixed, the mixture and added these ratios to each sample and left it dry for 24hr, then we put it in the container immersed in water, so that it lasted for seven days and then tested the strength test for all the samples so as to test the impact of the shells in the hardness of the sample as shown in Figure 4.

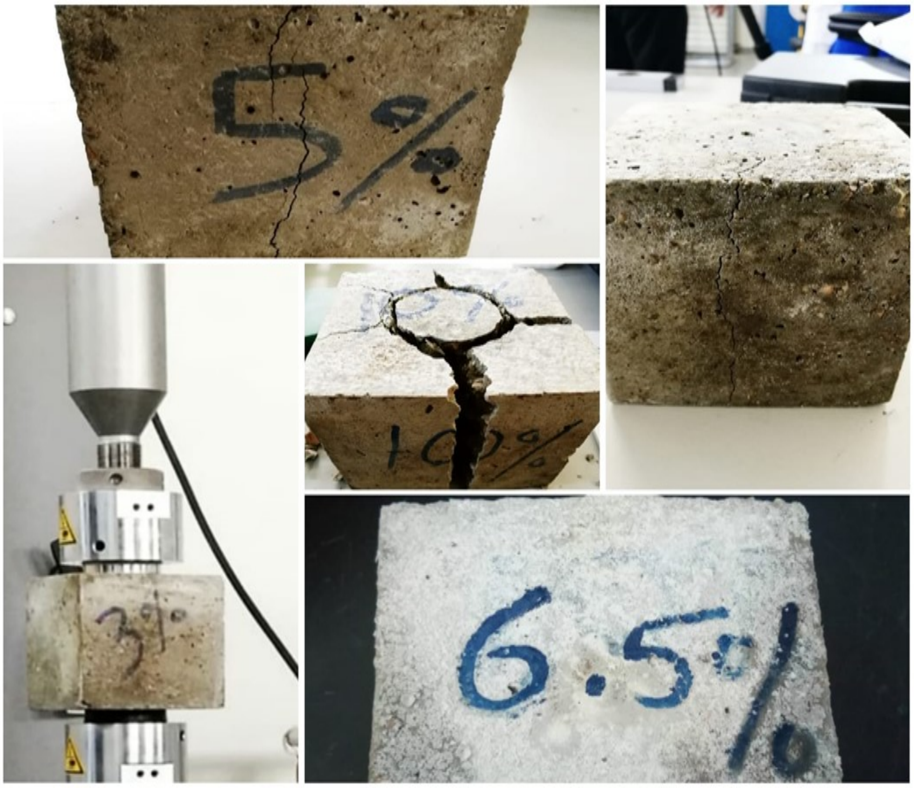

Figure 4:Measure mechanical properties for cement samples

3. Results and discussions

3.1 Compressive strength

Compressive strength is the ability of a material to withstand a pressing (compressive) force or it is represented force per unit area. Table 2 explains to measure compressive strength for 2 weeks of five samples. Sample 4 of 6.5 % of sea shell produced maximum compressive strength 60.1 N/mm^2 compare to 5 % of sea shell produced minimum compressive strength 49,6 N/mm^2

Table 2: Results of compressive strength.

Of sea shell powder	Sample-1 Compressive strength N/mm^2	Sample-2 Compressive strength N/mm^2	Sample-3 Compressive strength N/mm^2	Average Compressive strength N/mm^2
0%	59.8	52.7	54	53.5
3%	52.9	54.2	53.7	53.6
5%	49.8	50.1	48.9	49.6
6.5%	59.4	61.3	59.6	60.1
10%	52.28	51.7	52.02	52

Depend on experimental data that are represented in Table 2 to derive mathematical model using 6th degree polynomial as a numerical technique and norm residuals was equal 7.2084×10^{-13}as shown in Figure 5. Equation 2 represents the mathematical model.

$$Compressive\ strength\ = -0.0034757 \times x^6 + 0.065905 \times x^5 - 0.37438 \times x^4 + 0.62755 \times x^3 + 53.5 \quad (2)$$

$$\frac{dy}{dx} = -0.02013x^5 + 0.33x^4 - 1.48x^3 + 1.89x^2 \quad (3)$$

Let $\frac{dy}{dx} = 0$, to find maximum point.

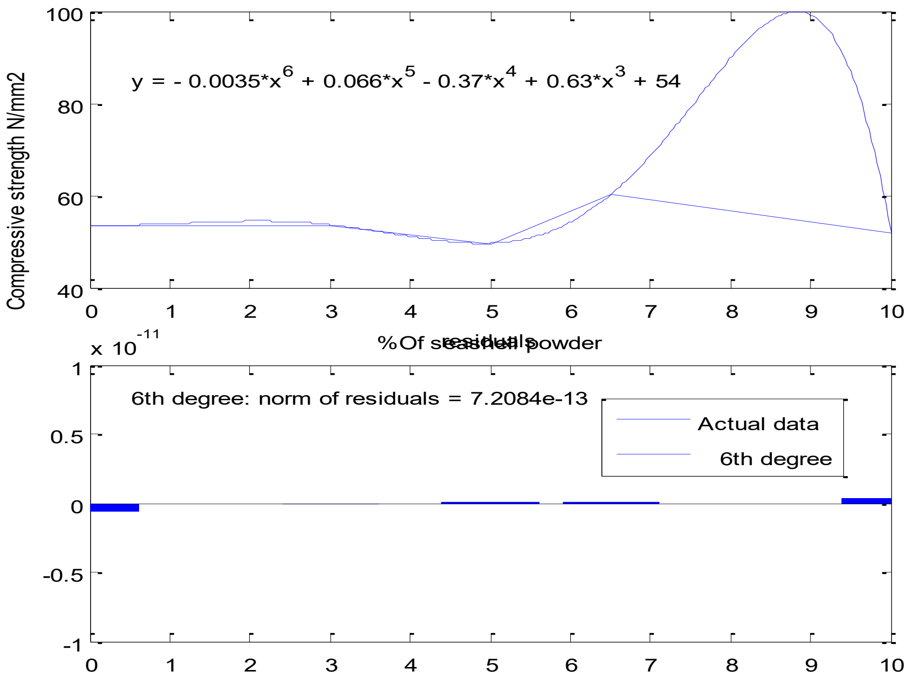

Figure 5: Mathematical model evaluate compressive strength.

After the first test to measure the compressive strength of the concrete samples and seeing the results, we used the mathematical model for the calculate the maximum and minimum percentage of shell powder to increase its strength. According to the numerical calculations, the percentages were 2.3, 4.2 and 9.9 . We prepared the samples and left them dry for 24 hours. After leaving samples immersed in water for 11 days, we tested the compressive strength. Shell powder 2.3% was the highest in strength, with a strength of 56.7N/mm^2. As for the 4.2% and 9.9% of the shell powder has shown less strength 53.21 and 51.11N/mm^2 respectively.

3.2 Split tensile strength

It is represented withstands loads tending to elongate. The results of split tensile strength were presented in Table 3. The test was carried out for five samples appropriate to IS 516-1959to gainsplit tensile strength of concrete at the age of 7 days. The same procedure was applied for all cubes of concrete using Universal testing machine of capacity 2000Kn.

Table 3: Results of split tensile strength.

Of sea shell powder	Sample-1 Split tensile strength N/mm^2	Sample-2 Split tensile strength N/mm^2	Sample-3 Split tensile strength N/mm^2	Average Split tensile strength N/mm^2
0%	52.03	51.37	51.1	51.5
3%	51.61	52	51.49	51.7
5%	47.1	46.95	47.55	47.2
6.5%	49.3	49.1	49.2	49.2
10%	48	49.2	49.2	48.8

Depend on experimental data that are represented in Table 3 to derive mathematical model using 6thdegree polynomial as a numerical technique and norm residuals was equal 4.8505×10^{-13}as shown in Figure 6. Equation 4 represents the mathematical model.

$$\textbf{\textit{Split tensile strength}} = -0.002 \times x^6 + 0.04 \times x^5 - 0.24 \times x^4 + 0.43 \times x^3 + 52 \quad (4)$$

$$\frac{dy}{dx} = -0.012x^5 + 0.2x^4 - 0.96x^3 + 1.29x^2 \quad (5)$$

Let $\frac{dy}{dx} = 0$, to find maximum point.

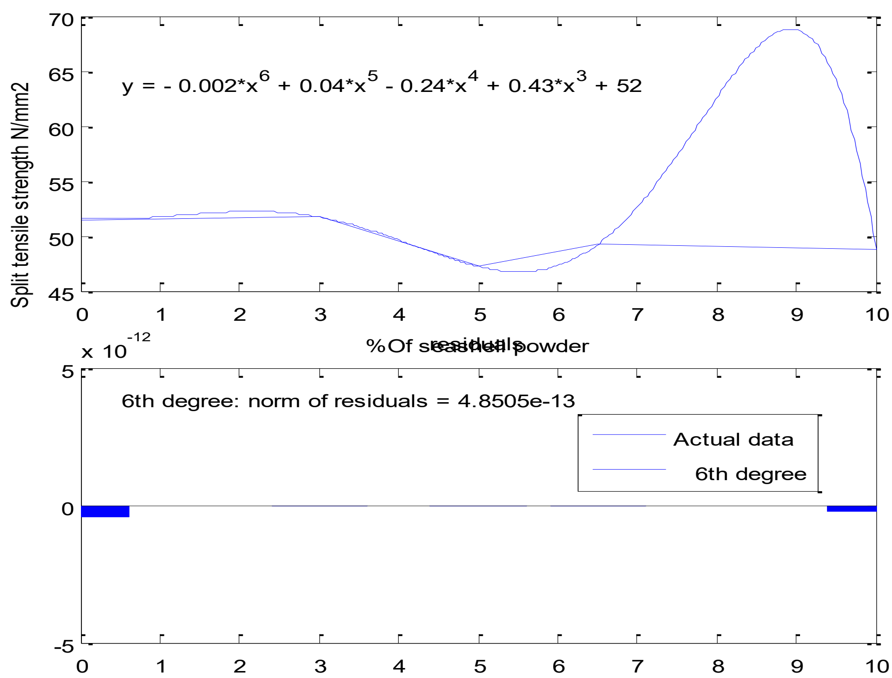

Figure 6: Mathematical model evaluate split tensile strength.

The same procedure of compressive strength was applied in split tensile strength. The optimum concentration of sea shell powder that depends on numerical technique 2.21 % and 6.47 were the highest in the split tensile strength about 53.89 N/mm^2 and 50.05 N/mm^2.

3.3 Flexural strength

It is represented the maximum amount of bending it can withstand. The results of flexural strength were presented in Table 4. The test was carried out for five samples appropriate to IS 516-1959to gainflexural strength of concrete at the age of 7 days. The same procedure was applied for all cubes of concrete using Universal testing machine of capacity 2000Kn.

Table 4: Results of flexural strength.

Of sea shell powder	Sample-1 Flexural strength N/mm^2	Sample-2 Flexural strength N/mm^2	Sample-3 Flexural strength N/mm^2	Average Flexural strength N/mm^2
0%	7.4	7.3	6.9	7.2
3%	8.4	8.4	8.4	8.4
5%	9.1	9.2	9.3	9.2
6.5%	10.01	9.57	9.52	9.7
10%	8.2	8.4	8.3	8.3

Depend on experimental data that are represented in Table 3 to derive mathematical model using 6thdegree polynomial as a numerical technique and norm residuals was equal 1.2239×10^{-13}as shown in Figure 7. Equation 6 represents the mathematical model.

$$\text{Flexural strength} = -0.00033 \times x^6 + 0.0075 \times x^5 - 0.058 \times x^4 + 0.16 \times x^3 + 72 \quad (6)$$

$$\frac{dy}{dx} = -0.098x^5 + 0.0375x^4 - 0.232x^3 + 0.48x^2 \quad (7)$$

Let $\frac{dy}{dx} = 0$, to find maximum point. The optimum numerical condition was 6.53% of seashell powder to have highest in the flexural strength about 9.7N/mm$^{2.}$

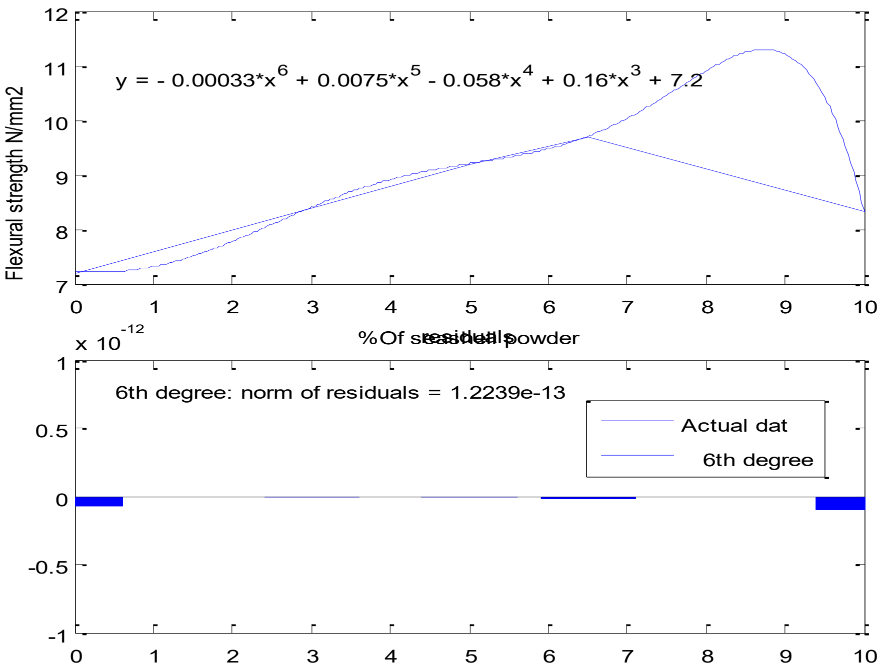

Figure 7: Mathematical model evaluate flexural strength.

4. Conclusions

This technique is merged between experimental and computational mathematical model to optimize theoretical results of high accuracy due to depend on real experimental results and employed it in actual state. This technique produced optimum outcomes.

Acknowledgements

Thanks a lot to my chemical engineering department of Dhofar University to provide all apparatus of experimental to make this work.

Competing interests

We have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Best regards

Dr. Ahmmed Saadi

Reference

1. Global Arabic Encyclopedia, Published by Encyclopedia Works publishing and Distribution, 1990, kingdom of Saudi Arabia

2. Bosch, T, Donald, Seashell Of Oman
3. S.Abinaya, S.Prasanna venkatesh, "An Effect on Oyster Shell Powder's Mechanical Properties in Self Compacting Concrete", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 6, June 2016.
4. G-L,.Yoon,B-T,Kim,B-O,Kim,S-H,Han.Chemical-mechanical characteristics of crushed oyster-shell, Waste management.23(2003)825-834.
5. P. Lertwattanaruk, N. Makul, C. Siripattarapravat, Utilization of ground waste seashells in cement mortars for masonry and plastering,Journal of Environmental Management 111 (2012): 133-141.
6. B. Safi, M. Saidi, A. Daoui, A. Bellal, A. Mechekak, K. Toumi, The use of seashells as a fine aggregate (by sand substition) in selfcompacting mortar (SCM), Construction Building Materials 78(2015): 430-438.M.
7. B.I.O. Dahunsi, Properties of periwinkle-granite concrete. Journal of Civil Engineering 8(2003): 27-35.
8. W-T,Kuo, H-Y. Wang, C-Y. Shu, D-S Su, Engineering properties of controlled low-strength materials containing waste oyster shells,Construction and Building Materials 46 (2013):128-133.
9. N.H. Othman, B.H.A. Bakar, M.M. Don, M.A.M. Johari, Cockle shell ash replacement for cement and filler in concrete, Malaysian Journal of Civil Engineering 25(2013): 201-211.
10. B. Safi, M. Saidi, A. Daoui, A. Bellal, A. Mechekak, K. Toumi, The use of seashells as a fine aggregate (by sand substition) in selfcompacting mortar (SCM), Construction Building Materials 78(2015): 430-438.M.
11. H. Cuadrado-Rica, N. Sebaibi, M. Boutouil, B. Boudart, Properties of ordinary concretes incorporating crushed queen scallop shells, Materials and Structures (April 2015).
12. Monita Oliviaa, Annisa Arifandita Mifshellaa, Lita Darmayantia, Mechanical properties of seashell concrete, Procedia Engineering 125 (2015) 760 – 764.
13. S.Abinaya, S.Prasanna venkatesh, An Effect on Oyster Shell Powder's Mechanical Properties in Self Compacting Concrete, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 6, June 2016.
14. Monita Olivia, Revina Oktaviani, Ismeddiyanto, Prpperties of concerete containing ground waste cockle and clam seashells. Procedia Engineering 171 (2017) , 658-663.
15. F.O. Okafor, Palm kernel shell as a lightweight aggregate for concrete, Cem. Concr. Res. 18 (1988) 901–910.
16. D.C. Okpala, Palm kernel shell as a lightweight aggregate in concrete,Build. Environ. 25 (1990) 291–296.
17. Elnaz Khankhaje , Mahdi Rafieizonooz , Mohd Razman Salim , Jahangir Mirza ,Salmiati , Mohd Warid Hussin, Comparing the effects of oil palm kernel shell and cockle shell on properties of pervious concrete pavement,

International Journal of Pavement Research and Technology 10 (2017) 383–392.