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Sea Shells Waste as Partial Replacement of Fine Aggregate in Concrete: A Review

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Abstract: Fast development in the recent years has increased the demand of natural fine aggregate to be used in construction industry and has made the construction industries in crisis to find a good alternative to handle this problem. Million tons of waste materials appear and was dumped untreated at the open fields or landfills leading to serious environmental problems could be investigated for their potential to be used as partial replacement of fine aggregate in concrete production. Different type of waste products such as fly ash, tobacco waste and rice husk has been used in the previous studies to determine the effectiveness of their use as a substitute of fine aggregate in producing the concrete. In this research, the partially displacement of different types of seashells as fine aggregate was analyzed and discussed based on the result from the previous research. The aim of this study is to determine the optimum percentage of seashells as a replacement of fine aggregates and to investigate the effect of concrete containing seashells as a partial fine aggregate replacement towards density, compressive strength and splitting tensile strength of concrete. Hence, by incorporating the different types of seashells for replacing fine aggregates would reduce the cost of the construction and the amount of sea shells disposal also can be reduced. Thus, it will create a clean environment and can reduce the demand of natural fine aggregates in future. The optimum percentage for cockle shell is 5% to 10%, for oyster shell is 20%, for scallop shell is 5% and 0% to 100% for seashells as replacement of fine aggregate in concrete work because it gives the highest value for compressive strength test compared to the other percentages

Keywords: Sea Shells, Fine Aggregate, Compressive Strength

1. Introduction

Concrete is the most widely used structure material in construction industry and is preferred all over the world. It is an important construction material that has been created a long time ago for constructing structures such as buildings, dams, tunnels, bridges, roads etc. Concrete is a composite manmade construction material consisting of a rotationally chosen mixture of binding material such as lime or

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cement, well graded fine and coarse aggregate and also water that hardens over times. The production of concrete remarkably increased during the past years and it is expected to continue rising in the future. This increase in demand will result in a shortage of natural resources to produce concrete especially natural aggregates which comprise three-quarters of the volume of concrete and also will result in the river being overexploited and causing degradation as well as environmental pollution. Besides, it has also led to an increase in cost, making it an expensive construction material. If the possible action is not taken by the authorities regarding this issue, the issues related to depletion of non-renewable resources will keep raising and will endanger the environment. Anticipating this issue, merged with the waste disposal problem, various types of waste materials have been tested their potential to be the partial replacement of fine aggregates in concrete production such as oil palm shell, tobacco waste, copper slag, various types of clamshells and others [1].
Malaysia has controlled 93% of the total shells production and one of the main producers of adult clams in Asia [2]. The highest production of adult cockles which are one of the main species in the aquaculture industry in Malaysia occurred in 2010 that is around 78,024.70 tonnes, in which the amount is not only estimate the number of clams production but also leads towards the amount of shells waste generated [2]. The discarded and untreated shells may cause unpleasant odour and unsightly appearance to the surrounding area. As the shells take a long time to decompose, it will become a pollutant to the environment and will pose negative impact to the nearby area. Untreated clamshells left for a long time can lead to microbial decomposition of salts into gases such as hydrogen sulphide, ammonia and amines that will result in serious environmental problems [3].

Thus, these problems has led to a promising solution towards the effort of integrating the clamshells waste as a partial fine aggregate replacement in concrete and at the same time offering options to preserve natural fine aggregate for our future generation. Some of the seashells waste can be processed for reuse that have the potential to be mixed in the manufacturing of this concrete. In this study, the seashells are expected to be able to give the optimum strength of the concrete or at least get the same compressive strength test value as the strength of the controlled concrete. Incorporation of this material as partial fine aggregate replacement in concrete making could reduce the quantities of seashells waste, reduce natural fine aggregate consumption and contribute towards a cleaner environment.

2. Literature Review

A seashell is a hard, protective outer layer that is usually generated by a sea animal. The animal's shell is a portion of its body. Beachcombers frequently come across empty seashells washed up on shore. The soft parts of the animal have been devoured by another animal or have disintegrated, thus the shells are empty. A seashell is typically made of calcium carbonate or chitin and is the exoskeleton of an invertebrate. The majority of shells that has been found are the shells of marine mollusks, partially because these shells are made of calcium carbonate, which lasts longer than chitin shells. Humans have utilized seashells for a variety of reasons throughout history and prehistory. Seashells are not the only kind of shells in different population but there are also shells that come from freshwater such as freshwater mussels and freshwater snails, and land snail shells. The aquaculture sector is one of Malaysia's most important industries. This is because of the strategic location, which allows for easy access to a protein source from the sea. Cockle shell is one of the great source of protein that can be obtained from the sea. The increasing of the annual production of sea shells will also indicates in the increasing of sea shells waste. The issue of waste disposal caused by the increased production of sea shells had led to an idea of turning it into a valuable material for a variety of applications.

3. Methodology

3.1 Flow Diagram

The implementation of work to achieve the objectives of this study is carried out. At the initial stage, literature reviews are prepared by collecting all relevant information from approved sources such as journals and technical papers that were obtained through the internet via various platforms such as google scholar, research gate, science direct and UTHM online library. When the research method is properly carried out, the review paper is a powerful source for researchers to gather the important information and to guide in making decision. Thus, the flow of this research methodology can be summarized in the flowchart shown in Figure 1.

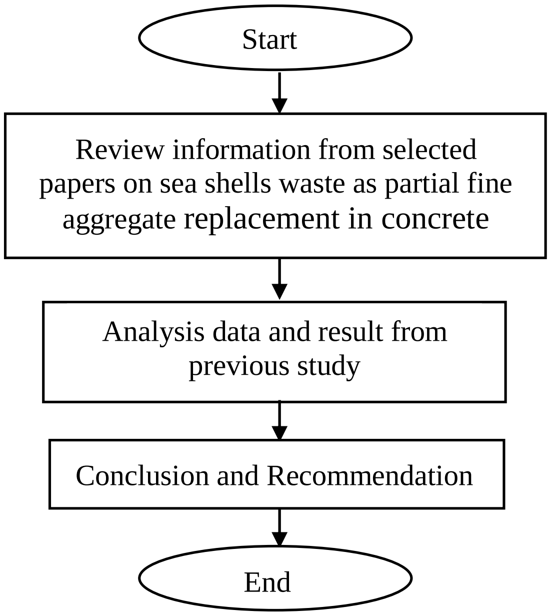

Figure 1: The flowchart of research methodology

3.2 Review Process

The first phase in the review process is research work. Research work or planning was carried out in this study to ensure the research process was conducted systematically and to ensure the research does not deviate from the objectives and scope of the study. In preliminary stage, the study was concentrated on review of previous studies seashells waste as partial fine aggregate replacement in concrete. Most of the study used seashells waste as a substitute of fine aggregate is due to the depletion of natural resources in Malaysia. Thus, the analyses on the use of sea shells waste as a partial fine aggregate replacement in concrete production is carried out.

The second phase is data collection process. Around 15 research papers were collected and reviewed to determine the compressive strength and split tensile strength of concrete containing seashells waste as partial fine aggregate replacement. The papers were reviewed within year 2010 until 2020 to ensure it is relevant. After that, the data that has been collected were analysed. The analysis involved two cases which are compressive strength and split tensile strength of concrete in order to obtain the best result. The main contributor in this study is the review of research paper involving the compressive strength test and also split tensile strength test of concrete containing clamshells waste. From the review, the optimum percentage of fine aggregate replacement can be obtained.

4. Results and Discussion

The results and discussion section presents data and analysis of the study in term of density, compressive strength and tensile strength of concrete containing crushed seashells as partial fine aggregate replacement.

4.1 Density

Density of concrete is a concrete solidity measurement. The concrete mixing process can be changed to produce a product with a higher or lower density. Concrete has a density of roughly 2400 kg/m3. The density of concrete has a significant impact on its mechanical qualities. Denser concrete has more strength and less voids and porosity than less dense concrete. As a result, water absorption will be reduced, and this form of concrete should last longer. Basically, the strength and durability of concrete is influenced by the parameters such as compaction, curing, method of mixing and grade and granularity of the aggregates. A summary of results for the A summary of results for the previous research studies on the density of sea shells waste replacement for 7 days and 28 days are shown in Table 1.

Table 1: Density Result

Author	Type of Seashells	Seashells Percentage (%)	Density (kg/m^3)	
			7 days	28 days
[4]	Mussel Shell	0	Not mentioned	2419.70
		10		2401.40
		30		2362.10
		60		2275.80
[5]	Mussel Shell	0	Not mentioned	2400.00
		25		2250.00
		50		2100.00
		75		2100.00
		100		2200.00
[6]	Cockle Shell	0	2282.21	2343.80
		5	2089.58	2381.25
		10	2039.58	2368.75
		15	2002.08	2350.00
[3]	Mussel Shell	0	Not mentioned	2370.00
		25		2220.00
		50		2090.00
		75		2100.00
		100		2110.00
	Scallop Shell	0	Not mentioned	2360.00
		20		2370.00
		40		2390.00
		60		2360.00

According to Gonzalez et al., [5], the density of concrete containing mussel shell waste shows downward trend as the percentage of mussel shells replacing the fine aggregate increases. However, the density increases when the fine aggregate is being replaced with 100% of mussel shells which is 2200 kg/m3. Two percentage obtained the same value with 2100 kg/m3 which are 50% and 75%. It was found that the optimum density obtained when the fine aggregate was not replaced with mussel shells.

Sainudin et al., [6] in his study indicates the density of utilization cockle shell powder with 0%, 5%, 10% and 15%. As can be seen in Table 1, the increasing of percentage of cockle shells resulted in the decreasing of the density of concrete on 7 days. It may due to incomplete hydration process. However, the density of concrete containing cockle shell resulting a higher density compared to the control concrete. Concrete with 5% of cockle shell used has the highest density. When concrete containing cockle shell were compared to control concrete, the density was altered by the minimum number of air voids. Even though it displays inconsistencies in each reading over the course of 28 days.

However, the density of cockle shell concrete varied from 0.26% to 12.27% when compared to control concrete. Thus, it has no effect on the cockle shell concrete' physical properties.

Eziefula et al., (2018) [3] reviewed two types of clamshells as substitute for fine aggregate in concrete which are mussel shells and scallop shells. With mussel shells replacing fine aggregate, the concrete was made in absolute volume percentages of 0%, 25%, 50%, 75% and 100%. From this study, the highest density obtained was control concrete with 0% of mussel shell replacing fine aggregate which is 2370 kg/m3 and the lowest is obtained when the fine aggregate was replaced with mussel shells at 75% which is 2100 kg/m3. However, when the fine aggregate was replaced with 40% of scallop shells, the highest density was obtained which is 2390 kg/m3.

4.2 Compressive Strength

Compressive strength refers to a material or ability of the structure to bear load over time. One of the tests used to assess the maximum capacity of compressive load that a structure can withstand before rupturing is the compressive strength test. The compressive strength value is divided into the maximum compressive load with the cross sectional area of the structure. A summary of results from previous study on compressive strength of clamshells waste after 7 days and 28 days are listed in Table 2.

Table 2: Compressive Strength Result

Authors	Type of Seashells	Percentage of Seashells waste (%)	Compressive Strength (MPa)	
			7 days	28 days
[7]	Cockle Shell	0	Not mentioned	48.22
		5		48.11
		10		50.24
		15		42.69
		20		34.00
		25		30.21
		30		27.65
[8]	Sea Shell	0	Not mentioned	27.27
		20		31.94
		40		32.22
		60		42.02
		80		44.40
		100		27.50
[9]	Sea Shell	0	Not mentioned	26.49
		2		28.52
		4		31.73
		6		31.73
		8		35.21
		10		36.64
		15		29.89
		20		27.47
[10]	Clam (lokan) Shell	0	Not mentioned	36.95
		10		39.71
		20		38.04
		30		42.86
[11]	Cockle Shell	0	23.50	34.20
		5	23.50	40.00
		10	30.00	40.05
		15	22.50	32.50
		20	22.50	31.80
		25	15.00	24.80

[12]	Oyster Shell	0	26.25	31.22
		10	28.72	33.34
		20	29.21	37.21
		30	27.43	32.52
		40	25.78	30.94
[13]	Periwinkle Shell	0	20.20	24.00
		10	18.00	23.70
		30	14.80	19.20
		50	14.00	18.50
		100	4.50	6.00
[4]	Mussel Shell	0	38.9	49.30
		10	36.5	48.00
		30	31.7	39.40
		60	21.6	26.50
[5]	Mussel Shell	0	Not mentioned	30.00
		25		20.00
		50		9.00
		75		8.20
		100		8.30
[6]	Cockle Shell	0	36.00	44.60
		5	49.30	55.10
		10	44.90	48.30
		15	42.90	43.90
[14]	Cockle Shell	0	Not mentioned	30.4
		5		28.0
		10		28.4
		15		27.1
		20		26.0
		25		24.6
[15]	Seashells	0	Not mentioned	36.2
		20		43.8
		40		48.0
		60		42.4
		80		37.5
		100		27.5
[3]	Clam Shell	0	Not mentioned	37.0
		10		40.0
		20		38..0
		30		43.0
	Mussel Shell	0	Not mentioned	29.0
		25		20.4
		50		9.7
		75		9.0
		100		9.0
	Oyster Shell	0	Not mentioned	29.0
		10		28.5
		20		29.0
	Periwinkle Shell	0	Not mentioned	25.0
		10		23.8
		30		18.0
		50		17.5
	Scallop Shell	0	Not mentioned	32.5
		5		34.0
		20		32.5

	40	30.3
	60	32.0

Ramakrishna & Sateesh [7] studied the using cockle shells waste as fine aggregate replacement of 0%, 5%, 10%, 15% and 20%. This study found that the compressive strength for 10% replacement has the highest value of 50.24 MPa compared to the others. The replacement of 5% and 10% helps to achieve higher concrete strength than plain concrete. The increased strength is most likely owing to the crushed cockle shell's effective role as a space filler. The compressive strength of crushed cockle shell continues to decrease as the content of crushed cockle shell increases by more than 10% replacement as shown in Figure 2.

A similar study has been tested by Muthusamy et al. [11]. It is seen that the highest compressive strength was obtained at 10% of replacement of fine aggregate with cockle shells on the 7th day and 28th day which are 30 MPa and 40.05 MPa. As can be seen, replacing river sand with crushed cockle shell up to 10% contributes to increased concrete strength. Replacing 5% and 10% of fine aggregate contributes towards improvement of concrete strength. The increase in strength is most likely due to crushed cockle shell's effective role as a filler. As the amount of crushed cockle shell added increase beyond 10% replacement, the compressive strength continues to decline. This preliminary research suggests that including a suitable crushed cockle shell content could be used to substitute natural river sand in the concrete construction with increased compressive strength.

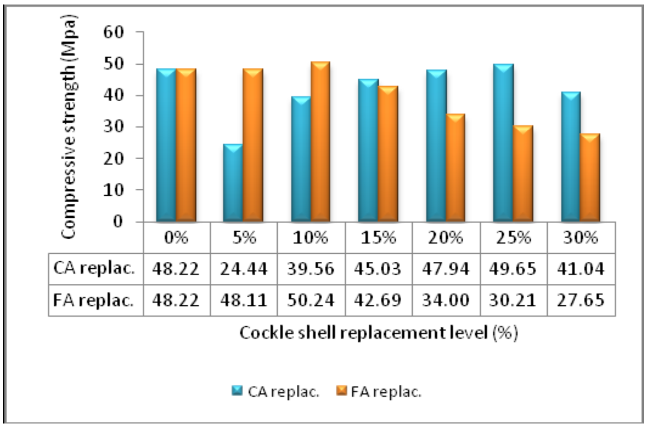

Figure 2: Graph of Compressive Strength of Concrete Containing Various Percentage of Cockle Shells at the Age of 28 Days [7]

From the previous study that used seashells as fine aggregate replacement conducted by Mohanalakshmi et al. [8], the highest compressive strength of concrete containing sea shells obtained on 28th day is when the sand is replaced with 80% of seashells. Based on the result shown in Table 2, the compressive strength continue to increase from the 0% replacement until the 80% replacement. As the amount of crushed cockle shell added increase beyond 80% replacement, the compressive strength continues to decline.

Pragadeesan & Harishankar [9] used various percentage of seashells as fine aggregate replacement which are 0%, 2%, 4%, 6%, 8%, 10%, 15% and 20%. The compressive quality of the cube samples was displayed in the Figure 3 for various mix extents. Three concrete cubes were formed for each mix proportion. The concrete cubes were examined after 28 days of curing. The average compressive strength of the material was taken into account and the strongest concrete is obtained when the fine aggregate was replaced with 10% of seashells. This might due to quality of concrete mixtures containing seashells is higher than concrete without seashells for a long time range. In the meanwhile, the compressive strength of concrete containing 4% and 6% of seashells obtained the same value which are 31.73 MPa. The compressive strength continue to rise along with the increasing of percentage of cockle shell replacement until 10% replacement and after that the compressive strength is decreasing.

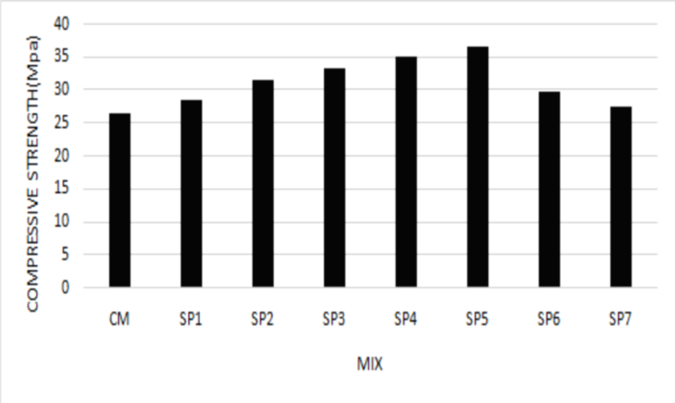

Figure 3: Compressive Strength of Concrete Containing Seashells [9]

A study about application of clam (lokan) shell as beach retaining wall that has been conducted by Yusof et al. [10] shows that lokan powder used as a substitute of fine aggregate gives a significant impact on the concrete strength. The strength of fresh concrete which does not contain any lokan powder is 36.95 MPa. However, by adding lokan powder to a 10% of mass fraction, the strength can be increased to 39.71 MPa. This might occur due to the filling effect of fine aggregate in concrete and also due to adhesive bond between particles. The strength of aggregate will increase if the adhesive bond between particles occurred as each particle needed more force to shatter. At 20% lokan powder, there is a sudden decrease to 38.04 MPa but it is still higher than reference specimen. It is also stated that 30% lokan powder had the highest compressive strength of 42.86 MPa. This might occur due to outstanding effect of micro filling and low porosity of cement matrix. The compressive strength value of 30% mass fraction of lokan shell that was higher than control concrete makes the researcher assume that it could be a potential choice for a beach retaining wall.

Aye et al. [12] studied on the strengthening of concrete by using oyster shell and marble powder. A total of 5 types of samples consists of 0%, 10%, 20%, 30% and 40% of oyster shells were used to replace fine aggregate in concrete production. From the result in Table2, the sample with 20% of oyster shells aggregate had obtained the highest compressive strength of 29.21 MPa on the 7th day and 37.21 MPa on the 28th day while the lowest compressive strength obtained was when the fine aggregate was replaced with 40% of oyster shells on both of 7th day and 28th day.

Soneye et al. [13], stated on their study that the control concrete obtained the highest compressive strength compared to the other concrete containing periwinkle shell. The result shows a declination of compressive strength of concrete when the replacement of fine aggregate with periwinkle shells take place and it was found that 100% replacement of fine aggregate with periwinkle shells give the lowest compressive strength in concrete.

4.3 Tensile Strength

Tensile strength is also one of basic properties in concrete. Its value is required to design structural elements of concrete, liquid retaining structures and roadways. Direct tensile strength of concrete is hard to determine, thus splitting tensile strength test is required to determine the tensile resistance of concrete by using a cylindrical specimen's according to ASTM standard. The successful operation of this test requires careful alignment of the cylinder to ensure uniform bedding, especially in the case of weak concrete. The test was basically tested on the 28th day of curing in order to obtain the maximum tensile strength of concrete. A summary of results for the previous research studies on the tensile strength of seashells waste replacement are shown in Table 3.

Table 3: Tensile Strength Result

Author	Type of Seashells	Seashells Percentage (%)	Splitting Tensile Strength (MPa)	
			7 days	28 days
[5]	Mussel Shell	0	Not mentioned	2.20
		25		1.60
		50		1.25
		75		1.05
		100		1.05
[7]	Cockle Shell	0	Not mentioned	4.88
		5		4.57
		10		4.69
		15		4.18
		20		4.08
		25		3.85
		30		3.68
[8]	Seashell	0	Not mentioned	2.047
		20		2.491
		40		2.623
		60		2.698
		80		3.694
		100		3.165
[9]	Seashell	0	Not mentioned	2.77
		2		2.90
		4		3.10
		6		3.14
		8		3.22
		10		3.38
		15		2.96
		20		2.84
[10]	Oyster Shell	0	2.54	4.36
		10	2.71	4.46
		20	3.16	4.73
		30	2.90	4.67
		40	2.44	4.30
[3]	Mussel Shell	0	Not mentioned	2.20
		25		1.70
		50		1.36
		75		1.14
		100		1.00
	Oyster Shell	0	Not mentioned	2.91
		5		2.82
		10		2.77
		20		3.20
	Scallop Shell	0	Not mentioned	3.00
		5		3.10
		20		3.27
		40		2.80
		60		2.90

Gonzalez et al. [5] studied the effects of seashell aggregates in concrete properties. This study found that the split tensile strength of control concrete specimen has the highest value of 2.20 MPa compared to the others. The tensile strength of mussel shell continues to decrease as the content of mussel shells increased by more than 25% replacement. The introduction of mussel shell aggregates reduces this property once further. In this situation, using mussel shell aggregate in structural concrete results in reductions of roughly 10%, regardless of the proportion of sand used. However, when non-structural concretes are examined, it is clear that when natural sand is replaced with mussel shell sand, the reductions are significantly greater, always exceeding 25%.

Ramakrishna & Sateesh [7] studied the using cockleshells waste as fine aggregate replacement of 0%, 5%, 10%, 15% and 20%. This study found that the split tensile strength of control concrete specimen has the highest value of 4.88 MPa compared to the others. The tensile strength of crushed cockleshell continues to decrease as the content of crushed cockleshell increases by more than 5% replacement.

From the previous study that used seashells as fine aggregate replacement conducted by Mohanalakshmi et al. [8], the highest tensile strength of concrete containing seashells obtained on 28th day is when the sand is replaced with 60% of seashells. Based on the result shown in Table 3, the tensile strength continue to increase from the 0% replacement until the 60% replacement. As the amount of crushed cockleshell added increase beyond 60% replacement, the tensile strength continues to decline.

Pragadeesan & Harishankar [9] used various percentage of seashells as fine aggregate replacement that are 0%, 2%, 4%, 6%, 8%, 10%, 15% and 20%. Three concrete cylinders were formed for each mix proportion. The concrete cylinders were examined after 28 days of curing. The average tensile strength of the material was taken into account and the strongest concrete is obtained when the fine aggregate was replaced with 10% of seashells and was found to be 3.38 MPa. The split tensile strength of 15% and 20% replacement cylinders were found to be 2.96 MPa and 2.84 MPa respectively on the 28th day. Control concrete has a split tensile strength of 2.77 MPa. The concrete cylinder containing 2% replacement of fine aggregate with seashell had a split tensile strength of 2.9 MPa. Concrete cylinders containing 4% replacement and 6% replacement were determined to be 3.1 MPa and 3.14 MPa respectively. The concrete cylinder containing 8% replacement had a split tensile strength of 3.22 MPa, which was higher than the typical strength. When compared to the standard mix, the 10% replacement had a 1.22 times higher split tensile strength.

Aye et al. [10] studied on the strengthening of concrete by using oyster shell and marble powder stated that the tensile strength of concrete is a distinctive property that is extremely important. A total of five types of samples consists of 0%, 10%, 20%, 30% and 40% of oyster shells were used to replace fine aggregate in concrete production. The test specimen, a 100mm cylinder, was put to the test for 7 and 28 days. Concrete with 20% of oyster shells obtained the highest tensile strength on the 7th day and 28th day than all other concrete mixes, as shown in the Table 3. As the amount of oyster shell in the concrete mix increases, the strength may be reduced due to unfilled micro voids in the mix.

Eziefula et al. [3] reviewed the properties of seashell aggregate concrete. In this previous study, the type of seashells used as fine aggregate replacement are mussel shell, oyster shell and scallop shell. Control concrete of mussel shell concrete obtained the highest tensile strength of 2.20 MPa and for concrete with fine aggregate replacement of oyster shells, 20% of oyster shells obtained he highest tensile strength. As for scallop shell as partial fine aggregate replacement in concrete, the highest tensile strength of concrete obtained is 3.27 MPa with 20% replacement.

5. Conclusion

Based on the results and discussion in this review paper, some conclusions can be made based on the objectives of this study. For density result, it can be seen that the control concrete has the highest density compared to the other concrete with various percentage of fine aggregate replacement by using mussel shells. From the research that has been conducted by Sainudin et al. [6], concrete containing 10% of cockleshell as fine aggregate obtained the highest density compared to the control concrete and the other percentage of replacement. For the analysis of scallop shells, the highest density is obtained by the 40% of replacement compared to the others. For most mix proportions, the density of concrete generally greater than 2100 kg/m3 when the fine aggregate was replaced with 50% of seashell. For the compressive strength and tensile strength analysis, there are various types of seashells waste used in replacing the fine aggregate in concrete such as cockleshell, lokan shell, mussel shell, scallop shell, seashell, and periwinkle shell. The result obtained from the various clamshells is fluctuated. However, based on the analysis on the replacement of different type of clamshells that has been reviewed, it can conclude that the strength of concrete decrease with increasing content of clamshells except for seashells and clamshells. Hence, not all type of clamshells is suitable for fine aggregate replacement in concrete. The optimum percentage for cockleshell is 5% to 10%, for oyster shell is 20%, for scallop shell is 5% and 0% to 100% for seashells as replacement of fine aggregate in concrete work because it gives the highest value for compressive strength test compared to the other percentages.

For future studies, the durability properties of seashells concrete can be determined by having durability test such as water absorption test, surface absorption test and water permeability test. Review study on impact value and crushing value can be done in order to analyse the strength properties of seashells. Moreover, use 5% to 10% of cockleshell, 20% of oyster shell, 5% of scallop shell and 0% to 100% of seashells as replacement of fine aggregate in concrete work to improve the compressive strength of concrete. Finally yet importantly, use the different method of curing process such as curing in the seawater to investigate if it can affect the results.

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