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Experimental Evaluation on Physical and Mechanical Properties of Concrete Containing Green Mussel Shell (*Perna viridis*) Powder as an Admixture

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Abstract: Mussel shell is a type of waste that is generated abundantly. However, the presence of chemical components such as calcium (CaCO₃) in mussel shells has shown its potential as filler materials in concrete designing. Therefore, this paper presents the experimental result for the physical and mechanical properties of concrete containing 1%, 2%, 3% and 4% Mussel Shell Powder (MSP) as additional material under 2.73% sodium chloride solution. The MSP has been cleaned, grinded and sieved 75µm sizes in order to obtain its final product. Compressive strength, split tensile, and capillary water absorption were determined. Statistical analysis was performed to investigate the correlation and level of significance using IBM SPSS in determining the optimal mix design for modified concrete. The performance of MSP concrete and control specimens are the main factor that been observed in this study. The increment percentages of MSP in concrete had led to reduce on its mechanical strength, however improved in its absorption rates. According to statistical analysis, it shows that low MSP percentages giving a significant value for compressive strength and very strong correlation coefficient compared to control specimens, thus it indicated minimum MSP percentages are more potential in improving concrete physical and mechanical performance.

Keywords: Mussel shell powder, admixture, physical and mechanical properties, significant, correlation, optimum

1. Introduction

Durability is one of the vital criteria should be deliberates in concrete's designing for infrastructure and building components. It prescribes concrete ability in withstanding without significant deterioration and maintaining

concrete performance during its life services (Demis & Papadakis, 2019). In other words, it was designed by considering the durability aspect which regard to its life span. Generally, concrete durability is resembled through its quality and engineering performances to be long-lasting against an external load. However, it may depend on various factor, i.e., concrete resistance towards alkali-silica reaction and sulphate, protection against corrosion for reinforcing concrete, mixes design, type of cement's selection, alternative materials use, heat of hydration reaction, resistance against aggressive the environment, etc. (Fodil & Mohamed, 2018; Neville, 2011). In recent years, concrete exposure to an aggressive environment is one of the most concerning studies among researchers in identifying its durability (Manjunath *et al.*, 2019). More recently, literature has emerged that the reaction of aggressive exposure potentially changes the crystal structure and causes an adverse effect to concrete durability (Mehta & Monteiro, 2014; Gruyaert *et al.*, 2012; O'Connell *et al.*, 2012). It was also supported by several researchers such as Shi *et al.* (2017) and Qiao, Suraneni & Weiss (2018). Thus, these might cause a major impact on concrete durability and its performance.

Pore's availability in is the key that artery depending on transportation rates due to concrete's porosity or permeability characteristics (Liu *et al.*, 2018; Jivkov *et al.*, 2013). High porosity will resulting higher rate of ingress and absorption. However, concrete pores can be minimized through a significant application of admixture, which potentially improves concrete permeability and strong effect against aggressive agents (Liu *et al.*, 2018; Jivkov *et al.*, 2013; Zhang *et al.*, 2017; Siad *et al.*, 2015; Roig-Flores *et al.*, 2015; Mehta & Monteiro, 2014). Since long, admixture had become one of the significant interests in most research, especially on mineral by-product type's admixture. This admixture is also known as materials that have no bond properties and act as inert materials (Neville, 2011). On the other hand, its reaction with cement's hydration helps in improving hydration reaction for hardening processes (Mehta & Monteiro, 2014). Besides that, it was also potentially promoting sustainability in concrete production by current practices (Hazarika *et al.*, 2018).

Table 1 - Chemical composition of seashells (Lertwattanakruk *et al.*, 2012)

Parameter (%)	Materials		
	Mussel shells	Cockle shells	Oyster shell
CaCO ₃	95.6	97.13	96.8
SiO ₂	0.73	0.98	1.01
Na ₂ O	0.44	0.37	0.23
Al ₂ O ₃	0.13	0.17	0.14
MgO	0.03	0.02	0.46
Fe ₂ O ₃	0.05	0.06	0.07
SO ₃	0.34	0.13	0.75
SO ₄	0.11	0.07	0.43
Cl	0.02	0.01	0.01

Seashell is a by-product material that has the potential to be used in concrete designing. Chemically speaking, seashells consist of more than 95% of calcium carbonate (CaCO₃) by weight, which makes it as the major component and suitable to be used as filler materials in concrete (refer to Table 1) (Lertwattanakruk *et al.*, 2012; Martínez-García *et al.*, 2017; Olivia *et al.*, 2015). A filler consists of uniform properties on its fineness that essentially act as beneficial elements in improving concrete durability, permeability, and workability (Neville, 2011; Sainudin *et al.*, 2019). A previous study by Olivia *et al.* (2015) stated that the utilisation of cockle shells as cement partial replacement in OPC concrete potentially in improving concrete mechanical strength. They found that the increment of curing duration on 7, 28, and 91 days with a 4% replacement showed an increment in tensile and flexural strength compared to OPC concrete due to bonds interface improvements between cement paste and aggregates in it.

In another major study by Lertwattanakruk *et al.* (2012), considering the used of ground seashell consists of short-necked clam, green mussel, oyster, and cockle as replacement materials in mortar cement plastering had improved its properties compared to conventional cement. It was reported that the existing seashell in mortar increased concrete strength, less drying shrinkage, and lower thermal conductivity. However, the increment of replacements' percentages up to 20% for each type of seashell had reduced its mechanical compressive strength. Therefore, the replacement of seashell shall be used in limited in a small quantity. Since seashell has more significant effects in reducing the concrete porosity rather than its strength. Thus, it may be suitable to create less permeable concrete.

According to Makhloufi *et al.* (2016), the application of CaCO₃ with additional materials such as blast furnace slag and natural pozzolan in mortar showed a lower deterioration of specimens in magnesium sulfate solutions. They mentioned that filler materials (CaCO₃) acted as the secondary role in reducing the ingestion of magnesium

sulfate (MgSO₄) with percentages of less than 30% from 90 to 180 days. Based on expansion analysis, it showed that specimens with percentages of 10% CaCO₃ indicated the lowest expansion effect compared to ordinary Portland cement (OPC) mortar. A study by Safi *et al.* (2015) concludes that the substitution of crush seashell as substitution sand by fine aggregates into 5 mm particle sizes could improve concrete porosity and absorption. The replacement percentage of seashells more than 50% significantly reduced its percentages of porosity due to particle distribution of seashells, which fit uniformly between surface grains. Thus, less porosity will inhibit the ingestion of water diffused into concrete microstructure through its capillary resulting in fewer absorption rates.

Based on previous literature, it has been justified that calcium carbonate (CaCO₃) is potentially useful in enhancing and improving concrete durability and permeability (Food and Agriculture Organization of the United Nations, FAO, (2018). Thus, this study is focusing on exploring mineral admixture consists of mussel shell waste as concrete additional materials, which then cured under sodium chloride (NaCl) solution. Overall, this research was conducted to identify the physical and mechanical properties of mussel shell powder concrete, in which the data from tasted specimens were analyzed using statistical analysis through significant and correlation tests to determine the optimum MSP percentages.

2. Materials and Experimental Methods

2.1 Materials and Sample Preparation

Seashells or mollusks from *Perna viridis* (green mussel shell) types were selected, which is one of the highest productions in Johor compared to other states in Malaysia based on the statistical report by the Department of Fisheries Malaysia respectively (Malaysia Fishery Department, 2022). At first, the mussel shell was cleaned to remove dirt, then dried in a drying oven for a temperature of 180°C for 1hour. Then, the mussel shell was crushed with Los Angeles Abrasion machine and sieved to obtain less 75µm particle size. Materials used such as OPC and MSP in this study follow according to ASTM C128-01 and BS EN 1097-6: 2013, with the specific gravity value of 3.09 for OPC and 2.51 for MSP, respectively (10g samples) (British Standard Institution 2013; Teychenné *et al.*, 1997). Fig. 1 and Fig. 2 show the mussel shell and MSP used in this study.

MSP concretes were mixed in 5 different batches denoted as NC, MSP1C, MSP2C, MSP3C, and MSP4C. The test specimens were designed according to the Design of Normal Concrete Mixes with water to cement ratio of 0.51 (Teychenné *et al.*, 1997). The weights of materials used for Portland cement, coarse, and fine aggregates were 0.42 kg,

1.21 kg, 0.57 kg, respectively for 0.001 m³ mould (cube sizes 100mm × 100mm × 100mm). Whereas, for 0.0024 m³ mould (cylinder sizes 200mm × 100mm) were 0.84 kg of cements, 2.42 kg of course aggregates, and 1.14 kg of fine aggregates. Each of the materials were wrapped using plastic to prevent the presence of moisture in it.

Table 2 shows the percentages of mix proportion for cube and cylinder moulds including the weight of MSP admixture used. Whereas, the curing method used in this study is the water curing method, in which the specimens immersed totally in water after unmolding. This method is selected due to its effectiveness and comprehensiveness way of covering the total surface area of each specimen. Sodium chloride (Bendosen C1119-3301231) solvent as in Fig. 3 was used with mixed percentages of 2.73% of the total weight of water used for curing purposes. The temperature of cured water was maintained at 20 °C to 29 °C according to a minimum and maximum temperature reading.

Table 2 - Mix proportion for specimens

Samples	Percentages admixture	MSP (kg)	
		Cube sizes	Cylinder sizes
NC	100% concrete	0	0
MSP1C	100% concrete + 1% MSP	0.024	0.048
MSP2C	100% concrete + 2% MSP	0.048	0.096
MSP3C	100% concrete + 3% MSP	0.072	0.145
MSP4C	100% concrete + 4% MSP	0.096	0.193

2.2 Experimental Works

Compressive strength analysis is one of the analyses to be obtained in this study to identify its maximum strength when exposed to loads. This analysis is measured on cubic sizes 100mm × 100mm × 100mm according to the BS EN 12390-3:2009 (British Standard Institution, 2009). Its strength was observed based on 7, 28, and 90 days curing for each percentage of MSPC specimens. Whereas, split tensile analysis is devoted to this study to identify the strong resistance of MSPC specimens toward tension that can cause cracking. This test is observed based on the EN BS standard 12390- 6:2009 with cylindrical sizes of 100mm (diameter) × 200mm (length) for each specimen (British Standard Institution for Splitting Tensile, 2009).

On the other hand, capillary water absorption is served for the determination of water absorption through its capillary. This test is carried out using another sample of cube sizes (100mm × 100mm × 100mm) and measured

based on 7, 28, and 90 days of curing. The standard follows as in the RILEM CPC 11.2 (RILEM, 1982). The specimens were weighted according to an oven-dried mass of 105 °C for 24 hours. Each specimen was covered with tape for each side surface to promote absorption through one surface area. Fig. 4 shows the description of capillary water analysis and its capillary absorption was calculated by using the following Eq. (1).

$$\frac{-Q}{A} = k \sqrt{t} \tag{1}$$

Where:

k : Capillary water absorption coefficient (cm/s)

Q: Quantity of water absorbed (cm³)

A: Area of water absorption (cm²)

t : Time (s)



Fig. 1 - Mussel shells



Fig. 2 - Mussel shells powder



Fig. 3 - Sodium chloride (Bendosen C1119-3301231)

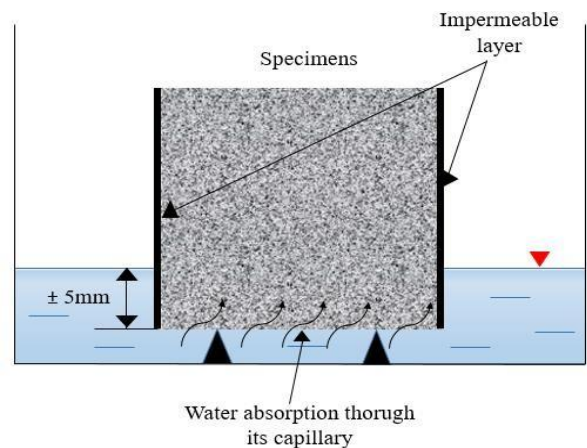


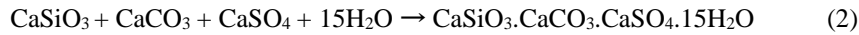
Fig. 4 - Capillary water absorption test

3. Results and Discussions

3.1 Analysis of Compressive Strength for Tested Specimens

Based on the compressive analysis, the increasing percentages of MSP tend to reduce concrete mechanical strength. As data presented in Fig. 5, it shows a strength reduction with an increment of MSP up to 4% (MSP4C) on 7, 28, and 90 days compared to the control sample (NC). According to Lertwattanakul *et al.* (2012), it is due to the properties of the materials of seashells itself that categorised as less reactive materials when corporate with Portland cement that causing less reaction. On the other hand, according to a study by Lee *et al.* (2008), they stated that the reduction of compressive strength may due to the formation of thaumasite ($\text{CaSiO}_3 \cdot \text{CaCO}_3 \cdot \text{CaSO}_4 \cdot 15\text{H}_2\text{O}$) calcium-silicate-sulfate-carbonate minerals that can be derived as in Eq. (2). Thaumasite formation could lead to CSH leaching, reducing C_3A , changes the

mono-ettringite phase (AFm) and effecting the hydration-aluminum compound in cement (Sun & Chen, 2018; Ramezani-pour & Hooton, 2013). This crystal compound occurred due to the high content of CaCO₃ (CO₃, carbonate ion) and the existence of calcium silicate hydrate (CSH), which could promote the assaulting of sulfate (SO₄⁻) from solution in concrete specimens. However, thaumasite formation in this study remains clearly explained due to unclear chemical analysis on SO₄⁻ ingress in concrete. Thus, further research needs to be done in order to identify the accuracy of thaumasite formation in MSP concrete.



Although overall data shows a descending trend with the increments of MSP percentages. However, there is an increment in concrete strength for MSP1C with 41.7MPa and 46.9MPa for 28 and 90 days, respectively. It indicates a higher value compared to other specimens. Studies by Hawlett, (1998) and Bonavetti et al. (2001), mentioned that CaCO₃ compound in mussel shells chemically reacted with C₃A, then formed calcium carboaluminate (C₃A · 3CaCO₃ · 32H₂O) compound at ettringite phase (AFt) in Eq. (3) and turned into calcium mono-carboaluminate (C₃A · 3CaCO₃ · 12H₂O) compound at mono-ettringite phase (AFm) in Eq. (3a). This compound has the potential to increase concrete strength and its ultimate strength (Li et al., 2018). A study by Hashim & Nhabah (2018), the limited amount of CaCO₃ in nano form could improve the compressive and split tensile strength compared to normal concrete on 7 and 28 days. Therefore, the minimum percentages MSP is still reasonable to be applied in the concrete mixture in order to increase its mechanical properties.

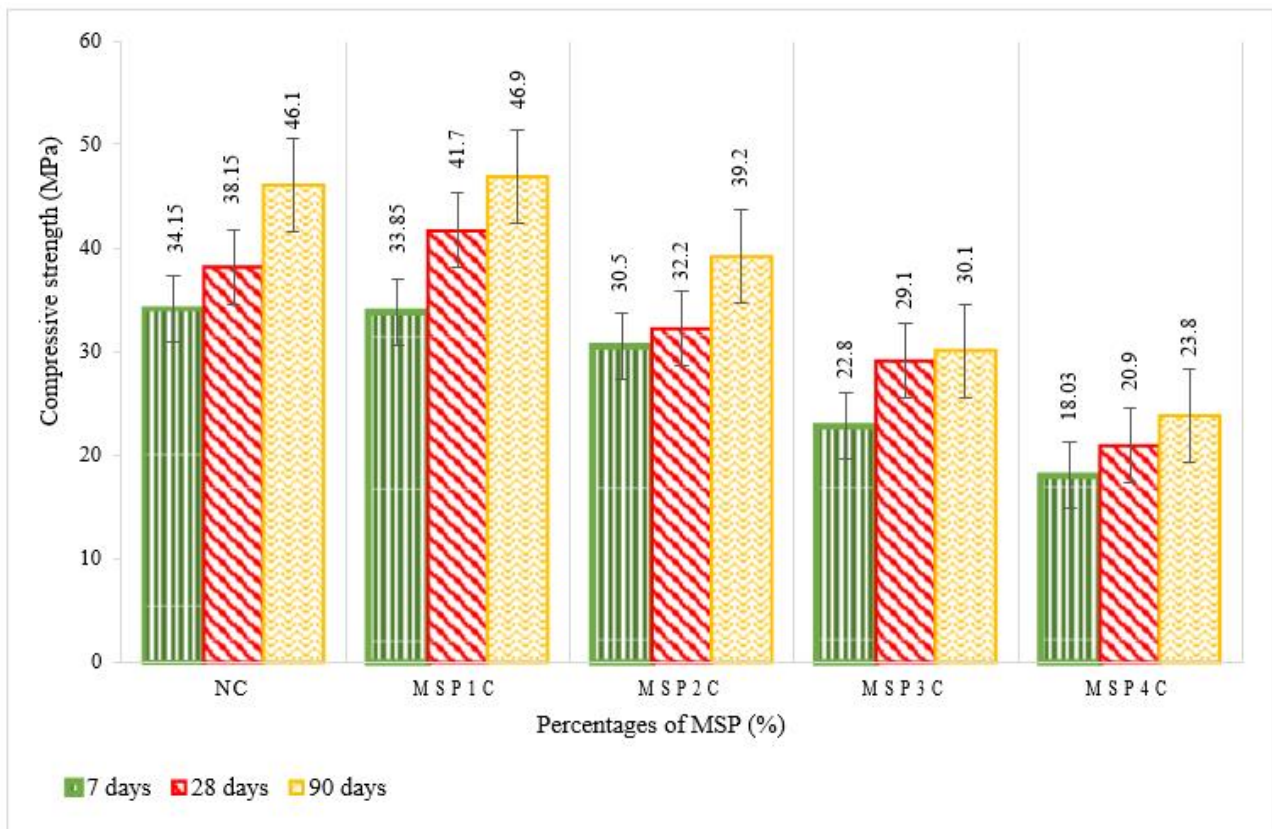
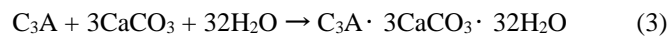


Fig. 5 - Compressive strength concrete specimens

3.2 Split Tensile Strength of Tested Specimens

Split tensile strength was analyzed from 100 mm × 200 mm cylinder specimens with water to cement ratio (w/c) of 0.51, then cured in NaCl solution as mentioned in the previous section. From the experimental results for this analysis, it is observed that normal concrete (NC) gives a higher split tensile strength on 7, 28, and 90 days respectively. Compared to MSP concrete, it shows a decreasing value of strength with the increments of MSP. Both graphs in Fig. 5 and Fig. 6 almost give the same trends that indicate the decline pattern. A similar split tensile strength reduction also reported by Olivia *et al.* (2017) with the increments of seashell powder in concrete by 4% compared to normal specimens. Hence, it is generally noticed that the filler effect of MSP does not improve in concrete split tensile strength.

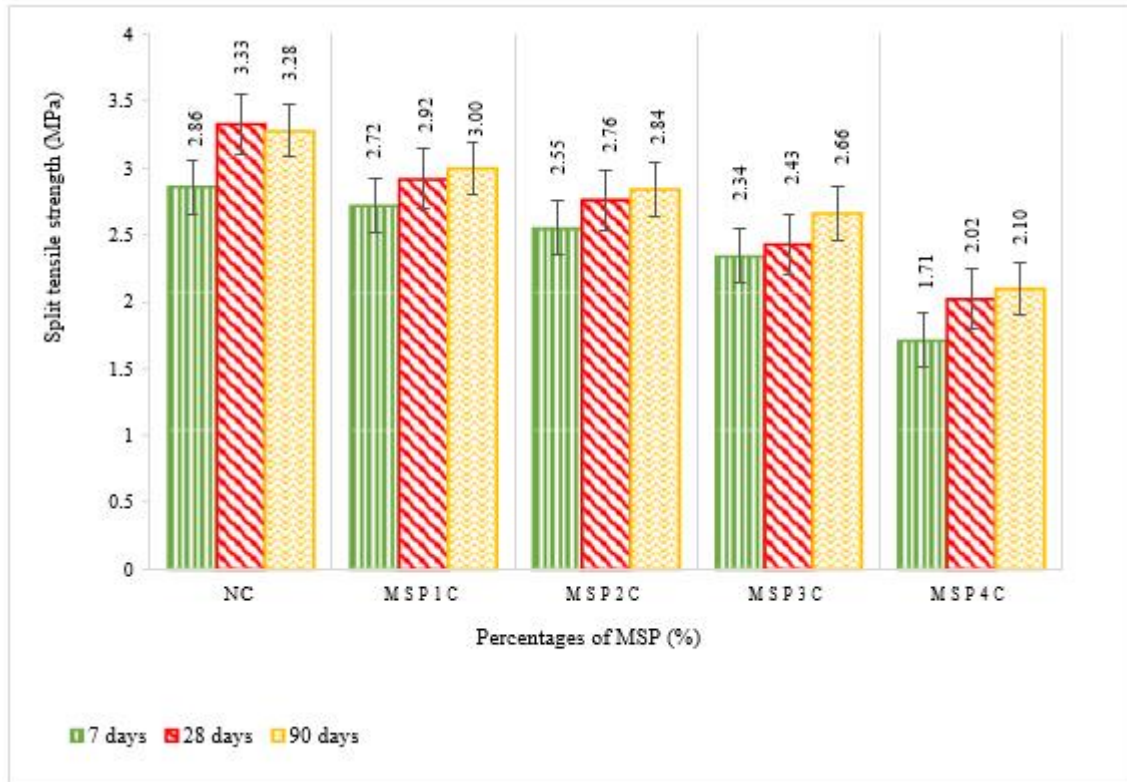
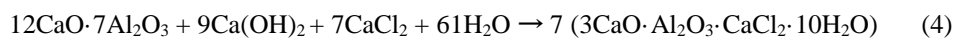


Fig. 6 - Split tensile strength concrete specimens

However, NC shows a small reduction in tensile strength at 90 days. It may be due to the absence of filler materials in concrete specimens, which make it more permeable compared to MSP concrete. Since there are no filler materials used in control specimens and the existence of sulfate ion (SO₄⁻) in solution, thaumasite reaction may not occur due to the less amount of carbonate (CO₃⁻²). On the other hand, a high concentration of chloride (Cl⁻) from solution potentially might cause the reason for NC losing its split tensile strength. According to Ragab *et al.* (2016) and Wang *et al.* (2019), a reaction of Cl⁻ with C₃A in concrete causes the formation of Friedel’s salt (3CaO·Al₂O₃·CaCl₂·10H₂O) Eq.4. This could affect the mechanical properties of concrete due to pressure that occurred from Friedel’s salt formation in concrete that exhibits the bonding-lose in the inner concrete micro-structure (Qiao *et al.*, 2018). This also was supported through a study by Jones *et al.* (2003). He stated that Friedel’s salt mechanism started to form at the age of more than 50 days after Cl⁻ entering the concrete inner part. Therefore, NC at 90 days giving a reduction in its tensile strength value compared to 7 and 28 days.



3.3 Analysis for Capillary Water Absorption

Capillary water absorption test was conducted in this study to evaluate the filler effect of MSP materials on concrete capillary pores. The results of this analysis were presented in Fig. 7. Overall, it is noticeable that the capillary water absorption for each specimen on 7 days is higher compared to 28 and 90 days. This is because the hardened paste consist of poorly un-hydrated crystal in various compounds that cause the existence of un-consistence pores at an early age (Neville, 2011). Therefore, it is resulting in a higher water absorption on its capillary pores. Besides that, there were inconsistent reading for tested specimens with increment percentages of MSP. Nevertheless, the increment seems to be in a small range that is less than tenths digit and does not correlate with compressive and split tensile strength. Thus, it was verified that the less capillary micro-structure does not give major effects on concrete mechanical properties for tested specimens.

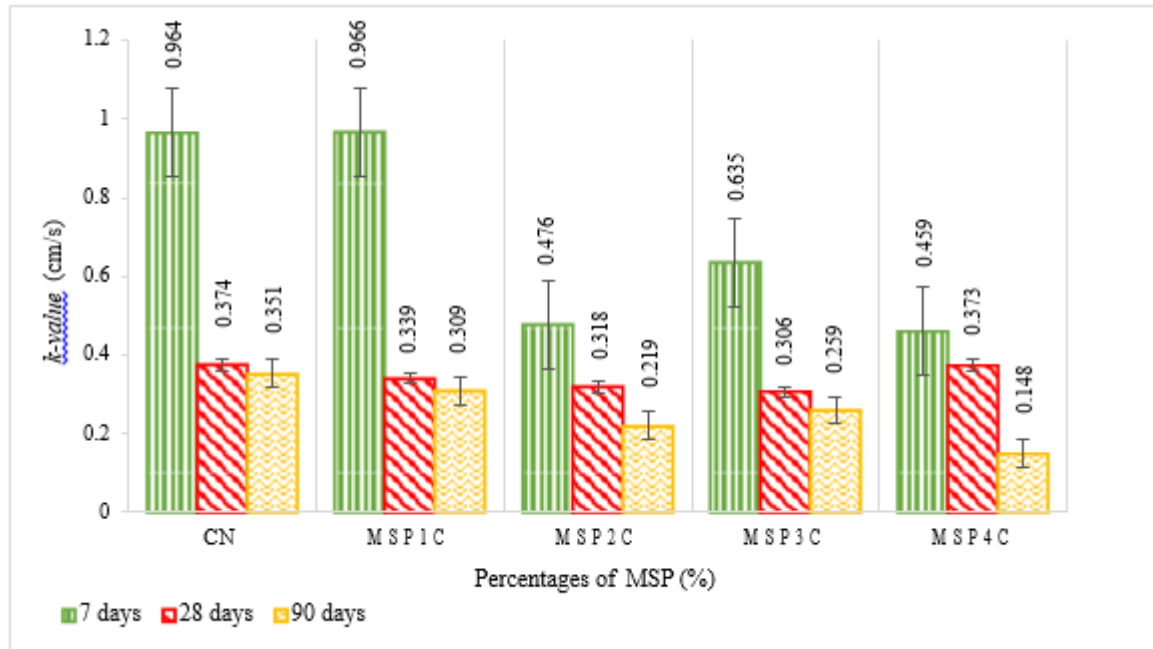


Fig. 7 - Capillary water absorption of concrete

Referring to the same graph, it is clearly noticed that the increment percentage of MSP up to 4% had reduced the capillary water absorption. MSP4C indicates the lower k-value that is 0.148cm/s in 90 days compared to other specimens (NC, MSP1C, MSP2C, and MSP3C). According to a study done by Li and Kwan (2015), the application of fines filler in concrete could reduce the water penetration depth and Cl ingestion (RCPT analysis) to concrete microstructure due to smaller sizes of the capillary pore in it. Even though their research materials are focusing on the utilisation of lime filler, however, its data observed still can be referred in this study since lime and mussel shell having similar major chemical compound consist of CaCO₃ (Lertwattanaruk *et al.*, 2012) or derived as calcium oxide (CaO) in each material (Prošek *et al.*, 2019; Ontiveros-Ortega *et al.*, 2018).

3.4 Statistical Evaluations

3.4.1 Correlation Analysis for Tested Specimens

The correlation test was adapted in this study to identify the strength relationship between the dependent variable and the independent variable (Kremelberg, 2011). It defines the strength of each variable according to its correlation coefficient (r) value. This analysis also represents the linear equation strength between variables. The nearest r-value to 1 or -1 will give a very strong correlation coefficient. Positive and negative symbols indicate its positive correlation (direct linear line) or negative correlation (inverse linear line) (Privitera, 2012). According to the graph correlation, the y-axis indicates dependent variables whereas the x-axis indicates independent variables. Table 3 indicates correlation value between each dependent variables while Table 4 indicates the correlation coefficient between dependent variables for each percentage of MSP used. Clearly, it is noticed that the compressive strength and split tensile strength initiate a strong correlation value (r =0.912), which near to 1.00 with a positive linear line as in Fig.8. Compressive strength and split tensile give almost a similar trend with the increment of percentages of MSP used. It shows that both variables are directly relatable to each other. This also was supported by Akinpelu *et al.* (2019) and Chhorn *et al.* (2018). Thus, split tensile strength trends line can be predicted with compressive strength.

Table 3 - Correlation analysis between each dependent variable

	Compressive strength	Split tensile strength	Capillary water absorption
Compressive strength	1	0.912	-0.076
Split tensile strength		1	0.041
Capillary water absorption			1

On the other hand, it was verified that the strength relationship for the compressive strength and capillary water absorption had given a weak strength with less gradient line as in Fig. 9. A similar result was also noticed between the strength relationship for split tensile strength and capillary water absorption as in Fig. 10. Since compressive and split tensile strength indicate a higher r-value compared to other dependent variables, thus this variable would be selected for further correlation analysis between each percentage as shown in Table 4. Subsequently, it can be seen that the compressive strength for MSP1C and MSP4C mostly indicates a higher r-value, which nearest to 1.00 and -1.00. However, further verification shows that MSP1C resulting in a stronger correlation with coefficient correlation (r) for each variable that nearest to 1.00 and -1.00 compared to MSP4C. Therefore, it was clearly shown that MSP1C resulting in the strongest significant correlation value.

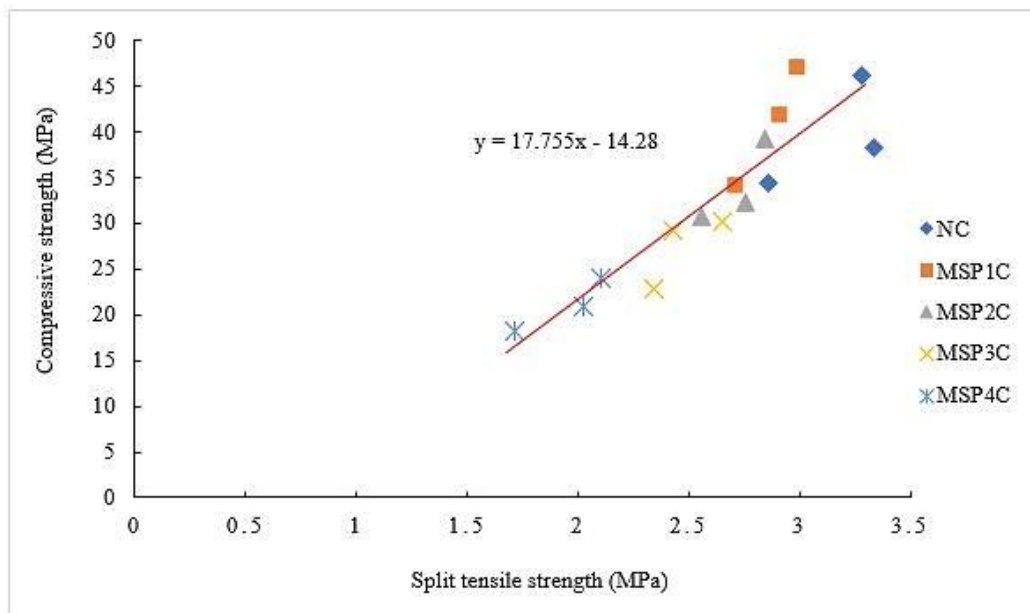


Fig. 8 - Relationship between compressive strength and split tensile strength on 7, 28 and 90 days curing

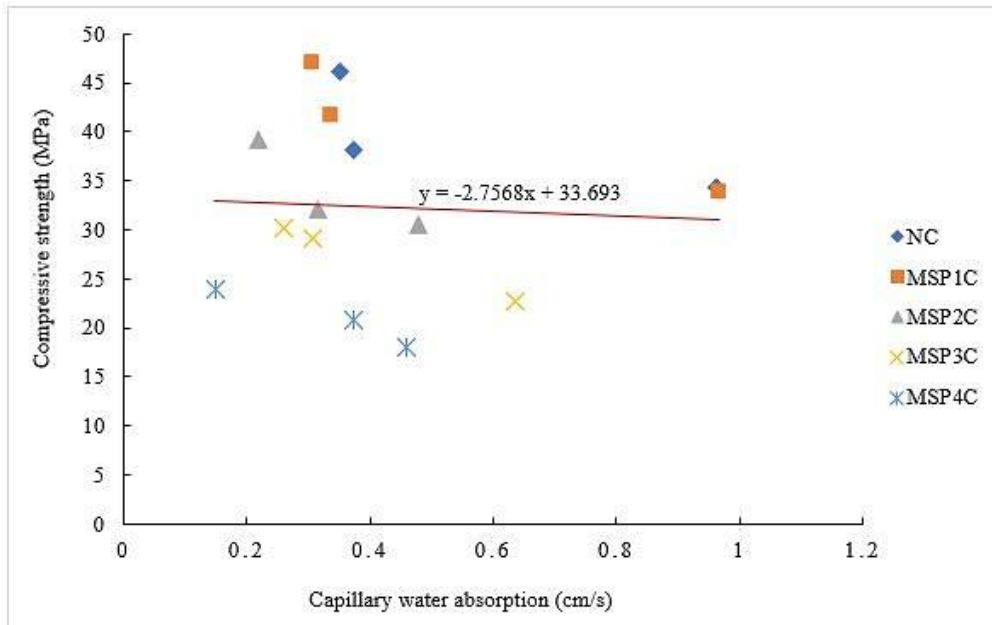


Fig. 9 - Relationship between compressive strength and capillary water absorption on 7, 28 and 90 days curing

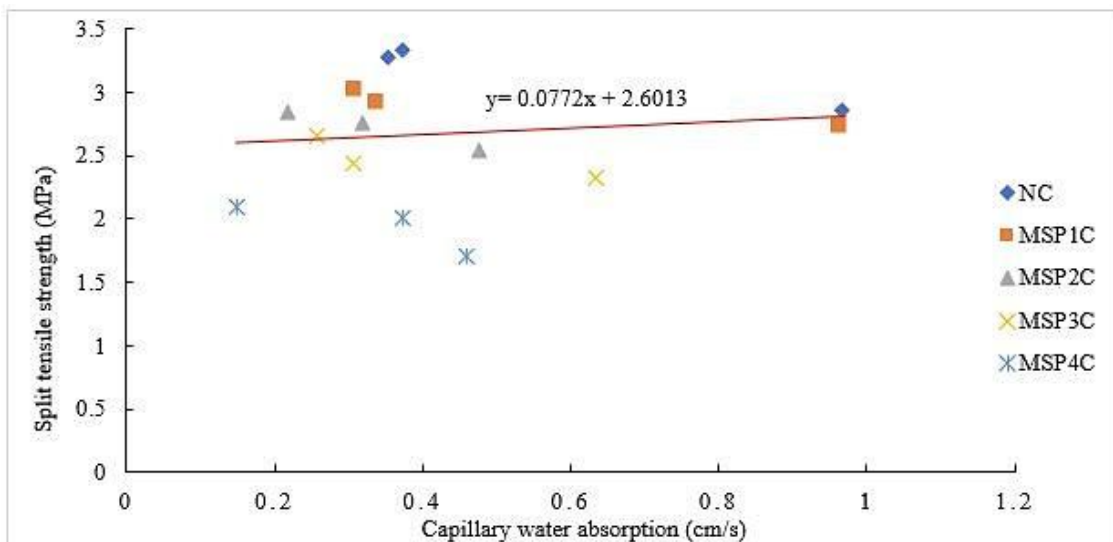


Fig. 10 - Relationship between split tensile strength and capillary water absorption on 7, 28 and 90 days curing

Table 4 - Further correlation coefficients between percentages of MSP

Dependent variables	NC (Split tensile)	MSP1C (Split tensile)	MSP2C (Split tensile)	MSP3C (Split tensile)	MSP4C (Split tensile)
NC (Compressive)	0.690	0.908	0.903	0.998	0.869
MSP1C (Compressive)	0.975	0.990	0.991	0.994	0.978
MSP2C (Compressive)	0.574	0.836	0.830	0.996	0.786
MSP3C (Compressive)	0.975	0.988	0.989	0.790	0.997
MSP4C (Compressive)	0.811	0.969	0.967	0.970	0.940

3.4.2 ANOVA Test for Statistical Analysis

The test of significant was carried out in this study to evaluate the significant level of an additional percentage of MSP to the experimental parameters tested in this study. The results of the analysis were summarized in Tables 5–10. Referring to Table 5–7, the highest mean for compressive, split tensile and capillary water absorption analysis was MSP1C (28), NC (28), and NC (7), respectively. Meanwhile, the lowest mean obtained was MSP4C (28), MSP2C (90), and MSP4C (90), respectively. However, in order to identify either there were significant effects, for the mean value of MSP used and curing time to physical and mechanical properties of specimens, ANOVA two-way was applied. It was necessary due to data collecting in this study consisted of more than one fix factor (independent variable), with more than two levels (k), which indicates the percentages of MSP used (Landau & Everitt (2004)). Thus, significant value can be determined through *p*-value from IBM SPSS result as in Table 8.

Based on results shown in Table 8 for the ANOVA test, it was observed that there is no significant difference of curing time on the compressive strength of specimens, since the calculated *p*-value is greater than 0.05. It shows that the interaction between percentages of MSP and curing time (*p*=0.783) on compressive value is not significantly difference. As in a similar table, it also shows that there is no significant difference of MSP percentages, curing time, and interaction between MSP percentages with curing time on concrete split tensile strength, with *p*-value is more than 0.05. Besides that, results for capillary water absorption analysis were also indicated similar outcomes between percentages of MSP, including the interaction between MSP and curing time analyzed (*p*> 0.05). According to a study by Makhloufi *et al.* (2016), they found that filler materials became more dominant at the age of more than 90 days. This had led to a smaller difference mean between each value that causing no significant different in results. Besides that, since all the specimens were cured using NaCl solution, it might cause some chemical reaction between hydration products and chemicals in the solution that could change concrete behavior as mentioned in previous section. Thus, these reactions may effect on concrete performance that causes no significant interaction between certain variables.

Table 5 - Statistical analysis on compressive strength

Sample	N	Mean (MPa)	Max (MPa)	Min (MPa)	Std. deviation
NC (7)	3	33.700	35.50	32.80	1.559
NC (28)	3	25.433	39.80	26.50	22.088
NC (90)	3	40.000	44.60	37.70	3.984
MSP1C (7)	3	33.367	34.30	32.40	0.950
MSP1C (28)	3	41.700	43.90	40.00	1.998
MSP1C (90)	3	31.267	47.10	46.70	27.078
MSP2C (7)	3	20.200	30.60	30.00	17.496
MSP2C (28)	3	32.167	32.70	31.70	0.503
MSP2C (90)	3	26.133	35.50	23.90	22.669
MSP3C (7)	3	22.767	24.30	22.00	1.328
MSP3C (28)	3	29.067	29.60	28.10	0.839
MSP3C (90)	3	30.133	31.80	28.10	1.877
MSP4C (7)	3	18.033	18.80	16.70	1.159
MSP4C (28)	3	13.933	21.20	20.60	12.070
MSP4C (90)	3	15.867	24.60	23.00	13.764

(*) = curing time

Table 6 - Statistical analysis on split tensile strength

Sample	N	Mean (MPa)	Max (MPa)	Min (MPa)	Std. deviation
NC (7)	3	1.907	2.15	1.79	1.651
NC (28)	3	3.330	3.41	3.15	0.156
NC (90)	3	2.190	3.45	3.12	1.904
MSP1C (7)	3	2.707	2.76	2.68	0.046
MSP1C (28)	3	2.920	3.23	2.81	0.272
MSP1C (90)	3	1.997	3.08	2.91	1.731
MSP2C (7)	3	1.700	2.57	2.53	1.472
MSP2C (28)	3	2.767	2.79	2.75	0.021
MSP2C (90)	3	0.947	1.05	0.91	1.640
MSP3C (7)	3	2.430	2.53	2.38	0.087
MSP3C (28)	3	2.433	2.53	2.35	0.112
MSP3C (90)	3	2.660	2.87	2.42	0.227
MSP4C (7)	3	1.707	1.80	1.63	0.086

MSP4C (28)	3	2.027	2.12	1.97	0.081
MSP4C (90)	3	1.370	2.12	1.99	1.188

(*) = curing time

Table 7 - Statistical analysis on capillary water absorption

Sample	N	Mean (MPa)	Max (MPa)	Min (MPa)	Std. deviation
NC (7)	3	0.964	0.964	0.965	0.001
NC (28)	3	0.250	0.374	0.233	0.216
NC (90)	3	0.234	0.351	0.219	0.203
MSP1C (7)	3	0.644	0.966	0.545	0.558
MSP1C (28)	3	0.339	0.339	0.338	0.001
MSP1C (90)	3	0.309	0.309	0.309	0.001
MSP2C (7)	3	0.317	0.376	0.298	0.275
MSP2C (28)	3	0.318	0.318	0.317	0.001
MSP2C (90)	3	0.219	0.223	0.217	0.001
MSP3C (7)	3	0.635	0.636	0.634	0.001
MSP3C (28)	3	0.204	0.217	0.201	0.177
MSP3C (90)	3	0.259	0.260	0.258	0.001
MSP4C (7)	3	0.459	0.459	0.458	0.001
MSP4C (28)	3	0.373	0.373	0.373	0.001
MSP4C (90)	3	0.148	0.201	0.117	0.001

(*) = curing time

Table 8 - ANOVA analysis for physical and mechanical analysis

Respond	Factor	Type III sum of square	df	Mean square	F	Sig.	Result
Compressive strength	MSP	2062.437	4	515.609	3.213	0.026	Significant ($p < 0.05$)
	Curing time	87.782	2	43.891	0.274	0.763	Not significant ($p > 0.05$)
	MSP*Curing time	750.287	8	93.786	0.584	0.783	Not significant ($p > 0.05$)
Split tensile strength	MSP	6.230	4	1.557	1.478	0.234	Not significant ($p > 0.05$)
	Curing time	5.884	2	2.942	2.793	0.077	Not significant ($p > 0.05$)
	MSP*Curing time	4.693	8	0.587	0.557	0.804	Not significant ($p > 0.05$)
Capillary water absorption	MSP	0.227	4	0.057	1.682	0.180	Not significant ($p > 0.05$)
	Curing time	1.177	2	0.588	17.458	0.00001	Significant ($p < 0.05$)
	MSP*Curing time	0.578	8	0.072	2.143	0.062	Not significant ($p > 0.05$)

However, according to the same table stated before, it shows that there was a significant different on the fixed factor for MSP percentages on compressive strength ($p=0.026$) and curing time on capillary water absorption analysis ($p=0.00001$). Hence, it is noted that percentages of MSP and curing time had given an effect on the properties of MSP concrete. Since there was a significant difference in the physical and mechanical properties of concrete, thus a Post-Hoc analysis was developed in this analysis. The ANOVA test is known as analysis variance, which is done to identify the overall different mean in groups (Berkman & Reise, 2011). However, this analysis only provided a significant result but not the exact point of the difference was located (Berkman & Reise, 2011; Gray & Kinnear 2012). Therefore, Post-Hoc analysis was observed to identify the exact point where the different point was located (Anting *et al.*, 2017). In this study, Post-Hoc analysis was conducted on curing time since it was a significant different on it compare to other fix factors ($p < 0.05$). In order to observe the exact different between each factor, *Fisher's Least Significant Difference* (LSD) with a multi-comparison test is performed with α value of 0.05, which means $p < 0.05$. The result obtained was shown in Tables 9 and 10.

Table 9 - Fisher’s Least Significant Different result from multiple comparisons analysis on compressive strength

Samples		<i>p</i> value	Results
NC	MSP1C	0.691	Not significant ($p > 0.05$)
	MSP2C	0.259	Not significant ($p > 0.05$)
	MSP3C	0.346	Not significant ($p > 0.05$)
	MSP4C	0.008	Significant ($p < 0.05$)
MSP1C	NC	0.691	Not significant ($p > 0.05$)
	MSP2C	0.131	Not significant ($p > 0.05$)
	MSP3C	0.184	Not significant ($p > 0.05$)
	MSP4C	0.003	Significant ($p < 0.05$)
MSP2C	NC	0.259	Not significant ($p > 0.05$)
	MSP1C	0.131	Not significant ($p > 0.05$)
	MSP3C	0.848	Not significant ($p > 0.05$)
	MSP4C	0.097	Not significant ($p > 0.05$)
MSP3C	NC	0.346	Not significant ($p > 0.05$)
	MSP1C	0.184	Not significant ($p > 0.05$)
	MSP2C	0.848	Not significant ($p > 0.05$)
	MSP4C	0.097	Not significant ($p > 0.05$)
MSP4C	NC	0.008	Significant ($p < 0.05$)
	MSP1C	0.003	Significant ($p < 0.05$)
	MSP2C	0.097	Not significant ($p > 0.05$)
	MSP3C	0.066	Not significant ($p > 0.05$)

The least comparison means between each response can be derived through its significant value (*p-value*). From Table 9, there was significant different existed between NC to MSP4C and MSP1C to MSP4C ($p < 0.05$). It shows that percentages of MSP are effecting the compressive strength for certain specimens, which cause a large difference in the mean. Filler materials such as MSP are very relatable to the mechanical strength of concrete due to its filler effect in reducing the number of micro-pores. However, an excessive amount could affect its mechanical characteristic, which causing strength loss with an increment of MSP. A similar result was also reported by Ismail *et al.* (2019). Thus, MSP usage should be minimised in small percentages. On the other hand, it was found that 7 days and 28 days curing time indicated a significant difference ($p = 0.011$) as in Table 10. It was also given similar outcomes on 7 days and 90 days curing time with a *p-value* of 0.004. However, it was not statistically significant on curing time between 28 days and 90 days with $p > 0.05$. It means that curing time between 28 and 90 days does not affect the capillary water absorption. Essentially to know that, the lesser value of water absorption through it capillary, the lesser quantity of micro-structure pores existing in the specimen. Therefore, a high value of water absorption through its capillary indicates a high void in specimens.

Table 10 - Fisher’s Least Significant Different result from multiple comparisons analysis on capillary water absorption

Samples		<i>p</i> value	Results
7	28	0.011	Significant ($p < 0.05$)
	90	0.004	Significant ($p < 0.05$)
28	7	0.011	Significant ($p < 0.05$)
	90	0.677	Not significant ($p > 0.05$)
90	7	0.004	Significant ($p < 0.05$)
	28	0.677	Not significant ($p > 0.05$)

4. Summary

MSP is one of the materials from mollusk species that consists of high calcium carbonates percentages, which could potentially act as filler materials when cooperated with concretes. The presence of MSP significantly increased the concrete compressive strength and reduced its capillary water absorption compared to control samples (NC). The

results showed that an addition of 1% MSP had increased compressive strength specimens to 33.40MPa, 41.70MPa and 46.90MPa compared to control samples of 34.15MPa, 38.15MPa, and 46.1MPa on 7, 28, and 90 days respectively. Furthermore, the increments of MSP to 4% had reduced capillary absorption to 0.148 cm/s compared to NC with 0.351 cm/s in 90 days. Even though the increment percentages of MSP could improve concrete permeability in reducing its capillary pores, however, the results do not significantly improve in its mechanical properties. Since concrete was designed based on its mechanical properties, thus, the percentages of MSP should considerably minimised in order to maintain its strength properties.

According to evaluation using statistical analysis, it shows that MSP1C indicates strong correlation coefficients compared to MSP4C. Whereas, based on IBM-SPSS, Fisher's Least Significant Difference (LSD) analysis indicates that there was a statistically significant different on MSP 1% ($p=0.003$) on compressive strength of concrete specimens. Generally, with consideration for both analyses, it can be concluded that MSP 1% is the most reliable percentage used as concrete additional materials in concrete design. However, further study is required in this research such as chemical analysis in order to identify accurate outputs based on the discussion that has been made previously.

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