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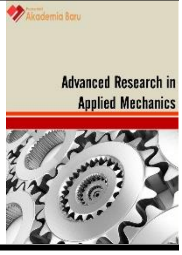

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Performance of Concrete Incorporating of Clam Shell as Partially Replacement of Ordinary Portland Cement (OPC)

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ABSTRACT

In Malaysia, the uses of concrete will be demand higher in future due to growing of construction industry. Ordinary Portland cement (OPC) known as dominant precursor in manufacturing of concrete, every tons of OPC produce will released similar amount of carbon dioxide (CO2) in activities of quarrying limestone and calcination. Clam shells known as fishery industry waste that have high potential as partial cement replacement in concrete due to its similar chemical composition with limestone which is used in manufacturing of Portland cement. Clam shells were prepared by cleaning, crushing, grinding and calcination. This study investigate the performance of concrete using clamshells as partial replacement of OPC. The properties of clam shell concrete such as density, water absorption, compressive strength and splitting tensile strength has been studies. These properties were compare with Ordinary Portland cement (OPC) concrete. Based on mixes using clamshells ash with proportion of 4%, 6%, and 8% by weight of cement, the optimum compressive strength was achieved for the mix that replaced cement by 6%. The clamshells concrete has higher compressive strength and density compare to OPC in 28th days. For splitting tensile strength on 28th days specimens SC 6% has highest splitting tensile strength compare to specimens SC 4% and SC 8% but splitting tensile strength for OPC concrete (5.1MPa) is higher than specimens concrete SC 6% (4.4MPa). Future studies for this research are first studies into the analysis between degrees of calcination should be made to quantify the value and assesse durability testing of seashell concrete other than water absorption test.

Keywords:
Clamshells, compressive strength, density, splitting tensile strength, water absorption

1. Introduction

Construction industry is booming and continue to grow. Concrete and its dominant precursor, Ordinary Portland cement (OPC) is the most used building materials in construction industry. In others words, Ordinary Portland cement (OPC) is an important construction material and also a strategic merchandised [1]. However, every tons of OPC produced will releases on average a similar amount of carbon dioxide (CO2) into atmosphere. The amount of CO_2 emitted during production of cement is nearly 900kg for every 1000kg of cement produced [2]. Quarrying known as primarily a

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stage in production of OPC while 7% of CO2 is produces during the operation of quarrying machinery [3]. Continuous mining will eventually cause a huge impact to the environment including erosion, loss of biodiversity, and contamination of soil, groundwater and surface water by chemical from mining process [4]. This data indirectly indicate that the footprint emissions of CO2 gave huge impact to the environment.

Mollusks in fishery industry provides nutritious food source, jewelry, pharmaceutical, and medicine for domestic and international market. Seashell of various mollusks such as clam, cockle, oyster, and scallops are available abundantly in Asian country. Nevertheless, production of mollusks species in Malaysia in 2014 was 42.6 thousand [5]. This value indicates the number of waste shell generated indirectly. While untreated dumping of waste seashell in public for long period can causes stench due to the decay of the remaining flesh in the shells or the microorganism decomposed of salt into air [6]. These problem eventually will affect the quality of people living and result in environment issue.

Number of studies has been done in utilize waste originating from different sources such as construction, industries, and agriculture as a substitutes materials in concrete in terms of sand, aggregate and OPC [7]. It was reported that the use of crushed scallop shells as aggregate could decrease the mechanical properties at higher replacement level. However, till now, there are not many studies related to the influence of mechanical properties of seashells as replacement of OPC due to the production of shells powder requires intensive energy to burn and grind [7].

Seashell waste is one of the potential waste material which can be utilized as partial replacement material of Ordinary Portland cement (OPC) [8]. It known as potential biomass sources for CaCO3 and also as a raw material for production of calcium oxide (CaO) after calcination due to the rich of CaCO3 in the shell [9], [10]. Studies has proved that calcium oxide in seashells can be convert to calcium oxide through calcination process. This shows that seashells contain calcium where known as sources of calcium oxide. This paper provides an experiment study to measure the performance of concrete incorporating of clam shells ash as partially replacement of OPC such as compressive test, splitting tensile test, water absorption test and density.

2. Methodology

2.1 Raw Material

The Ordinary Portland cement type I were used as a main binder. Fine aggregate and course aggregate were incorporate as main component of concrete. Coarse aggregate used in the mixture is in between 12.5mm to 20mm in diameter and in saturated surface dry condition (SSD) while fine aggregate used is sand.

2.2 Handling of Clam Shell

Clam shells waste were first collected from seafood supplier, fishery industries and household. The collected clam shells undergoes cleaning and drying process to remove dirt such as salt and the remaining flesh. After cleaning and drying, seashells is then crushed manually by using hammer before calcination. Crushed seashells is then transfer to the crucible cup and placed into muffle furnace at temperature 800˚C for 2 hours. After calcination, clam shell is then cooled to room temperature and grinded into powder form which shown in Figure 1.

Fig. 1. Clam Shell Ash

2.3 Mixture Proportion

Clam shell ash was used as partially replacement of cement at percentage of 0% (OPC), 4% (SC4), 6% (SC6), and 8% (SC8). Table 1 shows the mix proportion of clam shell concrete with different percentage of clam shell ash as replacement of cement. Water cement ratio of 0.45 was used in mix design of clam shell concrete. The mixed concrete were designed to achieve grade 35 which means 35 N/mm^2 28 days.

Table 1
Concrete Mix Proportion

Materials	**Mix Proportions (kg/m^3)**			
	OPC	**SC4**	**SC6**	**SC8**
OPC	467	448.32	438.98	429.64
Clam shell ash	0	18.68	28.02	37.36
Water	210	210	210	210
Coarse aggregate	596	596	596	596
Fine aggregate	1107	1107	1107	1107

2.4 Mixing and Casting

Raw material are prepared based on design proportion and mixed manually by using shovel. After mixed, the mixture is then transfer into mould for process of moulding. The mould with mixture is then placed on vibrating table for vibration to allow air bubbles to escape. There are total 48 concrete sample is casted in cubical and cylindrical mould with size 100mm X 100mm X 100mm and 100mm X 200mm. Cubical mould were used for density test, water absorption test and compressive test while cylindrical mould were used for splitting tensile test. Table 2 shows the specimen prepare for testing.

Table 2
Specimen Prepare for Testing

TYPE OF TESTING	SHAPE AND SIZE OF SAMPLE	AMOUNT OF SAMPLE	
		7th	28th
Compressive Strength (BS 1881: Part 116:1983) **Density Test** (BS 1881- 114:1983)	Cubical mould (100mm x 100mm x 100mm)	12	12
Splitting Tensile (BS 1881: Part 117: 1983)	Cylindrical mould (100mm x 200mm)	-	12
Water absorption (BS 1881: Part 122: 1983)	Cubical mould (100mm x 100mm x 100mm)	12	-

2.5 Testing and Analysing

The water absorption has been conducted according to BS 1881: Part122 [11] and for density test has been done according to BS1881: Part 114 [12]. The compressive strength of concrete was carried out according to BS 1881: Part 116 [13]. Splitting tensile test were carried out according to standard BS 1881: Part 117 [14] to determine the tensile strength of seashell concrete.

3. Results
3.1 Density Testing

The density test is carried out on clam shell concrete specimen which would be used for compressive testing. The density test is carried out by weighting the concrete specimen before curing and after curing for 1st, 7th and 28th days. The results of replace cement with clam shells on the density of seashell concrete specimens with 0%, 4%, 6% and 8% at 1st day, 7th days and 28th days are presented in Figure 2. The density of clam shell concrete with different percentage of clam shell ash replacement within 28 days are in between 2340kg/m³ to 2400kg/m³.

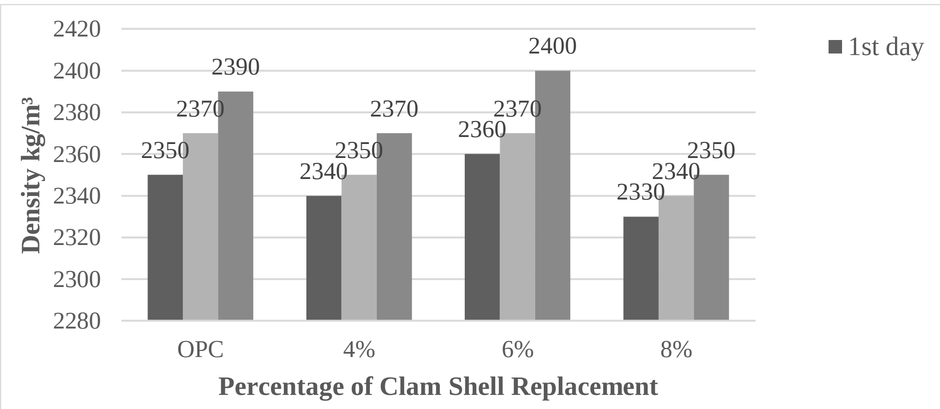

Fig. 2. Density of OPC and Seashell Concrete with Different Percentage of Clam Shell Ash as Replacement of OPC

As shown in Figure 2, the density of clam shell concrete with different percentage of clam shell ash replacement is increases with the concrete age, while 6% of clam shell as replacement of OPC (SC6%) has the highest density among the others. This is due to the fact of densification of hydration product which is calcium dioxide (CaO) in clam shell that increase the density at the same times reduce the porosity of the seashell concrete of the specimen.

3.2 Compressive Strength

The compressive strength of concrete with 0%, 4%, 6% and 8% of clam shell ash as partially replacement of OPC at 7th days and 28th days are shown in Figure 3. As shown in Figure 3, the compressive strength of each specimen increased accordingly as the age increased but further increase up to 6% resulted decreased in compressive strength due to the reduction of cement content. However, on 28th days specimen SC 6% shown significant increment in strength due to pozzolanic properties (calcium hydroxide CaOH) in clam shell ash which indicate the formation strength in concrete [15].

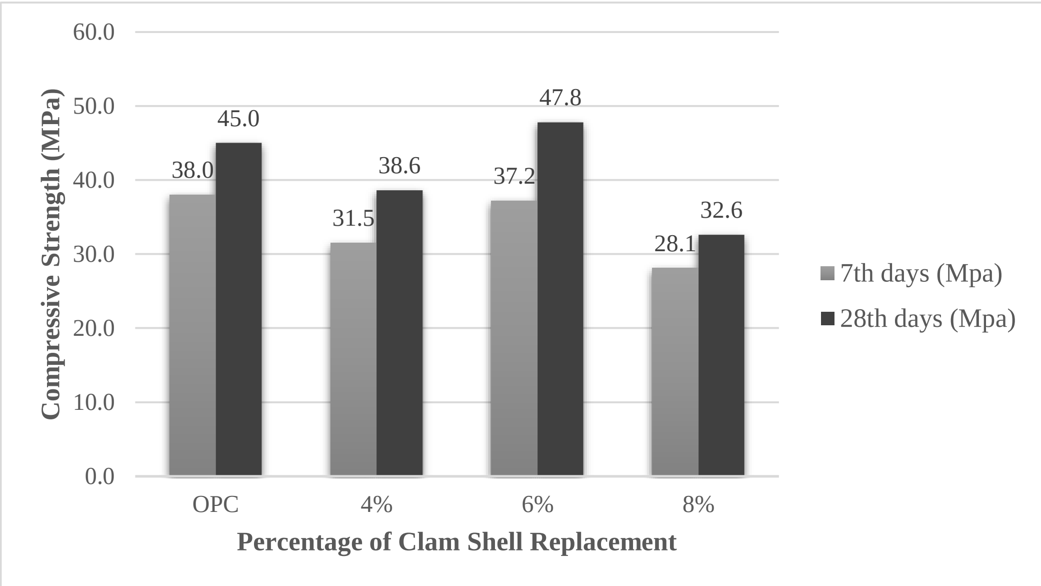

Fig. 3. Compressive Strength of OPC and Seashell Concrete with Different Percentage of Clam Shell Ash as Replacement of OPC

On 7th days, the specimens with 6% of clam shells ash as replacement of OPC has the highest compressive strength (37.2MPa) compare to others specimens with different percentage of replacement, while specimens with 8% of clam shells ash as replacement of OPC (SC 8%) has the lowest compressive strength (28.1MPa). As shown in Figure 3, the OPC concrete showed slightly higher compressive strength (38.0MPa) than the specimens SC 6% (37.2MPa). This is due to decrease of the cement content causes the rate of hydration in concrete reduce at early age [7,16.17].

On 28th day, specimen SC 6% showed the maximum compressive strength which is 47.8MPa while specimen SC 8% showed the minimum compressive strength which is 32.6MPa. Moreover, specimens SC 6% has higher compressive strength compare to OPC concrete which is 45MPa. This indicate that replacement of clam shell improved the latest strength of concrete as well as density of concrete [18].

Overall, the concrete specimen with 6% of clam shell ash as replacement of OPC has the highest compressive strength on 7th days and 28th days. Therefore, 6% known as the optimum ratio of clam shell ash as replacement of OPC in concrete.

3.3 Water Absorption Testing

Figure 4 shown the percentage of water absorption of concrete specimen with different percentage of clam shell ash replacement. As shown in Figure 4, percentage of water absorption decreased from OPC specimen to specimen with 6% of clam shell ash replacement (SC 6%) but increased on specimen with 8% of clam shell ash replacement (SC 8%).

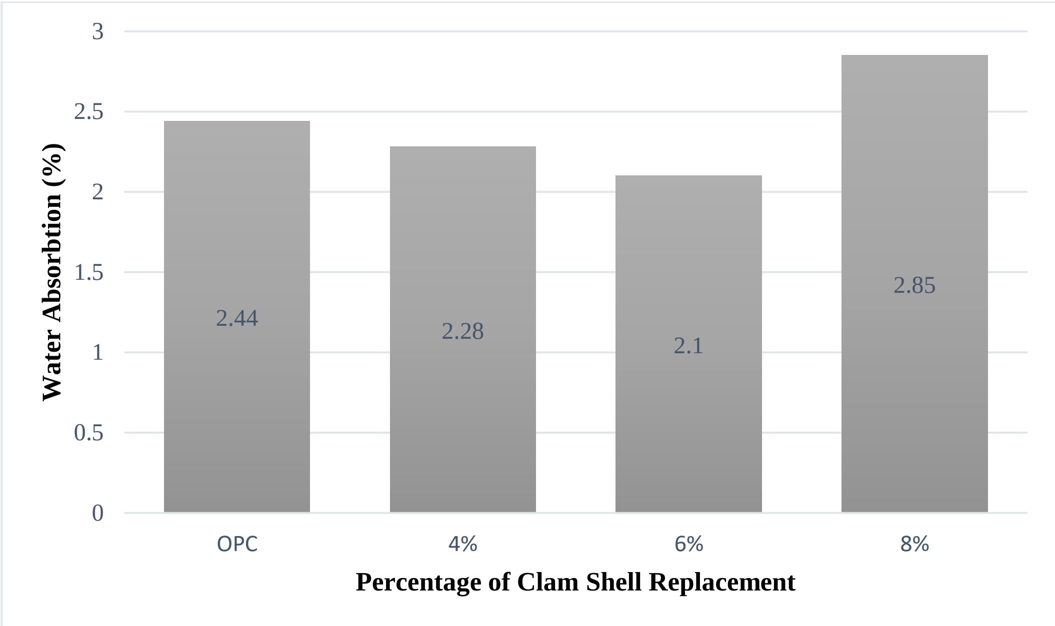

Fig. 4. Percentage Water Absorption of OPC and Seashell Concrete with Different Percentage of Clam Shell Ash as Replacement of OPC

As shown in Figure 4, concrete specimen with 8% of clam shell ash as replacement of OPC (SC 8%) shows the highest percentage of water absorption (2.85%) while concrete specimen with 6% of clam shell ash as replacement of OPC (SC6%) shows the lowest percentage of water absorption (2.1%). This is due to the present of the porosity on the specimen causes the percentage water absorption increases as the percentage of clam shell ash increases. This has been proved on Figure 5 and 6.

Figure 5 and Figure 6 shown the satisfactory and unsatisfactory failure of specimen concrete with 6% and 8% of clam shell ash as replacement of OPC. As shown in Figures 5 and 6, specimen with 6% of clam shell ash as replacement of OPC has less porosity compare to specimen with 8% of clam shell ash as replacement of OPC.

Furthermore, percentage water absorption of concrete specimens explained the statement discussed on density where the density of specimen concrete increases as the percentage of clam shell ash increases due to less present of porosity in concrete. Specimen with 6% of clam shell as replacement of OPC has highest density and lowest percentage of water absorption. This show that specimen concrete with 6% of clam shell as replacement of OPC has lower porosity of concrete.

Fig. 5. Unsatisfactory Failure of Specimen Concrete with 6% of Clam Shell Ash as Replacement of OPC

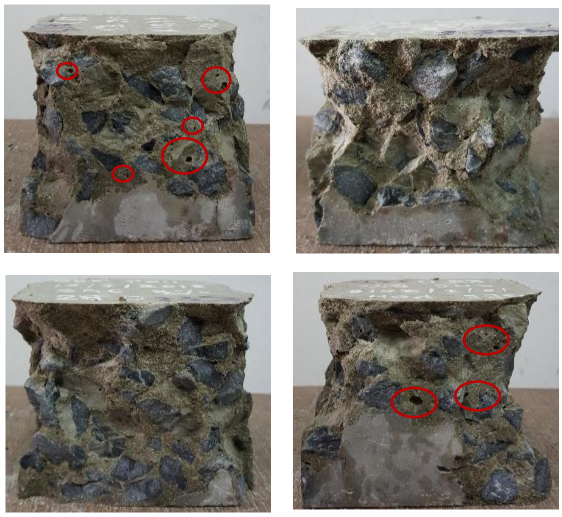

Fig. 6. Satisfactory Failure of Specimen Concrete with 8% of Clam Shell Ash as Replacement of OPC

3.4 Splitting Tensile Strength

The splitting tensile strength of concrete with 0%, 4%, 6% and 8% of clam shell ash as partially replacement of OPC at 28th days are shown in Figure 7. As shown in Figure 7, splitting tensile strength for OPC concrete (5.1MPa) is higher than seashell concrete. This is due to the bonding strength of the aggregate is disrupted by the cement replacement [18].

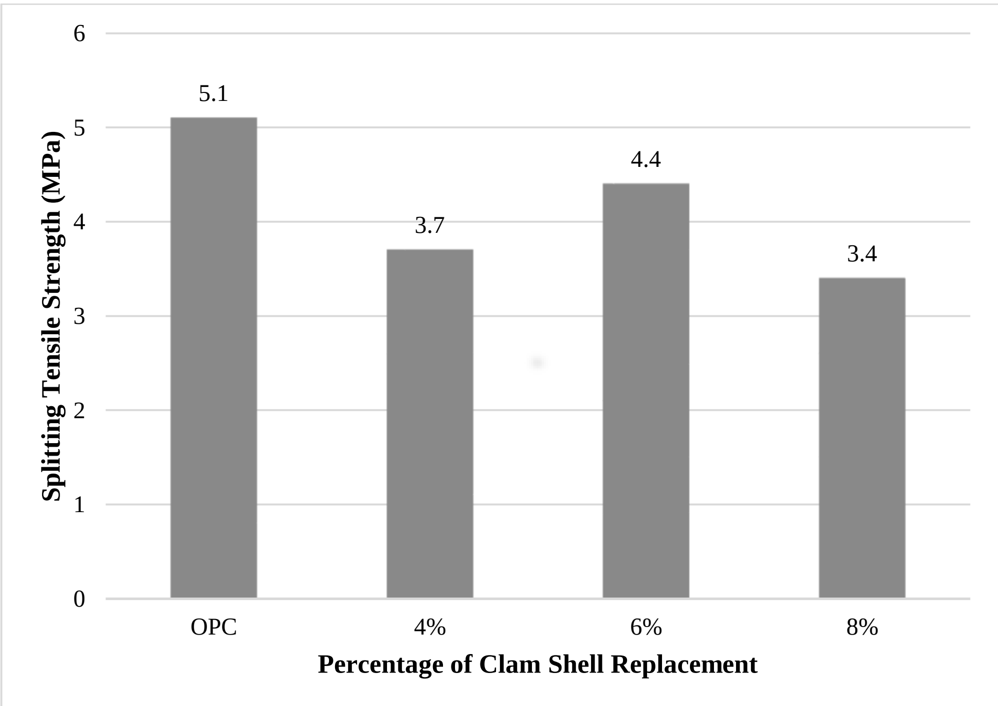

Fig. 7. Splitting Tensile Strength of OPC and Seashell Concrete with Different Percentage of Clam Shell Ash as Replacement of OPC

By comparing among the seashells concrete, specimen with 6% of clam shell ash as replacement of OPC (SC 6%) has highest splitting tensile strength which is 4.4MPa while specimen with 8% of clam shell ash as replacement of OPC (SC 8%) has lowest splitting tensile strength which is 3.4MPa. This shows that seashell concrete with 6% of clam shell as replacement of OPC performed good adhesion between aggregate and cement paste compare to 8% [18].

Overall, the concrete specimen with 6% of clam shell ash as replacement of OPC has the highest splitting tensile strength on 28th days. Therefore, 6% known as the optimum ratio of clam shell ash as replacement of OPC in concrete.

3.5 Optimum Proportion of Clam Shell Ash as Replacement of OPC

The summary result of density test, compressive strength, water absorption and splitting tensile test of seashell concrete with 0%, 4%, 6% and 8% of clam shell ash as partially replacement of OPC are presented in Table 3.

Table 3
Summary Results of Density Test, Compressive Strength, Water Absorption and Splitting Tensile Strength

Sample	Density (kg/m^3)			Compressive Strength (MPa)		Water Absorption (%)	Splitting Tensile (MPa)
	1st day	7th days	28th days	7th days	28th days	28th days	28th days
OPC	2350	2370	2390	38.0	45.0	2.44	5.1
SC 4%	2340	2350	2370	31.5	38.6	2.28	3.7
SC 6%	2360	2370	2400	37.2	47.8	2.10	4.4
SC 8%	2330	2340	2350	28.1	32.6	2.85	3.4

For overall performance, seashell concrete with 6% of clam shell ash as replacement of OPC known as optimum replacement percentage of clam shell ash as partially replacement of OPC in concrete due to results of highest compressive strength, splitting tensile strength and lowest percentage of water absorption among others seashell concrete. Moreover, seashell concrete with 6% of clam shell ash as replacement of OPC has the highest density on 28th days among other specimen.

4. Conclusions

The overall objective in this research is to analyze the optimum proportion of clam shell ash as replacement of OPC in term of strength development in concrete. Testing were done in this research were density test, water absorption test, compressive strength test and splitting tensile strength test. High content CaO in clam shells ash will causes the slow hydration process that lead to reduce strength of concrete in early age. This answer why specimens concrete, SC 6% has the highest compressive strength compare to specimens SC 4% and SC 8% at 7th days. But compressive strength for OPC concrete (38.0MPa) is slightly higher than specimens concrete SC 6% (37.2MPa). Conversely, replacement of clam shell improved the latest strength of concrete. On 28th days, specimen concrete

SC 6% has the highest compressive strength whereas specimen concrete SC 8% has the lowest. Moreover, on 28th day specimens SC 6% has higher compressive strength compare to OPC concrete. Densification of hydration product (CaO) in clam shell increase the density of concrete as the proportion of clam shell ash increase, but further increment of clam shell reduced the density of concrete due to the present of the porosity. In density testing, concrete specimens with 6% of clam shell ash as replacement of OPC (SC 6%) in concrete has the highest density whereas specimen with 8% of clam shell ash as replacement of OPC (SC 8%) has the lowest. Therefore for water absorption test, specimen concrete SC 6% has the lowest percentage (2.1%) of water absorption while specimen SC 8% has the highest percentage of water absorption (2.85%) due to the densification of calcium oxide in clam shell reduced the porosity of the concrete. For splitting tensile test, concrete specimens SC 6% has the highest splitting tensile strength compare to specimens SC 4% and SC 8%. But splitting tensile strength for OPC concrete (5.1MPa) is higher than specimens concrete SC 6% (4.4MPa). This indicate that the bonding strength of the aggregate is disrupted by cement replacement while compare to specimen SC 4% and SC 8%, SC 6% performed good adhesion between aggregate and cement paste. In conclusion, seashell concrete with 6% of clam shell ash as replacement of OPC known as optimum replacement percentage of clam shell ash as partially replacement of OPC in concrete due to results of highest compressive strength, splitting tensile strength and lowest percentage of water absorption among others seashell concrete.

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