

## NUTRIENT LEACH FROM CONCRETE ARTIFICIAL REEF INCORPORATING WITH ORGANIC MATERIAL

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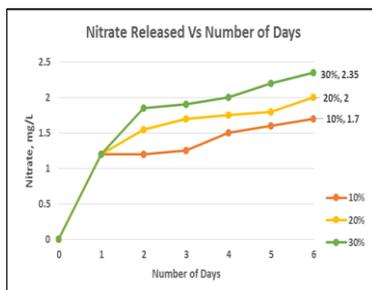
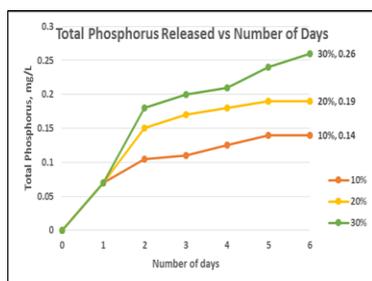
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### Graphical abstract



### Abstract

Solid waste from the construction site has always been an environmental issue in this country. Poor management has often resulted with the solid waste being dumped in open field even though these waste materials be recycled for new products. The recycled waste will not only reduce the environmental problem, but it will also contribute to new innovations and technology. This article discusses the design and fabrication of the artificial reef using recycled waste concrete from the construction industry. The artificial reef is added with organic material which is peanut's shell. The organic material was used to provide organic nutrients inside the artificial reef. Laboratory tests were conducted to determine the compressive strength of the reef and to measure the organic nutrients; nitrate ( $\text{NO}_3\text{N}$ ) and phosphorus (TP) released from the reef when it was placed in the water. From the results, it was found that the artificial reef with added peanut's shell achieved a maximum compressive strength of 31.3 MPa. It was also found that the organic material in the reef dispersed nutrients into the water.

**Keywords:** Recycled aggregate, artificial reef, organic material, compressive strength, density, organic nutrient

### Abstrak

Sisa pepejal dari tapak pembinaan sering menjadi isu alam sekitar di negara ini. Pengurusan yang buruk sering mengakibatkan sisa pepejal dibuang di tempat terbuka walaupun bahan terbuang ini boleh diguna semula bagi menghasilkan produk baru. Bahan terbuang yang diguna semula ini boleh mengurangkan masalah alam sekitar malahan juga menyumbang kepada inovasi dan teknologi baru. Artikel ini membincangkan tentang rekabentuk dan fabrikasi tukun buatan menggunakan konkrit kitar semula dari industri pembinaan. Tukun ini juga dicampur dengan bahan organik iaitu kulit kacang. Bahan organik digunakan bagi menghasilkan nutrient organik dalam tukun buatan tersebut. Ujikaji makmal dijalankan bagi menentukan kekuatan mampatan tukun dan juga bagi mengukur nutrient organik yang dibebaskan oleh tukun ini setelah ia berada di dalam air. Daripada keputusan yang di catat, didapati tukun buatan ini boleh mencapai kekuatan mampatan maksima sehingga 31.3 MPa. Hasil kajian juga menunjukkan bahan organik di dalam tukun buatan ini mengeluarkan nutrient ke dalam air iaitu nitrate ( $\text{NO}_3\text{N}$ ) and phosphorus (TP).

**Kata kunci:** Batu baur kitar semula, tukun buatan, bahan organik, kekuatan mampatan, ketumpatan, nutrien organik

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## 1.0 INTRODUCTION

An artificial reef (AR) is a manmade structure that may mimic some of the characteristics of a natural reef. Submerged shipwrecks are the most common form of artificial reef. Oil and gas platforms, bridges, lighthouses, and other offshore structures often function as artificial reefs. Artificial reefs were also created in underwater areas that require a structure to enhance the habitat for reef organisms, including soft and stony corals and the fishes and invertebrates that live among them. Materials used to construct artificial reefs have included rocks, cinder blocks, and even wood and old tires. Recently, the type of materials used as AR has widened to limestone, steel as well as concrete [1].

AR is also defined as one or more objects of natural origin deposited purposefully onto the seafloor to influence physical, biological or socioeconomic processes related to living marine resources [2]. Traditionally, the most prominent use of ARs has been to mitigate the depletion of fishery stock resulting from overly harvest and habitat degradation [3]. Other purposes of AR deployment include coastline conservation, harbour stabilization, recreational surfing, aquaculture and habitat protection and restoration [4].

Concrete has been found to be very favourable for artificial reef construction. It does not degrade in seawater, can be made to have neutral pH, is easily moulded, and not easily moved once in a place. Concrete has a demonstrated high success rate as artificial reef material in both marine and estuarine environment. The obvious reason for this high rate of success is the strong compatibility of the material with the environment in which it is placed, and for the purpose for which it is placed. Concrete is generally very durable and stable in reef applications.

However, pure concrete materials can be expensive and may later leach elements which can be toxic to marine organisms and hence destructive to the environment. Therefore, organic materials are added to the concrete reef mixture to promote aquatic organism growth. This organic material release usable nutrients to microorganisms in the vicinity of the artificial material. Some of the suitable organic materials may include peanuts shell, animal by-products, and other waste materials from plant or animal origin.

This paper evaluates the potential of an improved artificial reef using reinforced concrete from waste construction material with added organic material as a new habitat and its effectiveness in increasing the productivity of the area and diversity of fish fauna.

Recycling the waste aggregate in this study is aimed to reduce the environmental issue related to inefficient solid waste management and preservation of natural aggregate.

The recycled coarse aggregates in this research were produced by the crushing of old concrete cubes used for compressive strength testing in the Structural and Material Laboratory in Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor. The strength class of the old concrete cubes was C20 to C25. The crushing was conducted with a hammer. The recycled aggregate produced was sieved with a maximum size of 20 mm. Crushed concrete particles were separated into standard fractions of coarse aggregate (5-10 mm, 10-14 mm and 14-20 mm), according to BS 882: 1992: Table 3.

## 2.0 NUTRIENTS IN ESTUARINE ECOSYSTEM

Groundnut shells contain an average of 68% organic matter, 6.8% crude protein, 18.2% crude fiber, and 7.1% ash. Another nutritional composition analysis of groundnut shells indicates that the shells contain 65.7% cellulose, 21.2% carbohydrates, 7.3% protein, 4.5% minerals and 1.2% lipids [5].

Estuaries are transitional environments, the meeting place of land, fresh water and ecosystem. Nitrogen and phosphorus are key water quality parameters in estuaries [6]. Depending on their chemical forms (or species), nitrogen and phosphorus can have significant direct or indirect impacts on plant growth, oxygen concentrations, water clarity, and sedimentation rates, just to name a few. Nitrogen and phosphorus are essential elements of DNA and protein building blocks, yet often subject to environmental limitation in natural ecosystems. Nitrogen's primary role in organisms is protein and DNA synthesis; plants also use this substance in photosynthesis [7]. Nitrogen and phosphorus play such important roles in the estuarine ecosystem.

## 3.0 EXPERIMENTAL PROGRAMME

The experimental programme is divided into two phases. Phase 1 involves laboratory work to determine the material properties and to fabricate the artificial reef. Phase 11 involves the measurement of nutrients leached or released from the reef when it is put in the water.

### 3.1 Phase 1

#### 3.1.1 Material Properties and Reef Fabrication

The reef is fabricated using various materials; cement (OPC), sand, recycled aggregate, water and peanut's shell. The sand used were 3 mm in size. Recycled aggregate passing 20 mm and retained on 4.75 mm sieve were used. The aggregate must be free from any contamination which adversely affect its quality which include clay agglomerations, aluminium, products containing tar, glass, chloride,

plastics, polystyrene and materials leading to alkali-aggregate reactions. Due to the high water absorption, recycled aggregates were soaked in water for one hour before mixing. The substitution of natural coarse aggregate with recycled aggregate was made by weight. Peanut's shell need to be clean and free from clay and other fine material before it was added to the concrete admixture. The water/cement ratio was kept constant at 0.45.

The material properties of the reef were determined from compressive strength test on the concrete cubes. The cubes (150 cm x 150 cm x 150 cm) as shown in Figure 1 were cast and tested to determine the compressive strength of each reef with different percentage of organic material. Total number of three cubes were cast for each percentage of peanut's shell added (10%, 20% and 30%) and tested under compressive strength at age of 28 days. Three cubes with no added peanut's shell were cast as control samples.



Figure 1 Concrete cubes



Figure 2 AR cast in a formwork

### 3.1.2 Reef Fabrication

The reefs were fabricated with different percentage of peanuts shell which are 10%, 20% and 30% from the volume of the reef. Formworks were designed to cast the reef with the dimension of 0.5 m x 0.5 m x 0.3 m with a hollow section of dimension 0.25 m x 0.25 m x 0.3 m as shown in Figure 2. Sand, cement, recycled aggregate and water were first mixed in the

concrete mixture. Different percentage of peanut's shell was added gradually into the mixture to control its density. The density was controlled to achieve the targeted compressive strength of about 30 MPa. The size of AR was chosen so that it has enough weight to avoid it from moving once it was placed in the water. The hollow section was designed to attract fishes to approach it.

### 3.2 Phase 11

This phase involves the determination of nutrients released from the artificial reef with different volume of peanut's shell. The artificial reef were placed inside the sea water tank for one week. The water samples were taken every day for six (6) days to measure the organic nutrient leached from the reef into the water. There were two (2) tests conducted to measure the organic nutrients released from the reef; total phosphorus (TP) and Nitrate (NO<sub>3</sub>-N).

#### 3.2.1 Determination of Organic Nutrient

The water sample is taken before the reef is put inside the water to observe the organic nutrient inside the water. The artificial reef were then put inside the water tank and the wave simulation is conducted. (Figure 3) The water sample will be taken again after the reef is put inside the water to determine the organic nutrient leached from the reef to the water.



Figure 3 AR placed in the water tank before the wave simulation was conducted.

For measuring the dispersion of nutrients into the water, samples must be collected in clean glass or plastic bottles and must be analysed as soon as possible for best results. In order to preserve samples for later analysis, the sample pH must be adjusted to less than 2 with concentrated sulphuric acid (about 2 mL per liter).

## 4.0 RESULTS AND DISCUSSION

### 4.1 Compressive Strength

The artificial reef with different volume of organic material are designated in Table 1 as AR-10%, AR-20% and AR-30% for reef with 10%, 20% and 30% organic

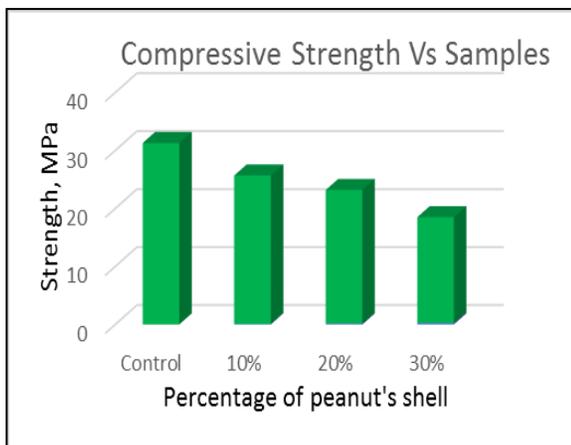
material, respectively. AR-C represents the control reef without added organic material.

**Table 1** Compressive strength of Artificial Reef with added peanut's shell

Cube specimens	Strength (kN/mm <sup>2</sup> )
AR-C	31.3
AR-10%	25.6
AR-20%	23
AR-30%	18.2

Table 1 presents the comparison of compressive strength for different percentage value of peanut's shell contained in the artificial reef at 28 days. From the graph in Figure 4, it was found that the increased percentage of peanuts shell in the concrete resulted with decreased strength of the concrete. For the concrete without peanuts shell, the strength value after 28 days was 31.3 MPa. Meanwhile, the strengths were recorded at 25.6 MPa, 23 MPa and 18.1 MPa for 10%, 20% and 30% of peanuts shell added to the concrete, respectively. The decreased strength is resulted from lesser bonding between the cement, sand and aggregate particles due to existence of the peanut's shell. Lesser bonding could also due to the mortar which is still glued to the surface of recycled aggregates [8].

The decreased values of the compressive strength with increased percentages of peanut shell added was because peanuts shell absorbed water in the mixture of concrete and create more voids. The fibrous cell in the peanuts shell was the reason why it absorb the water. Less water makes the hydration process imperfect. The increasing void in concrete will lead to the reduction in the strength of concrete.



**Figure 4** Compressive Strength versus Percentage of Peanut's Shell

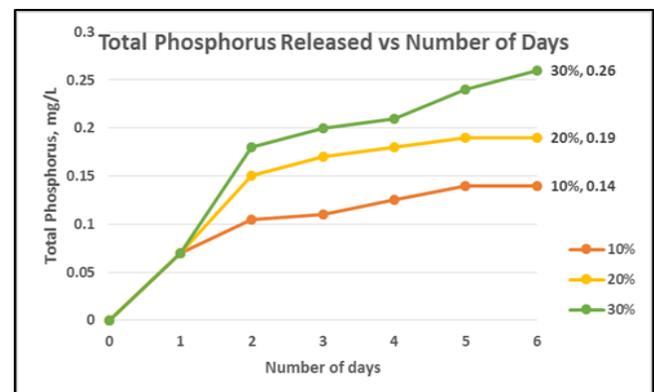
#### 4.2 Measurements of TP and Nitrate

a) Total Phosphorus (mg/L P)

Table 2 and Figure 5 illustrate the value of total phosphorus released from reefs with various percentage of peanut shells added. For 10% peanut shells added in the concrete, it recorded the lowest value of phosphorus which is 0.14 mg/L. The highest value of phosphorus recorded was 0.26 mg/L that is from 30% of peanuts shell added in the concrete. For 20% peanuts shell added in concrete, the value of phosphorus recorded is 0.19 mg/L. This indicates that the higher the percentage of peanuts shell added to the reef, the higher the value of the phosphorus leached into the water.

**Table 2** Total phosphorus released from AR with various percentage of peanut's shell

Percentage of Peanuts Shell	Water Sample Collected (day)	Total Phosphorus (mg/L P)		
		1	2	Average
10%	1	0.07	0.07	0.07
	2	0.11	0.10	0.105
	3	0.11	0.11	0.11
	4	0.13	0.12	0.125
	5	0.14	0.14	0.14
	6	0.14	0.14	0.14
20%	1	0.07	0.07	0.07
	2	0.15	0.15	0.15
	3	0.17	0.17	0.17
	4	0.18	0.18	0.18
	5	0.19	0.19	0.19
	6	0.19	0.19	0.19
30%	1	0.07	0.07	0.07
	2	0.18	0.18	0.18
	3	0.20	0.20	0.20
	4	0.21	0.21	0.21
	5	0.24	0.24	0.24
	6	0.26	0.26	0.26



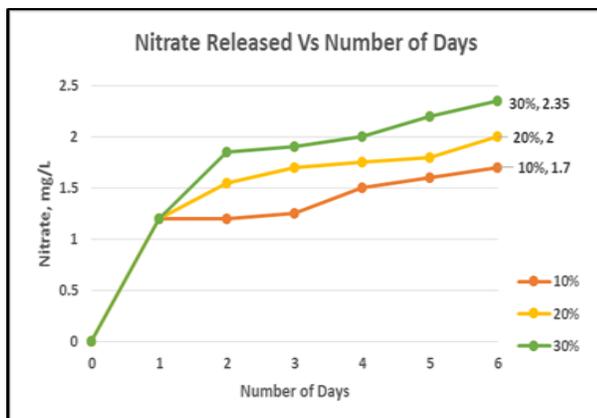
**Figure 5** Total Phosphorus versus number of days

b) Nitrate (mg/L NO<sub>3</sub>-N)

From Table 3 and Figure 6, it was found that the highest value of nitrate is 2.35 mg/L that was from 30% of peanuts shell added in concrete. For 20% peanuts shell added in concrete, it shows the value of 2.0 mg/L nitrate. The lowest value of nitrate was found from 10% of peanuts shell added in concrete that is 1.7 mg/L. It can be concluded that the higher the percentage of peanuts shell added to the reef, the higher the value of nitrate leach from the reef to the water.

**Table 3** Nitrate Released from AR

Percentage of Peanuts Shell	Water Sample Collected (day)	Nitrate (mg/L NO <sub>3</sub> -N)		
		1	2	Average
10%	1	1.2	1.2	1.2
	2	1.2	1.2	1.2
	3	1.2	1.3	1.25
	4	1.5	1.5	1.5
	5	1.7	1.5	1.6
	6	1.7	1.7	1.7
20%	1	1.2	1.2	1.2
	2	1.6	1.5	1.55
	3	1.8	1.6	1.7
	4	1.8	1.7	1.75
	5	1.8	1.8	1.8
	6	2.1	1.9	2.0
30%	1	1.2	1.2	1.2
	2	1.9	1.8	1.85
	3	2.0	1.8	1.9
	4	2.0	2.0	2.0
	5	2.3	2.1	2.2
	6	2.3	2.4	2.35



**Figure 6** Nitrate Release versus number of days

## 5.0 CONCLUSION

From the results recorded, it can be concluded that the higher the percentage of peanuts shell added to the reef, the higher the nutrient leached from the reef to the water. This indicates that the increased peanuts shell give a positive effect to the nutrient release which is good for the marine ecosystem. On the contrary, the increased of peanuts shell in the reef reduced the compressive strength of the concrete. However, this should not be of any disadvantage to the reef because it is reinforced by the steel reinforcement and therefore will be able to sustain the water pressure as expected.

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