Performance of concrete containing mussel shell (Perna viridis) ash under effect of sodium chloride curing

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Abstract. Mussel shell is a type of waste that consist large amounts of calcium content (CaCO$_3$ (>95%)). It is potentially to be used as concrete filler which can reduce porosity in concrete micro-structure (compacted concrete) and indirectly reduce quantity of water used to maintain concrete workability. This paper investigates the performance of mussel shell waste as an admixture in normal concrete. These waste were crushed using ball mill for 5 hour then sieved with 75μm sieve sizes. Five different percentages of mussel shell ash (MSA) were incorporated in concrete as an admixture 0%, 1%, 2%, 3% and 4% (S0, S1, S2, S3 and S4) base on w/c 0.5 according to DoE method with total of 90 samples. Specimens then were cured using 2.37% of sodium chloride (NaCl) solution for 7 and 28 days. Data were analysed according to physical, mechanical and its durability properties of materials and its specimens. Particle size analysis (PSD), specific gravity, SEM image and setting time are measured on MSA, OPC and samples MSA concrete included slump analysis for concrete workability. While its mechanical and durability properties of MSA concrete were analyses through compressive, split tensile and water capillary absorption. The result showed that increment percentages of MSA could effect on the strength of both compressive and split tensile. However, minimum percentages of MSA of 1% gained higher strength compared to control specimen. The differences between MSA percentages and its curing duration incorporated indicating an improvement while S1 and S3 indicates lower rate of capillary absorption for 7 and 28 days each. Overall, the results to establish concrete strength improvement of MSA in concrete should be limited to 1% uses. While S2 and S4 for concrete permeability and workability. With this percentages, concrete display an improvement behaviours according to its strength and durability towards sodium chloride exposure.

1. Introduction
Waste management had becomes one challenging issue in Asian region included other developing country since before. The waste generated seen to give negative impact due to its increment rate per year and it’s prevail the ability of related parties in controlling its production [1]. According to a study by Badgie et al., [2], it was expected that average waste generated in Asian will increased to 1.8 million tonnes which is 5.2 million meter square each days if it was not controlled. The key factor of
this issue is caused by socioeconomic by community accordance with economic upturn in terms of business, manufacturing and others [3].

Mussel production is one of fishery sector that contributed in economic resource to national income in Malaysia. According to statistic by Malaysia Department of Fisheries, it was estimated about 1,827.27 metric tonnes green mussel were produced in year 2016 and increased about 154.14 tonnes compared to previous year [4]. However, this mussel production had contributed to waste increment [3] which 33% from mussel product is consist of it shell [5] that will be discarded after mussel fill been collected. This shells could lead to excessive quantity of mussel waste that generates from mussel production. Thus, it was confirmed that the fisheries industry could generates over 1 million tonnes of waste in worldwide which was implied a significant waste problem on a global scale [5].

One of the simply way to overcome and reduce waste increment issue by applying recycle method towards material which can minimize waste quantity [3]. Further research had developed in recent years to study the use of mussel shell waste as construction material. Recently, mussel shell as an addition in cementitious material that used in concrete mixing and its effect on concrete properties was studied. Various studies against mussel shell has been undertaken by researchers in identifying the potential of material. It was applied in many departments course to reduce mussel shell waste quantity and it clearly giving positive feedback among researcher. Xiong [6] found that mussel shell could become filtration media in reducing the amount of phosphate up to 55% in water. Based on construction materials sector, seashell such as mussel species is one natural occurrence that consist of calcium source in form of calcium carbonate which were applied in cements industries other than lime stone, lime and dolomite [7]. Martinez-Garcia et al. used recycle materials consist of mussel shell as aggregates partial replacement could improve strength development of harden concrete [5]. In a previous experimental investigation by Oliviae al., Kuo et al. and Othman et al., it also found that the utilisation of seashell in concrete giving positive reaction toward quality of concrete based on its quantity to cement mixture within 4% to 5% respectively [8]-[10].

Durability is one of important properties in concrete that should be stressed which will affect towards its strength and serviceability. Concrete consist of low resistance towards ion penetration due to its pores structures [11]. Exposure of concrete towards aggressive environment such chloride, sulphate, carbon dioxide and etc. that came naturally or industries waste could disturbances its durability properties [12]. Exposure of concrete to sodium chloride is one an example of aggressive environment that came from sea-water due to it highly amount of sodium (Na) and chloride (Cl) ions from its salinity [7]. NaCl is classified as salt type that has been found could damage concrete strength and durability through its chemical interactions [13]. A study by Qiao [14] state that penetration of NaCl into concrete could lead to the formation of Friedel’s salt forms in its cementitious materials due to reaction of Cl ion and C3A. This could cause to loose of concrete flexural strength due to dissolution and leaching of Ca(OH)2 and C-S-H and also crystallization pressure of Friedel’s salt. [14-15]. While the present of other ion such sulphate could cause exceeded amount of gypsum and ettringite due to its reaction between Ca(OH)2 and C3A which can cause concrete deterioration [16]. Thus, the penetration of aggressive ions should avoided and solved in order to reduce its impact towards concrete strength and quality.

Mussel shell is one of the material with CaCO3 (>90%) composition which exceed CaCO3 percentage contained in limestone (>75%) [12][17] According to Sun & Chen, (2018) calcium carbonate possess filler properties which consists of small particle sizes compared to Portland cement [18]. It also potentially to increased concrete workability and reduce quantity of water used [12]. Since mussel shell consist of filler properties due to its higher CaCO3 content, it was expected to reduce porosity and permeability of concrete due to its incorporated between cementitious product into concretes. Thus, the penetration of ion and aggressive environment toward concrete could be difficult due to low permeability in term of capillary pores and maintained properties of concrete. A study by Higgins [19], addition calcium carbonate that is small in concrete which contains ground granulated blast furnace slag (GGBS) could increase potential towards sulphate resistance. The analysis was observed according to the concrete with addition and absence of CaCO3 then were cured in
magnesium sulphate (MgSO$_4$) and sodium sulphate (Na$_2$SO$_4$). It was explained that addition of CaCO$_3$ had increased compressive strength compared to normal concrete. It because CaCO$_3$ has filling effect that potentially fill small pores in concrete causing difficulty Na$_2$SO$_4$ and MgSO$_4$ penetrates into concrete specimens. Overall, through application of mussel shell either as addition or partially replacements with Portland cements was significantly to be used and complied awareness towards sustainability development.

The aim of this research is to assess effect of utilisation of mussel shell as an admixture on the concrete properties towards aggressive environment. Thus, mussel shell ash (MSA) were added to concrete mixture then cured using sodium chloride solution. The physical mechanical properties of MSA were studied to evaluate its behaviour. The rationality and accuracy of mixed design developed are verified through comparison of two different factor on experimental observation. Finally, the influences of differences percentage and duration curing on the compressive and tensile strengths and water capillary absorption are analysed and discussed to determined optimum percentages of MSA in concrete based on its mechanical and durability properties for each specimens.

2. Experimental and physical properties of materials

2.1. Raw material

The specimens were analyzed through the preparation of raw materials that used in this study included water, coarse aggregate, fine aggregate, ordinary Portland cement and mussel shell. Mussel shell that had originally dumped from mussel production process were collected, cleaned and dried. Then the MSA product were obtained through crushing process of mussel shell for five hours using ball mill then were sieved to 75μm. The physical properties (specific gravity, setting time, PSA, slump test) were define in table 1.

| Table 1. Physical properties of OPC and MSA as admixture for cementitious materials |
|-----------------|-----------------|---------------|---------------|---------------|---------------|
| Description     | Chemical compound | OPC | MSA | Percentage total replacement (%) |
|                 |                 |     |     | S1 | S2 | S3 | S4 |
| Physical         | Specific gravity | 3.09 | 2.51 |     |     |     |     |
| properties       | PSD             | 10%  | 3.81 | 0.85 |     |     |     |
|                  |                 |     |     | 30% | 12.55 | 2.53 |     |     |
|                  |                 |     |     | 50% | 18.29 | 8.48 |     |     |
|                  |                 |     |     | 60% | 21.15 | 11.67 |     |     |
|                  |                 |     |     | 70% | 24.93 | 15.49 |     |     |
| Setting time (mins) | Initial    | 98  |     | 98 | 95 | 95 | 92 |
|                  | Final         | 289 |     | 288 | 285 | 282 | 270 |
| Slump value(mm)  | 37            |     | 35  | 42 | 53 | 59 |

- = not determined

Cleaned mussel shell and its product of mussel shell ash (MSA) was shown as in figure 1 and figure 2. The raw of MSA and Ordinary Portland cements (OPC) properties were identified through its specific gravity analysis. OPC and MSA were complies with specification according to BS EN 197-1: 2000 with value of 3.09 while 2.51 respectively (10g sample of OPC and MSA) [20]. Neville state that there were relationship between specific gravity and setting time on concrete properties [16]. Thus, setting time analysis were obtained in this paper according to BS EN 196-3: 2005 for both ordinary OPC and MSA towards its initial and final setting time (400g of MSA, OPC and with addition MSA S1, S2, S3 and S4, 200mL water) [21].
The result show that early setting time for MSA paste (S2, S3 and S4) developed faster early setting time (<96 minutes) compared to S1 and OPC (98 minutes). According to data observe from Table 1, the increment of percentages of MSA had lead to faster initial setting time same goes to its final setting time value (>289 minutes). According to Wen-Ten et al., it’s due to MSA properties that consist high rates of hydration to absorb water [22]. Apart from that, particle size distribution (PSD) of MSA were analysed according to standard method of BS ISO 13320:2009 using CILAS 1180 Liquid (0.04μm – 2500μm) [23]. Fineness of substances could accelerates strength of concrete due to faster reaction of hydration process [12]. Thus, PSD analysis were obtained in the study to identified fineness of MSA and OPC particle diameter which can contributes in promoting the development of concrete at early strength due to its surface contact to react with hydration products in concrete mixture.

PSD analysis for OPC and MSA was defined as in figure 3 and figure 4. According to both figure, MSA consist smaller diameter sizes compared to OPC. Data obtained for 10% cumulative, it shows the size of MSA were 0.85μm and 3.81μm for OPC. While for 50% and 60%, it was 8.48μm and 18.29μm, 1.67μm and 21.15μm each. According to 70%, the cumulative was 15.49μm and 24.93μm. Based on maximum diameter of materials from both graph and cumulative value for each percentages, MSA indicates lower diameter compared to OPC which were 20μm for MSA while 25μm for OPC. The value from each cumulative percentages in both graph proved that particle diameter of MSA was significantly suitable materials to be used as concrete admixture due to its small diameter particle sizes compared to OPC.
SEM image was identified according as in figure 5 and figure 6. Based on both figures, it showed that 1.00KX zoomed MSA consist of fine particle compared to OPC which suitable to be used as filler in concrete. Particle characteristics of the MSA agglomerates showed that the shapes and size are consistent and almost similar to each other compared to OPC which formed in different sizes and particle shapes. It is due to OPC comprised from four type of minerals compounds such tri-calcium silicate (C₃S), di-calcium silicate (C₂S), tri-calcium aluminate (C₃A) tetra-calcium aluminoferrite (C₄AF) and oxide composition such CaO, SiO₂, Al₂O₃, Fe₂O₃, MgO, SO₃ and etc. [5, 7, 24] compared to MSA which major oxide composition consist of 95% calcium carbonate (CaCO₃) [17]. According
to Hawlett, OPC compound and oxide orientated with various size fraction such coarser than 90μm and in between 45μm to 90μm [17]. Due to in variety sizes, it microscopy sizes and shape would be varies compared to MSA.

![Figure 5. SEM image of OPC](image1)

![Figure 6. SEM image of MSA](image2)

### 2.2. Concrete mixture

In this study, specimens were separated in classes which were mixed in 5 separate batch of concrete mixing (S0, S1, S2, S3 and S4 MSA). It was calculated and designed according to Design of Engineering (DoE) method with 0.50 (w/c). The concrete mixing process was carried out using mechanical method (minder). The details of materials used for each specimens of water, fine and course aggregates were define as in table 2 and table 3. Whereas, admixture value of concrete design to ash materials (S1, S2, S3 and S4) were 0.024kg, 0.048kg, 0.072kg and 0.096kg each for 0.001m$^3$ mould and (S1, S2, S3 and S4) 0.048kg, 0.096kg, 0.145kg and 0.193kg for 0.002m$^3$ mould.

| Code | Percentages admixture          |
|------|--------------------------------|
| S0   | 100% concrete                  |
| S1   | 100% concrete + MSA 1%         |
| S2   | 100% concrete + MSA 2%         |
| S3   | 100% concrete + MSA 3%         |
| S4   | 100% concrete + MSA 4%         |

| Materials | Cements | Course Aggregates | Fine Aggregates | Water |
|-----------|---------|------------------|----------------|-------|
| Cube      | 0.42    | 1.21             | 0.57           | 0.21  |
| Cylinder  | 0.84    | 2.42             | 1.14           | 0.42  |

According to concrete workability summarized in table 1, the slump value of each 1%, 2%, 3% and 4% MSA specimens were 35mm, 42mm, 53mm and 59mm respectively. Overall, it showed that the concretes slump value increases with the increases of MSA percentages. S4 indicates the highest slump value followed with S3 and S2. It proved that, CaCO$_3$ were able in improving concrete workability and handling purposes [12]. On the other hand, percentage value of S1 record lowest slump value compared to plain concrete. This is due hot weather during mixing process of S1 mixture.
carried out had accelerate further process cements hydration and reaction towards formation of C-S-H gel [25]. Although it is not a preferred choice of the interferences arising from the presence including the formation of interfaces during hot weather, however S1 slump value according to DoE calculation were in the range of 30-60mm and it was considered accepted due to its medium workability level with range of 35-75mm according to Neville [12, 16]. Further examination of the literature revealed that the variability observed in the appraisal of literature appears to the assessed variability of the effect of MSA towards concrete properties.

2.3. Solution preparation
Sodium chloride will be used in this paper to study its reaction and effect towards MSA concrete. Type of NaCl used were C1119 Bendosen 3301231. While the percentages of NaCl that will be used is 2.73% which been mixed with water for curing purposes. The percentages was selected according to its salinity content 3.5% from sea water salinity level, 78% of them is consist of NaCl [12]. Hence, to obtain similar impact towards NaCl composition contained in sea water, utilisation of 2.73% NaCl solvent were used in this study. Measurement method for quantity of NaCl uses are based on the total weight of water that been used for curing purposes. While, the temperature of cured water was maintained with 20 ºC to 29 ºC according to minimum and maximum temperature of water been measured using thermometer.

2.4. Compressive strength test
Compressive strength is one of mechanical analysis which done to concrete specimens to obtain the maximum limits of load been exposed until its failed [24]. It was normal analysis that been done in order to identified concrete strength. The amount and strength percentages are depends on numerous factor such type of cements, type of mixes, admixture uses and etc. [17]. Thus, the effect of MSA in concrete were study in this paper. Normally, there are two type of specimens that will be used in this analysis either cube or cylinder specimens. However, cube (100mm x 100mm x 100mm) specimens were selected in this research due to handling purposes and reduce quantity of materials used. The compressive strength were analysed according to each percentages of MSA and also curing duration using NaCl. The procedure of these analysis ac-cording to BS EN 12390-3:2009 [26].

2.5. Split tensile test
In general, concrete were designed to identify maximum resistance towards its compression limit when exposed to load. However, some relevant knowledge about resistance towards tension also need to be considered to obtain its maximum load which can cause cracks on concrete [12, 16]. Tensile analysis can be divide into three categories which are direct tensile strength analysis, bending analysis and split tensile analysis [12]. On the other hand, split tensile strength analysis were selected in this study which accordance to EN BS standard 12390-6:2009 [27]. Concrete cylindrical with 100mm x 150mm sizes were obtained using compression machine where each sample placed between saucer in line with horizontal axis and then load imposed until sample breach form separatist along diameter vertical axis sample.

2.6. Water capillary absorption test
Water absorption through its higher capillary content are cause by the concrete consist of high porosity [28]. Water molecule will penetrate through its capillary pores when attraction force between pores exceed the attraction force between water with water. Thus, the rates of pressure absorption are depending on its diameter of porous concrete structure [29]. According to this study, water capillary absorption were analysed to identify the rates of water absorption through its capillary which been measured according to its weight specimens when contact with bottom surface of specimens only. This is because tape will be wrap on surrounding surface of specimens to prevent absorption happened on other surface. This experiment was carried out according to RILEM CPC 11.2 standard [30].
3. Mechanical and durability properties of concrete

3.1. Compressive strength.
Compressive strength is usual analysis that be analysed for harden concrete. It meet the criteria in strength properties of concrete itself. Compressive strength of MSA concrete were measured through difference MSA used (0%, 1%, 2%, 3% and 4%) and curing period (7 and 28 days) to evaluate the features and performance for each sample. The result of this analysis are shown in table 4, where each value were taken according to average data for three cube. It show that MSA used in these study is superior to MSA properties as filler which can enhance strength of concrete. The result shows that the higher compressive value for 7 days curing is S0 with 34.15MPa while for 28 days is S1 with 41.7MPa. While S4 indicates lower compressive value in 7 and 28 days which were 18.03MPa and 20.9MPa each. As in figure 7, it shows the graph pattern plotted obtained relationship of compression strength against curing duration. From the graph, concrete with MSA mixture recorded decline. Among of each of different MSA percentages used, MSA with S1 showed the best performed which result the highest compressive strength value compared to control and other specimens.

| Percentages of MSA (%) | Average compressive strength (MPa) |
|------------------------|----------------------------------|
|                        | Curing period (days)              |
|                        | 7      | 28      |
| S0                     | 34.15  | 38.15   |
| S1                     | 33.4   | 41.7    |
| S2                     | 30.5   | 32.2    |
| S3                     | 22.8   | 29.1    |
| S4                     | 18.03  | 20.9    |

Table 4. Compressive strength of control and MSA concretes.

Figure 7. Compressive strength of MSA concrete.
However, it seems that the increments of MSA could decrease its compressive strength, although it increased the strength at the age of 28 days compared to 7 days curing. It can also be seen from Table 4 that at the age of both days, the addition of MSA in concrete resulted in a higher concrete strength with a minimum MSA percentages. A study by Lee states that, utilization of CaCO$_3$ could lead to the decreases strength of concrete [31]. The reaction of OPC with CaCO$_3$ could effect on the binding properties of concrete which resultant to strength loses [12][18].

3.2. Split tensile.
Tensile strength one of major parameter in analyses concrete strength in this research towards cracking value. Figure 8 and table 5 indicates the results of the split tensile strength, where each value was taken from three average specimens. In 7 and 28 days curing, it’s showed that S0 records the highest tensile strength opposed S1, S2, S3 and S4 which is 2.86 MPa and 3.33MPa each. Meanwhile, MSA expansion recorded reduction in split tensile strength. It shows that S1, S2 and S3 in 7 and 28 curing period day were 2.72MPa and 2.77MPa, 2.55MPa and 2.76MPa, 2.34MPa respectively. Based on data obtained, S4 records the lowest split tensile strength value in 7 and 28 curing day. From both graph in figure 7 and figure 8, it shows that both split tensile and compressive strength giving almost similar reduction pattern with the increment of MSA percentages. According to Yan, compressive and split tensile strength are significantly related which split tensile strength can be predicted based on it compressive strength value [32]. Thus, the graph pattern produced for compressive strength and split tensile almost the same in accordance with increase of MSA.

| Percentages of MSA (%) | Average split tensile strength (MPa) |
|------------------------|--------------------------------------|
|                        | 7  | 28  |
| S0                     | 2.86 | 3.33 |
| S1                     | 2.72 | 2.92 |
| S2                     | 2.55 | 2.76 |
| S3                     | 2.34 | 2.43 |
| S4                     | 1.71 | 2.02 |

Figure 8. Split tensile strength of MSA concrete.
3.3. Water capillary absorption.
Permeability of concrete were controlled by its capillary porosity which the coefficient of permeability are rely with capillary pores [12]. Thus, the efficiency of the absorption force depends on the nature of the pores surfaces and diameters of concrete itself [33-34]. Capillary absorption was measured based on 7 and 28 days curing in NaCl solution and analysed for 24 hour maximum duration. The capillary absorption coefficient (k-value) were obtained in Table 6 and graph were plotted according to 7 and 28 days curing specimens presented as in figure 9.

Table 6. Results of water capillary absorption coefficient (k-value).

| MSA percentages (%) / days | Time (s) | k-value (x10^{-3})(cm/s) |
|---------------------------|---------|-------------------------|
|                           | 300     | 600 | 1200 | 1800 | 3600 | 10800 | 21600 | 86400 |
| S0 7 days                 | 10.007  | 2.041 | 1.443 | 1.021 | 1.833 | 1.636 | 0.953 | 0.964 |
| S0 28 days                | 6.351 | 1.089 | 0.962 | 0.629 | 0.833 | 0.866 | 1.497 | 0.374 |
| S1 7 days                 | 10.392 | 1.837 | 1.010 | 1.061 | 1.750 | 1.636 | 0.987 | 0.966 |
| S1 28 days                | 3.464 | 0.953 | 0.577 | 0.471 | 0.556 | 0.321 | 0.544 | 0.339 |
| S2 7 days                 | 2.021 | 0.408 | 0.674 | 0.314 | 0.556 | 0.642 | 0.408 | 0.476 |
| S2 28 days                | 4.234 | 0.408 | 0.722 | 0.629 | 0.444 | 0.289 | 0.431 | 0.318 |
| S3 7 days                 | 2.502 | 0.408 | 0.674 | 0.314 | 0.500 | 0.577 | 0.295 | 0.635 |
| S3 28 days                | 4.041 | 0.816 | 0.866 | 0.629 | 0.333 | 0.609 | 0.227 | 0.306 |
| S4 7 days                 | 3.175 | 1.225 | 0.481 | 0.471 | 0.556 | 0.738 | 0.340 | 0.459 |
| S4 28 days                | 3.657 | 0.544 | 0.577 | 0.314 | 0.611 | 0.577 | 0.249 | 0.373 |

Figure 9. Water capillary absorption k-value versus time.

The result show that higher water absorption through capillary had decreased by the increases amount of MSA used in concrete admixture. According to both value and plotted graph in figure 10, the capillary absorption through 7 days curing of control concrete 10.007cm/s for initial five minutes. Increases of MSA to 2%, 3% and 4% lead to capillary absorption to 2.021cm/s, 2.502cm/s and 3.175cm/s each during first five minutes. Even tough, absorption rate for 1% value is higher compared
0% value and the increases of MSA had increased water absorption through its capillary, however the absorption value had decreased accordingly with the time. During the final time (24 hours), the absorption of S1, S2, S3 and S4 are 0.966cm/s, 0.476cm/s, 0.635cm/s and 0.459cm/s which decreasing compared to previous time and it was lower compared S0 specimens.

Based on 28 days curing, it shows that the absorption had decreases compared to 7 days duration for S0 and S1 in five minutes intervals. However, S2, S3 and S4 indicates higher capillary absorption in 7 days curing which are from 2.021cm/s to 4.234cm/s, 2.502cm/s to 4.041cm/s and 3.175cm/s to 3.657cm/s respectively in the first five minutes. As the increases of duration time to 24 hours, the rate of capillary absorption start decreasing to 0.318cm/s, 0.306cm/s and 0.373cm/s. It can be seen that the water proofing effects of MSA tend to appear more obviously in the concrete mixtures containing MSA admixture compared to control specimens. From both value in 7 and 28 days specimens, its shows that the water capillary absorbing more water at early time compared to final time. According to Jalal et al., its due to fully dried sample are more tendency and consist higher rates absorbing water at early times compared to sample which were immersed for long times in water, however longer time resulting more realistic absorption value [35]. Thus, the value were taken only according to 24 hours duration.

According to data obtained, the results obviously show descending trends by increase in time of coefficients k-value. Its shows that MSA obviously tend in giving effects towards water proofing in concrete compared to normal specimens. It may due to MSA itself which contained filler properties due high CaCO$_3$ which reduce capillary pores in concrete specimens. Less porosity could lead to less permeability concrete which can reduce the ions from penetrates into the concrete which can give impact to its strength [12, 17, 16]. Thus, the addition of MSA with micro particles tend in improving pore structure of concrete which can reduce the rate of capillary absorption significantly.

4. Conclusion
In this study, utilisation of mussel shell ash that generates from mussel waste as an admixture in concrete has been studied. Then, its materials, concrete specimens were analysed according to data collected above. Based on results in this study on the performance of mussel shell ash concrete under curing effect on sodium chloride solution. The physical properties related to MSA (specific gravity, setting time, PSA, slump value) remain unimpaired with OPC which MSA consist small particle diameter of 10%, 30%, 50%, 60% and 70% cumulative and lower specific gravity value compared to OPC. It was analysed that small particle suitable to a filler in concrete. According to workability analysis, it seen that the increment of MSA could improve fresh concrete workability with the higher slump by using 4% MSA. The setting time for MSA indicates faster initial and final value due to its properties in hydration reaction with cements. The MSA addition percentages in term of performance of fresh properties were S4 as in (Table 1).

Addition of MSA into concrete contributed in reducing its mechanical properties. It shows in Table 4 and Table 5 which the increment of MSA percentages had reduce it compressive and split tensile strength. S4 indicates the lower mechanical strength in 7 and 28 days curing in NaCl solution with 18.03MPa, 20.9MP for compressive value and 1.71MPa, 2.02MPa for tensile value. Split ten-sile strength indicates the same patterned as compressive value with the increment of MSA. It due to reaction sequences in MSA (>95% CaCO$_3$) [17] as filler which later stages causes formation of ettringite leading first then to gypsum deposition and finally to thaumasite formation due to C-S-H breakdown forming from present of sulphate [31, 36-39]. However, MSA still can be applied in concrete mixture but should permitted in minimum quantity.

According to water capillary absorption analysis, it seen that MSA could reduce concrete permeability. Data were obtained according based on final times of analysis due to its realistic value compared to early value. Result as in Table 6 indicates that rate capillary absorption of S0 (0.964cm/s and 0.374cm/s) is higher compared to S2, S3 and S4 during final time (24 hours) for 7 and 28 days curing with 0.476cm/s and 0.318cm/s, 0.635cm/s and 0.306cm/s, 0.459cm/s and 0.373cm/s
respectively. Is seen that the lowest rate of absorption was S3 for 28 days curing and S4 for 7 days curing. Overall, the significant k-value for water capillary absorption is S2.

Although the addition of MSA to concrete does not affect the relationship between it permeability of the each specimens to its strength, the optimum percentages on MSA content for concrete strength was stressed by S1, S2 for permeability and durability and S4 for workability and early strength development. The utilisation of mussel shell might be in small amount and percentages, however if it was applied in larger scope in construction materials, it could involve in large quantities which was potentially improving concrete properties and also reduce the mussel shell waste generated.

5. References

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Acknowledgement
The authors would like to thank the Faculty of Civil and Environmental Engineering, UTHM and Cluster of Advanced Construction Materials, Jamilus Research Centre, UTHM for the opportunities, facilities and support in conducting this study.