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A Review: Effects Of Mussel Shell Ash As Concrete Mixture Under Sodium Chloride Exposure

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Abstract: This research study focuses on previous works based on the effect of corporation mussel shell in concrete designing under sodium chloride exposure. Among the waste issue generated from fishery sector, it can be identified is that seashells waste such as mussel shell has been dumped into landfills. Seashell is one of waste that are potentially to be used as recyclable materials. From a scientific point of view, seashell waste rich in mineral elements which is similar to cement. It consist of calcium carbonate ($CaCO_3$) which is more than 90% calcium carbonate compared to lime that been used in cement production. Therefore, the focus of the previous review studies focuses on the use of solid waste from the seashells. In every review research of the study, shells have the potential to be a mixture or substitute in concrete. In a review of the study conducted, there are severals articles that have been referred to get the optimal percentage for seashells mixture which this percentage can be used in subsequent studies. This review is done based on previous study on laboratory test including compression strength tests, tensile strength tests and density. For the physical properties of the seashells were studied based on the analysis of specific gravity and chemical composition from the previous review studies. From a previous review study, the use of seashells has the potential to be a mix in concrete to improve compressive strength, density and tensile strength. Once researched, it also has a high capacity or equivalent to ordinary conventional concrete that is exposed to aggressive environments such as seawater (whose main chemical composition is high sodium chloride). This previous review study is focused on 28 days curing and mussel shell. Among of this previous review study, can conclude that the optimum percentage of seashells as cement mixture is between 2 – 3% for the compressive strength, 2-4% for the density and 2-6% for the tensile strength. Optimum percentage for curing for 28 days is 2.37% concentrated of sodium chloride (NaCl) with 1% of mixture for mussel shells in concrete.

Keywords: Mussel Shell, Sodium Chloride, Compression Strength

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1. Introduction

Today, the development of infrastructure in a country is accelerating with the development and housing that has been successfully built. It is the backbone to the development of a country. Therefore, the use of natural resources such as seashells is highly recommended for use in any required sector. In the construction sector, various new ways and ideas have been put in place to improve the use of natural resources. Many of the natural resources needed to produce buildings are mainly concrete and aggregate.

In addition, some wastes can be processed for use such as seashells that have the potential to be mixed materials in the manufacture of the concrete. In this previous review study, the seashells are expected to be able to increase the strength of concrete or at least get the same strength value as normal concrete strength. Mussel shell in particular has a very high content of 90% calcium carbonate ($CaCO_3$). If desired in contrast to the calcium content present in limestone, its content contains only 75% calcium carbonate ($CaCO_3$) [1].

The characteristics and similarities of seashells skin waste are seen to have the potential to be made as a mixture to the original material of concrete. Therefore, this study aims to find out the effect of concrete mix of seashells powder on curing in sodium chloride through the previous review studies. The focused for this previous review study is to find out the ability of seashells concrete mixture of mussel shell against the curing in sodium chloride and identify the optimum percentage of the use of seashells as a partial mixture in concrete that were focused on mussel shell. This previous review studies is also focused to identify the physical properties of seashells include specific gravity and chemical composition of seashells such as mussel shells, cockle seashell and other else seashells but focused on mussel shell.

Waste materials such as seashells are generally disposed immediately to landfills. From a scientific point of view, waste products such as mussel shells are seen to have mineral elements found in cement which is calcium carbonate ($CaCO_3$) [2]. Therefore, this review was carried out on effects of mussel shell mixture concrete on curing in sodium chloride. The objectives for this previous review study is to identify the physical properties of seashells, to determine the ability of seashells concrete mixing against curing in sodium chloride and to identify the optimum percentage of the use of seashells as a partial mixture in concrete. Malaysians focused on physical properties, ability and optimal percentage of seashells. The use of seashells in concrete was reviewed and analyzed from collection of previous studies. Total of 50 literature reviews from previous research that published in year 2006 until 2020 were compared in term of experimental results.

2. Literature review

Literature review which has been used in this previous review study is about concrete, coarse aggregate, fine aggregate, cement and more focused on mussel shell. And also literature review for the previous review study of laboratory density test, compressive test and tensile test.

2.1 Concrete

Concrete is a mixture of cement, water, fine aggregate and coarse aggregate. These ingredients are designed according to the specific mixing rate as prescribed. It is the main and important material in the construction of a structure. In mixtures of concrete, materials such as cement and water are the active ingredients, while coarse aggregate and fine aggregate are inert materials [3]. Therefore, the concrete mix specification needs proper study to produce quality concrete. The use of high-strength concrete has provided many advantages including reducing the size of beams and columns, and can increase the height level of buildings [4]. Concrete is also an excellent fire resistance material and it can retain its structure for a longer period of time than steel structures [5].

2.2 Coarse aggregate

Coarse aggregate is make an important role in providing strength and durability to concrete structures. Coarse aggregate is a material that has its own physical properties that can affect the strength of concrete when mixed with cement, fine aggregate and water. The material and texture of the surface are the main factors that determine the strength of the aggregate bond. Coarse aggregate and concrete are easy to find failure when there are some types of minerals that are inappropriate or undesirable. In general the compressive strength of coarse aggregate is much higher than the compressive strength of concrete mix. The lowest coarse aggregate compression strength ever measured is about 80MPa and this value can reach up to 530MPa (quartz rocks) [3]. The strength of concrete will also be influenced by the surface texture of coarse aggregate such as smoothness factors and the presence of foreign materials such as dry sludge, soil or organic matter attached to or attached to it. A rough surface texture will result in a stronger rough bond compared to a smooth texture. Therefore, these features will help produce concrete that has good strength

2.3 Fine aggregate

Fine aggregate such as river sand is a natural material that is exposed to the environment. Therefore, the fine aggregate used should be clean and free from any dirt, organic matter and chemicals that could affect the quality and strength of the concrete [3]. The definition used by geologists for the size of fine aggregate particles is measure between 0.0625mm to 2mm. Every grain in this size range is known as fine gravel grain. Next are small stones, with particle sizes ranging between 2mm to 64mm. Next is mud which is a small particle from girth 0.0625mm to 0.004mm. The size specification between fine aggregate and pebbles has remained the same for more than a century, but particles with a circumference of 0.02mm have been defined as fine aggregate under the Albert Atterbeerg standard used as early as the 20th century [6].

2.4 Cement

The original materials used for the manufacture of Portland cement are natural rocks such as limestone contained calcium oxide (CaO), silica (SiO_2) and aluminium oxide (Al_2O_3). Natural rocks that belong to the cement are "Calcareous" and "Argillaceous". In this literature review study, the cement used is ordinary Portland cement (OPC). Common Portland cement is the most popular cement used in the construction industry. According to the ASTM C150 term, Portland cement is defined as hydraulic cement produced from crushed limestone that consists of hydraulic calcium silicate and contains one or more forms of additional calcium silicate. The composition of common Portland cement chemicals consists of calcareous (CaO) of 60% to 67%, Silica (SiO_2) of 17% to 25%, Alumina (Al_2O_3) of 3% to 8%, Iron Oxide (Fe_2O_3) of 0.5 % to 6%, Magnesium oxide (MgO) content of 0.1% to 4%, Sulfur Trioxide (SO_3) of 1% to 3%, Sodium oxide (Na_2O) and Potassium (K_2O) were between 0.5% to 1.3% respectively [7].

2.5 Mussel shell

Mussel shell is one of the species containing a source of calcium in the form of calcium carbonate used in the cement industry in addition to limestone, lime and dolomite [8]. Fisheries industry can produce more than 1 million tons of waste worldwide which is the biggest problem on a global scale [2]. Physical properties of mussel shell are included for specific gravity and chemical composition. For the mussel shells specific gravity is between 2.86 to 3.01 lower than cement's specific gravity which is 3.11 to 3.15. The mussel shells is a type of shell that has a round and oval shape at the tip of the skin and has two pieces of dark green skin (moss green) and light green stripes on the edge [9]. For the mussel shells chemical composition, the highest percentage of chemical composition in mussel shells is calcium carbonate, $CaCO_3$ which is 95.6% [10]. The second most chemical composition in mussel shell is calcium oxide, CaO which is 53.38%. Lack of calcium oxide, CaO will reduce the strength of cement [2].

2.6 Density

For the previous study on laboratory density test, most of the previous review study showed the values obtained are as needed as the density of concrete decreases with increasing percentage of seashells. The lowest density was recorded on the periwinkle shell mixture of 75% and the highest mixture was recorded on the seashells mixture of 25% for a curing period of 28 days [11]. The density of fresh limestone powder concrete should also be considered when investigating the mechanical behavior of the material as it affects the elastic modulus and compressive strength. Due to the presence of limestone in the concrete, it causes a decrease in density [12].

2.7 Compressive strength

For the previous study on laboratory compressive strength test, most of the previous study showed the values obtained are as needed as the compressive strength of concrete decreases with increasing percentage of seashells. The activity index is seen to decrease as the level of mixing periwinkle shell powder with Portland cement increases [13]. The amount of calcareous oyster seashells powder mixed should be limited to less than 6% with regard to the workability and mechanical properties of the concrete [14]. This is because a significant decrease related to compressive strength is seen beginning to show a decrease in the percentage of mixture of more than 6% compared to the control sample.

2.8 Tensile strength

For the previous study on laboratory tensile strength test, most of the previous study showed the values obtained are as needed as the tensile strength of concrete decreases with increasing percentage of seashells. the tensile strength of the concrete mix provided should be placed in a horizontal position and the load will be applied gradually and results will be taken [15]. The strength of concrete increase when the time period for the curing process increase. The curing period of concrete is important because it will maintain the process of hydration of cement with water until the concrete reaches optimum strength. A longer curing period is also important to ensure that the strength of the concrete can be increased from the pozzolanic reaction [16].

3. Methods

A methodology is a system of methods used in a study. It is a systematic way to solve a problem and explain, describe and discuss the process of research, instruments that have been used during data collection and the methodology to analyse and to obtain the result in order to achieve the objective of this research.. All the procedures and flow of previous review works of concrete effects of mussel shell mixture on curing in sodium chloride will be explained in details.

3.1 Data collection process

The preparations for the study have been done to ensure that the research implementation process can be done in an orderly manner. This thesis focuses on the previous research on the use of seashells as an additive in concrete. Part of the review for the study that uses seashells as an additive in concrete is to get the optimum percentage for the density, compressive strength and tensile strength. Analysis was focused on performance using mussel shells as additives for cement, fine aggregate and coarse aggregate in concrete.

A total of 50 highlights of the research study were conducted to assess the density, compressive strength and tensile strength of concrete containing seashells and limestone were collected and analyzed. Research on the physical properties such as chemical composition and specific gravity between seashells and limestone was also collected and researched. Papers were analyzed between years 2006 and 2020 to ensure that scientific results remain relevant and up-to-date. There are 24 previous review studies on physical properties, 43 previous review studies on ability to density, compressive strength and tensile strength of seashells in concrete and 4 previous review studies on seashell concrete against curing in sodium chloride.

4. Results and Discussion

The results and discussion section presents data and analysis of the previous review study. This section is organized based on the stated objectives which is to identify the physical properties of seashells, to determine the ability of seashells concrete mixing against curing in sodium chloride and to identify the optimum percentage of the use of seashells as a partial mixture in concrete.

Table 1 shown the number of review studies and specific gravity of seashells as partial mixture in concrete accordance to 13 previous review studies on specific gravity of seashells in concrete. Accordingly, the specific gravity for all types of seashells as partial mixture in concrete is in ranged 1.42 to 3.03. It is shown that the most review studies found in mussel shells as a partial concrete mixture with a total of 8 previous review studies and specific gravity values ranged from 2.82 to 3.01.

Table 1: Specific gravity of various seashells

Types of seashells	Specific gravity
Mussel [1][10][17-21]	2.82 – 3.01
Cockle [10][18][20-24]	2.82
Oyster [10][18-21]	2.65
Clam [18][21]	2.71
Scallop [20]	2.50 – 2.64
Periwinkle [10][20]	1.42

Table 2 shown the percentages of chemical composition in seashells accordance to 24 previous review studies. The highest calcium oxide, CaO content is found in the periwinkle shell with 55.53% compared to mussel shells 53.38%. Calcium oxide, CaO deficiency will reduce the strength of cement. Calcium oxide, CaO deficiency causes cement to hardening quickly. The chemical composition is focused on mussel shells from the previous review studies.

Table 2: The percentages of chemical composition in seashells

Chemical composition (%)	Type of seashells					
	Cockle [10][18-28]	Oyster [10][18-21][29-32]	Clam[18][20-21][26]	Mussel [1][10][17-21][31]	Scallop [20]	Periwinkle [10][13][20][29][32]
SiO_2	1.6	1.01	0.84	0.73	0.10	26.26
Al_2O_3	0.92	0.14	0.14	0.13	0.10	8.79
Fe_2O_3	-	0.07	0.06	0.05	0.03	4.82
CaO	51.56	53.59	53.99	53.38	53.70	55.53
MgO	1.43	0.46	0.08	0.03	0.18	0.40
K_2O	0.06	0.02	0.03	0.02	0.01	0.2
SO_3	-	0.75	0.16	0.34	0.32	0.18
Na_2O	0.08	0.23	0.39	0.44	0.50	0.25
$CaCO_3$	-	96.8	96.8	95.6	-	-

Table 3 shown the optimum percentage based on its density values of replacement and mixing of seashells in concrete. Based on previous review studies, there are 8 previous review studies that discuss the density values of seashells in concrete. The optimal percentage for the density performance is focused for the mix of mussel shells in concrete and the optimal percentage of the partial mixture is between 2% to 4%.

Table 3: Optimum percentage based on density of replacement and mixing of seashells in concrete

Types of seashells	Fine aggregate replacement (%)	Coarse aggregate replacement (%)	Cement replacement (%)	Concrete mixture (%)
Cockle	-	7% [15]	4%-5% [10][21][22][25]	-
Clam	-	-	4% - 6% [10][21][26][33]	-
Mussel	30% [31]	-	-	2% - 4% [1][34]

Table 4 shown the optimum percentage based on compressive strength values of replacement and mixing of seashells in concrete. There are 43 previous review studies for replacement and mixture that discuss the compressive strength value of seashells in concrete. The optimum percentage for the compressive strength performance is focused for the mix of mussel shells in concrete and the optimum percentage of the partial mixture is between 2% to 3%.

Table 4: Optimum percentage based on compressive strength of replacement and mixing of seashells in concrete

Types of seashells	Fine aggregate replacement (%)	Coarse aggregate replacement (%)	Cement replacement (%)	Fine aggregate mixture (%)	Concrete mixture (%)
Periwinkle	-	25% [29]	10% [10]	-	-
Cockle	10% [24][28][35]	20% - 25% [36-37]	4% - 5% [10][21-22][25]	-	4% [26]
Oyster	5% - 20% [10][19][38]	-	5% - 15% [19][21][30]	-	3% [14]
Clam	-	-	4% - 6% [10][21][26] [33]	-	-
Mussel	20% [31]	-	5% [10]	-	2%-3% [1][34]

Table 5 shown the optimum percentage based on tensile strength values of replacement and mixing of seashells in concrete. There are 43 previous review studies for replacement and mixture that discuss the tensile strength value of seashells in concrete. The optimum percentage for the tensile strength performance is focused for the mix of mussel shells in concrete and the optimum percentage of the partial mixture is between 2% to 6%.

Table 5: Optimum percentage based on tensile strength of replacement and mixing of seashells in concrete

Types of seashells	Fine aggregate replacement (%)	Coarse aggregate replacement (%)	Cement replacement (%)	Fine aggregate mixture (%)	Cement mixture (%)
Periwinkle	-	-	30% [32]	-	-
Cockle	10% [24][28][35]	21% - 25% [36-37]	4% - 5% [10][21-22][25]	-	-
Oyster	20%	-	-	-	-
Clam	-	-	4% - 6% [10][21][26][33]	-	-
Mussel	-	-	5% [10]	-	2% - 6% [1][34]

Table 6 shown the optimum percentage based on compressive strength values of replacement and mixing of seashells in concrete when curing in sodium chloride. There are 4 previous review studies for replacement and mixture that discuss the compressive strength value of seashells in concrete when curing in sodium chloride. The optimum percentage for the compressive strength is focused for the mix of mussel shells in concrete and the optimum percentage of the partial mixture is 1% and the optimum percentage for curing in sodium chloride for 28 days is 2.37% concentration of sodium chloride.

Table 6: Optimum percentage based on compressive strength of replacement and mixing of seashells in concrete when curing in sodium chloride

Types of seashells	Cement replacement (%)	Cement mixture (%)	Curing in sodium chloride (%)
Cockle [23]	5%	-	5%
Mussel [1]	-	1%	2.37%

Among of this results of previous review study that focused on mussel shell, the table shows that the optimum percentage of mussel shells as cement mixture is between 2 - 3% for the compressive strength, 2 - 4% for the density and 2 - 6% for the tensile strength. Optimum percentage of curing for 28 days is 2.37% concentrated of sodium chloride (NaCl) with 1% of mixture for mussel shells in concrete. For the physical properties, specific gravity values for mussel shell is in ranged from 2.82 to 3.01and calcium oxide, CaO in mussel shells is 53.38%.

5. Conclusion

From this previous review study, we can conclude that all of the objective are achieved. The first objective for this study is to identify the physical properties of seashells. Physical properties of seashells include specific gravity and chemical composition. For specific gravity, It was observed that the higher the specific gravity the higher the strength of concrete. For chemical composition, calcium oxide, CaO deficiency will reduce the strength of cement and also deficiency causes cement to hardening quickly.The second objective for this study is to determine the ability of seashells concrete mixing against curing in sodium chloride. For the compressive strength, 5% of partial cement replacement for cockle seashells curing in 5% sodium chloride and the compressive strength value is 22.0MPa compared with 1% of partial cement mixture for mussel shells curing in 2.37% of sodium chloride and the compressive strength value is 41.70MPa. So we can conclude that the ability of partial cement mixture is better than partial cement replacement.

The third objective for this study is identify the optimum percentage of the use of seashells as a partial mixture in concrete. So for the optimum percentage is 5% of partial fine aggregate mixture for sea shell and 2-6% of partial cement mixture for mussel shell. So we can conclude that the lower the percentage of seashells mixture, the higher the concrete strength of the seashells mixture. For the recommended to the next researchers for a better result is try to analyze the use of cement replacement with 5% to 15%, fine aggregate with 10% to 20% and coarse aggregate with 15% to 25% in concrete to determine the strength of the replacement concrete. And also try to analyze the use of cement mixture with 1% to 5% and fine aggregate with 1% to 10% in the concrete to determine the strength of the concrete mix. And lastly try to analyze the laboratory study using mixed or replacement of seashells concrete other than mussel shell, mollusc seashell and cockle seashell for curing in sodium chloride.

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