CHAPTER 5

The Durability of Waste Shell Husk Concrete

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Abstract

A huge amount of shell husks is thrown away annually without any commercial return. This causes massive pollution and environmental problems. To mitigate the problem, shell husks have been used as recycled aggregates for the manufacture of concrete or cement-based composite materials. The mechanical properties of concrete specimens containing different percentages of shell husk aggregates namely 0, 10%, 20%, 30%, and 40% in the ratio of mass are demonstrated. The purpose of this study is to investigate the overall response of the mechanical properties of concrete as well as cementitious composites with different percentages of shell husk as a replacement for coarse aggregates. Various tests which measure the compressive strength, tensile strength and durability of concrete containing different percentages of shell husk were conducted.

Keywords—shell husk, concrete, durability, mechanical properties

1. INTRODUCTION

According to [1], concrete is a mixture of coarse aggregate, fine aggregate and cement. Concrete-making techniques, concrete quality and concrete mix ratio should be emphasised for good concrete production and quality. The strength of concrete increases with age and increased strength continues for some time. Increasing the compressive strength of concrete is highly dependent on temperature and humidity during the hardening process. Water-cement ratio is among the main factors that controls the strength of concrete. Fig.1.1 shows the relationship between the strength of concrete and water-cement ratio [2].

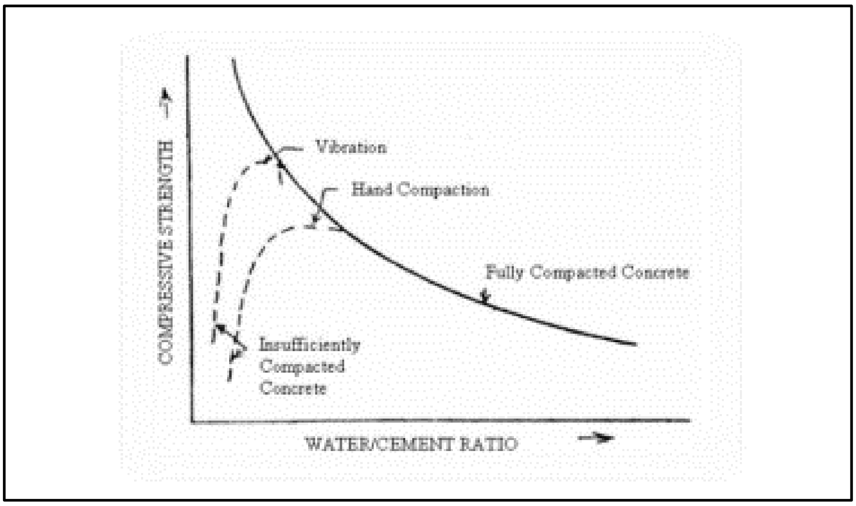

Fig. 1: The relationship between the strength of concrete and water-cement ratio [2]

Fig. 1 shows the relationship between the strength of concrete and water-cement ratio [2]. In concrete mix design, the ratio of the amount of water to the amount of cement used (both by weight) is called the water-to-cement ratio (w/c). These two elements are responsible for binding everything together. The water-to-cement ratio largely determines the strength and durability of concrete when it is cured properly.

The higher the water-to-cement ratio (that is the more water that is added for a fixed amount of cement), the more the strength of the resulting concrete is reduced. This is mostly because adding more water creates a diluted paste that is weaker and more susceptible to cracking and shrinkage. Shrinkage leads to micro-cracks, which are zones of weakness. Once the fresh concrete is placed, excess water is squeezed out of the paste by the weight of the aggregate and the cement paste itself. When there is a large excess of water, that water bleeds out onto the surface. The micro channels and passages that were created inside the concrete to allow that water to flow become weak zones and micro-cracks. Other than the water-cement ratio, concrete strength is also very dependent on the preparation process. If there is a change of mixture quality or a change of ratio in the mixture, the strength of concrete and the concrete with admixture will be affected.

Sea shells contain many proteins and are easily obtainable. A considerable number of shells is largely discarded and only a small amount of it is used for the manufacture of cosmetics and traditional goodies [20]. The rest of the shells contain chemical compounds such as lime (CaO). Therefore, it can be used as a substitute material in cement production. Besides that, the use of shells is expected to reduce environmental pollution. This study will examine the use of shells as a supplementary material for the manufacture of eco-concrete [3].

Statistics by the Department of Fisheries Malaysia showed that 57,544.40 tonnes of sea shells were harvested along the west coast of Peninsular Malaysia including Johor and Pahang in 2011 [4]. Utilising seashells reduces the storage of marine waste, reduces the exploitation of quarried aggregates and helps improve the performance of concrete mix designs [5].

2. RESEARCH ON THE USE OF SHELLS FOR CONCRETE PRODUCTION

The studies below investigated the mechanical properties of concrete or cementitious composites with 0, 10%, 20%, 30%, and 40% of sea shells as coarse aggregate in the ratio of mass. A comparison of the test results and a pertinent discussion of the investigated parameters are depicted in this case study. Table 1 below shows the list of research studies using different types of shells as a replacement material in concrete mixes [6-9, 19].

Table 2: Various types of shells used as a replacement material in concrete.

Researchers	**Country**	**Type of Shells**	**Replacement Material In Concrete**
Sugiyama, (2004)[6]	Japan	Scallop	Coarse Aggregate
Falade, (1995) [7]	Nigeria	Periwinkle	Coarse Aggregate
Eun-Ik Yang *et al.,*(2005) [19]	Korea	Oyster	Fine Aggregate
Yusof *et al,* (2011) [8]	Malaysian	Clam	Fine Aggregate
Muthusamy & Sabri, (2012) [9]	Malaysian	Cockle	Coarse Aggregate

Cement products for masonry and plastering which incorporated the use of ground waste seashells (short-neck clam, green mussel, oyster and cockle shells) were investigated by Lertwattanaruk et al., (2012) [10]. The use of shells as aggregate material was found to decrease the strength and workability of concrete compared to normal concrete. A higher proportion of shells decreases the strength of concrete. The calcium carbonate (CaCO3) content (accounts for 95-99% by weight) in cockle shells is high and almost equal to the calcium carbonate content in limestone [11]. Consequently, the physical and chemical properties of cockle shell ash is also similar to limestone. Therefore, it is suitable to be used as a filler material in concrete. In this study, different proportions of cockle shells (10%, 15%, 25% and 50%) were used as a cement replacement material [12]

3.0 MATERIAL

3.1 Seashells

The dried seashells were taken to the laboratory to be crushed into a very fine powder. A sieve analysis test was conducted and all the shells that do not pass through the 4.75mm sieve were considered as coarse aggregates [13].

3.2 Cement

Cement is a material which is used to bind solid bodies together by hardening from a fresh or plastic state. In this research work, locally available ordinary Portland cement was used.

3.3 Aggregate

The coarse aggregate was air dried to obtain a saturated surface dry condition to ensure that the water cement ratio was not affected. A few aggregate characteristics that affect the workability and bond between concrete matrixes are shape, texture, gradation and moisture content. In this study, crushed aggregates from the quarry with a nominal size of 5-10 mm was used in accordance to BS 882-1992 [14]. Fine aggregate is commonly known as sand and should comply with coarse, medium, or fine grading needs. The fine aggregate was saturated under surface dry conditions to ensure that the water-cement ratio was not affected. The oven dried aggregate will then pass through a 600μm sieve before it is used in the test [14].

3.3 Water

The chemical reaction between water and cement is very significant in achieving the cementing property. Hydration is the chemical reaction between the cement and water which helps in achieving the cementing property after hardening. Therefore, it is necessary that the water used does not contain any substance that may affect the reaction between the two components.

4.0 FINDINGS

This study mainly investigated the overall mechanical properties of concrete or cementitious composites with different percentages of crushed sea shells as coarse aggregate replacement.

4.1 Compressive Strength

The compressive strength of concrete specimens is taken as the maximum compressive load it can carry per unit area. The specimen is usually in the form of a cube. It is compressed between the platens of a compression testing machine by a gradually applied load. The compressive strength test was carried out on 100 x 200 mm concrete cylinders in accordance with BS 1881: part 116 [16]

Table 3: Compressive strength test results at the age of 7, 14 and 28 days [17]

Concrete Mixes	**Compressive Strength**		
	7 days	**14 days**	**28 days**
Seashells (0%)	30.49	38.24	45.45
Seashells (10%)	26.79	34.83	37.32
Seashells (20%)	33.87	42.92	48.96
Seashells (30%)	24.68	27.69	29.44
Seashells (40%)	24.13	26.40	27.66

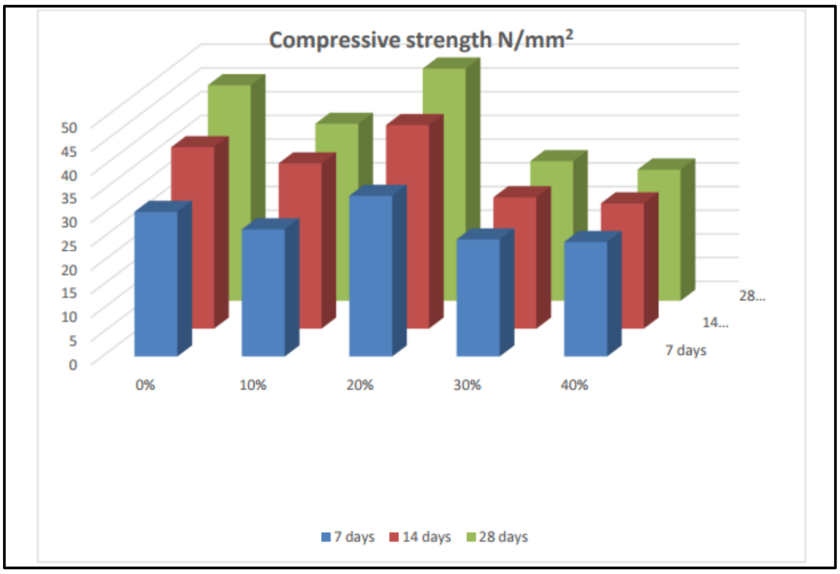

Fig. 5: Result of compressive strength for 7, 14 and 28 days [17].

As shown in Table 3, the first column shows 0% replacement representing normal concrete followed by 10%, 20%, 30%, and 40% of seashell content. After the concrete was casted in moulds, it was cured three separate durations of 7 days, 14 days and 28 days. Three samples were cast for each mix giving three compressive strength values which were averaged to obtain the average strength. The tables that follow show the full calculated values of the respective strength which are further illustrated by fig. below.

The compressive strength of the concrete mixture is shown in Fig. 5.1. As the curing period increases, the compressive strength increases accordingly. The compressive strength develops along with the ratio of cement and shells. On the other hand, 40 % the sea shells had the smallest strength value compared to other ratios.

The influence of the ground seashells on compressive strength could reduce the early strength of concrete. The ground seashells have less calcium content (CaO) than cement. This causes a slow hydration process. However, after 28 days, the increment in strength was quite significant for seashell concrete.

4.2 Tensile Strength

Tensile strength is one of the important properties of concrete. Generally, it is unusual for concrete to resist direct tension. This is because of its lower tensile strength and its brittle nature. The split tensile strength is very important for the determination of the load at which the concrete specimen will crack or break completely. This method consists of a concrete cylinder measuring 200mm in length and 100mm in diameter which is placed in a compressing machine. The load is then applied vertically from the top to the bottom [18]. Plywood or cardboard is added in between to ensure even loading.

Table 5.2: Split tensile strength results [17]

Concrete Mixes	**Flexural Strength (N/mm2)**		
	7 days	**14 days**	**28 days**
Seashells (0%)	5.63	5.76	6.2
Seashells (10%)	5.18	5.22	5.74
Seashells (20%)	5.99	6.39	7.95
Seashells (30%)	4.94	5.28	5.86
Seashells (40%)	4.93	5.22	5.76

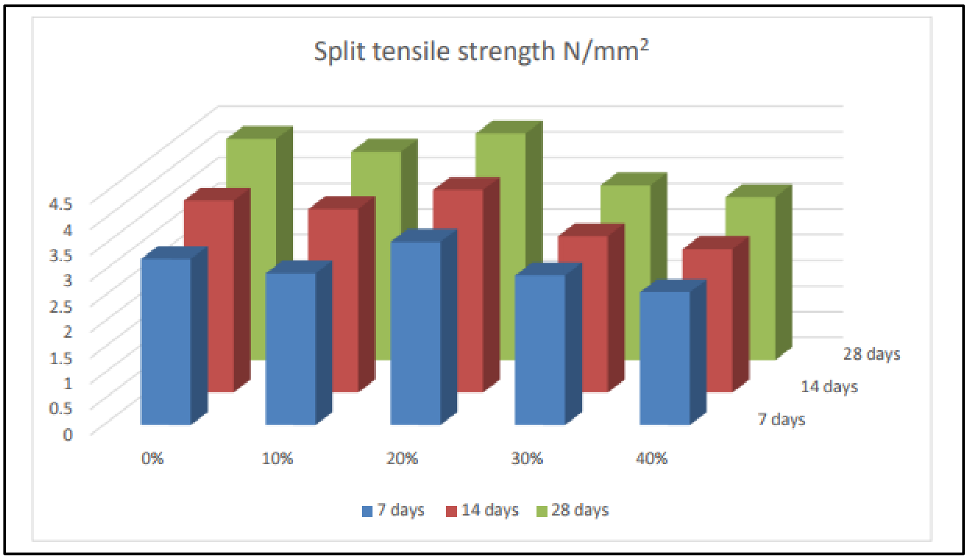

Fig. 5.2: Result of tensile strength for 7, 14 and 28 days [17].

The compressive strength of the concrete mixture is shown in Fig. 5.2. On the other hand, 20 % of seashells obtained the highest strength value compared to other ratios. For overall performance, samples cured for 28 days produced the highest density and compressive strength. The high tensile strength was likely due to improved bonding at the interface.

5.0 CONCLUSION

Based on previous research, using seashells as a partial replacement in concrete is a good alternative as it reduces the depletion of natural resources such as sand and granite. Besides that, it also reduces the accumulation of waste marine materials. The following conclusions can be drawn from this study:

- Leaching of pervious concretes quickly occurs after coming into contact with the leaching solution. The presence of shells appears to influence the quantity of leaching calcium. The calcium carbonate in the shells dissociates in demineralized water to release calcium.

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