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Experimental Study on Two-Layer Reinforced Concrete Beam with One Layer of Clam-Shell Aggregate Concrete

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ABSTRACT: *This paper reports the structural implication of a two-layer reinforced rectangular concrete beam withone layer of clam-shell aggregate concrete. Twelve concrete beams (1200x100x150-mm) reinforced with 2Φ10mm in the tensile face and 2Φ8mm in the compressive face. Φ6mm deformed bars were used as shear reinforcement at 200mm spacing were cast in various grouped;-Beams cast completely of crushed stone aggregates concrete of 1:2:4 mix (Type-MC).-Beams with crushed stone aggregate concrete 1:2:4 mix with a depth of 75mm at the compression layer and clamshell concrete 1:2:3 mix with a depth of 75mm at the tension layer (Type-M1).-Beams with clamshell aggregate concrete 1:2:3 mix with a depth of 75mm at the compression layer and 75mm of crushed stone aggregate concrete 1:2:4 mix at the tension layer (Type-M2). -Beams with clam-shell aggregate concrete 1:2:3 with a depth of 50mm at the tension layer and 100mm of crushed stone aggregate concrete 1:2:4 mix at the compression layer (Type-M3). All the beam types were subjected to two-point load application. Results showed that the two-layer beams with clam-shell aggregate concrete 1:2:3 with a depth of 50mm at the tension layer and 100mm of crushed stone aggregate concrete 1:2:4 mix at the compression layer had higher bending capacity than the control beams produced completely of crushed stone aggregate concrete of 1:2:4 mix. While two-layer beams with crushed stone aggregate concrete 1:2:4 mix with a depth of 75mm at the compression layer and clam-shell concrete 1:2:3 mix with a depth of 75mm at the tension layer was observed to have the same bending capacity as the control beams produced completely of crushed stone aggregate concrete of 1:2:4 mix. Two-layer beams produced with clam-shell aggregate concrete 1:2:3 mix with a depth of 75mm at the compression layer and 75mm of crushed stone aggregate concrete 1:2:4 mix at the tension layer had lower bending than the control beams produced completely of crushed stone aggregate concrete of 1:2:4 mix. The study also revealed that control beam, Type-MC, was noticeably stiffer than all the two-layer beams. The deflections of all the two-layer beams at ultimate failure load were higher than that of the control beams cast completely of crushed stone aggregates concrete. The highest deflection was reported in beam Type M1, with crushed stone aggregate concrete 1:2:4 mix with a depth of 75mm at the compression layer and clam-shell concrete 1:2:3 mix with a depth of 75mm at the tension layer. In the course of loading, it was observed that MC, M1, M2 and M3 beams failed in a fairly ductile manner; this could be for the reason that the load capacity of MC, M1, M2 and M3 would have been reached with a small amount of inelastic distortion. Base on the findings, it is recommended that two-layer beams with one layer of clam-shell as coarse aggregate concrete at the compression zone can be of great use in the concrete industry.*

KEYWORDS: *Two-Layer Beam,Crushed Stone Concrete, Clam-shells Aggregate Concrete, Moment Capacity*

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I. INTRODUCTION

Concrete is one of the largest used composite material in the construction industry. The amount of concrete used for each person per year is estimated at approximately 3000 kilograms [1]. In the last century, universally, concrete production has increased significantly, and the desire for concrete is expected to continue to increase in the future [2]. Natural aggregates (sand and crushed stone) are the principal constituents of concrete. Because of the bulk quantity of concrete produced per day, a large amount of natural aggregate is reasonably produced for the production of concrete. It is conventionally assessed that the world's aggregate usage exceeds 40000 billion kilograms per year, while 64 to 75% of the crushed aggregate is used for concrete (UNEP Global Environmental Alert Service, Sand, Rarer Than One Thinks, [3], Processing of natural aggregates has a negative influence on the environmental, risking irreversible land loss. Due to these environmental problems, authorities have restricted mining in certain locations in the world [4]. Environmental protection is the basic value of sustainable development, designed to protect the environment and protect the planet's natural reserves. Due to sustainability issues related to concrete production, researchers are sourcing substitute sustainable materials for concrete. Many alternative materials used to produce concrete are reprocessed materials from industrial waste.

The agricultural sector provides food and service for humans and thus, performs a vital role in the national economy [5]. Shells areprotective of the fish and are agricultural waste. Various shellfishes are utilized as food, and uneatable shells are deserted These shells are often of little economic value and are often discarded in a dump yard, generating an unpleasant odour. In places where considerable amounts of seashell leftovers are produced,the seashells can produce serious environmental difficulties. A lasting solution to this effect is touse sea-shells as aggregate in concrete. Since seashells had desirable properties, efforts have been made in employing seashells as a total replacement for crushed stone aggregate in concrete.

In places where large amounts of shell waste are produced, shells can produce severe environmental nuisances. A lasting solution to the challenge facing shell waste management sector is that shells are utilized as particle sizes greater than 4.75mm in concrete. Because of the required properties of the shell, the effort had been made to use the shell as part or all of the natural aggregate in the concrete. In particular,residents in riverine areas use shells as a substitute for concrete structures. [6]. Scientific investigation on the practice of sea-shells as particle sizes greater than 4.75mm substitute materials in concrete have been researched for decades to find the viability of practical applications. Apart from protecting natural resources, the use of shells in buildings also helps to protect the environment. Cost savings can also be achieved when reusing materials that do not require landfill [7]. The usage of waste shell in concrete as reprocessed construction materials makes costs of transportation and processing more advantageous than traditional aggregates [8].

Clam-shells are a hard-shielding outer layer. It is formed by marine life and they are part of the body. Clam-shells are generally obtained in coastal or municipal solid waste. Clam-shells are durable materials and consequently, suitable for coarse aggregate in double-layer beam. The chemical composition of Clam-shells and granites are analogous but in different proportions. Donatelle, [9] acknowledged the fact that the process of obtaining seashells is relatively eco-friendly compared to the mining of granite sediment which generates greenhouse gas.

According to Muthusamy et al [10], the substitution of appropriate cockle shell with particle sizes greater than 4.75mm content is capable of producing workable concrete with acceptable strength. Adewoyeand Adegoke[11] concluded that the substituting granite with (35.4-42.5%) waste periwinkle shells aggregates were found satisfactory and is economical. Dahunsi [12] investigated the compressive strength of concrete formed both with periwinkle-shells aggregate and in combination with crushed stone. Results confirmed that concrete with periwinkle shells as coarse aggregates had a reduced compressive strength than concrete formed with periwinkle- shells aggregate in combination with crushed stone. Olutoge et al, [13] observed that replacing crushed stone with 10% Crushed Clam-shell aggregate can yield light compressive and flexural strength of 18.7N/mm^2 and 2.77N/mm^2 respectively. Utilizing crushed Clam-shell aggregate as particle sizes greater than 4.75mm will reduce cost and also benefit the management of these non-biodegradable agricultural wastes in the environment.

In this article, we aimed to investigate the structural performance of a two-layer reinforced rectangular concrete beam with one layer of clam-shell aggregate concrete.

II. MATERIALS AND METHOD

Materials

Cement: The binder used in the study was Portland Limestone Cement of grade 42.5. It conformed to [14].

Fine Aggregate: The fine aggregate employed was obtained from River-Nun at Wilberforce Island, Bayelsa State, Nigeria. it confirmed to [15].

Coarse Aggregate: Crushed stones particle size 12mm was used as coarse aggregate, obtained from Yenagoa, Bayelsa State, Nigeria. It conformed to [15].

Clam-shells Aggregate**.** Clam-shells aggregates were obtained from Amassoma, Bayelsa state. The clam-shells utilized in this study were the residues after the eatable part removed. They were washed and manually crushed to achieve the required particles sizes. It conformed to [15].

Water: Clean water obtained from the Civil Engineering Department at the Niger Delta University was used. It conformed to [16].

Formwork: Marine plywood was employed for the forming of the beams. It conformed to[17].

Internal Reinforcement: Deformed steel bars were used as flexural and shear reinforcement. It conformed to [18].

Method

Beam Samples: Rectangular concrete beams were formed using deformed steel bars as flexural and shear reinforcement. Total twelve reinforced beams were formed with two deformed bars of 10mm diameter as flexural reinforcement and two deformed bars of 8mm diameter as hanger reinforcement. Shear reinforcements were prepared with 6mm diameter deformed steel bars. The sizes of the rectangular beam were 1200mm x 100mm x 150mm depth, having an effective span of 1100mm. The rectangular concrete beam samples were grouped into;

Type-MC: Beams and cubes cast completely of crushed stone aggregate concrete of 1:2:4 mix.

Type M1: Beams with crushed stone aggregate concrete 1:2:4 mix with a depth of 75mm at the compression layer and clam-shell concrete 1:2:3 mix with a depth of 75mm at the tension layer.

Type M2: Beams with clam-shell aggregate concrete 1:2:3 mix with a depth of 75mm at the compression layer and 75mm of crushed stone aggregate concrete 1:2:4 mix at the tension layer.

Type M3: Beams with clam-shell aggregate concrete 1:2:3 with a depth of 50mm at the tension layer and 100mm of crushed stone aggregate concrete 1:2:4 mix at the compression layer.

Type-MP: Cubes cast completely of Clam-shell aggregates concrete of 1:2:3 mix ratio.

The beam samples were cured for 28 days. After curing, all the rectangular concrete beams were studied under two-point loads.

Cubes Samples: Fifteen square concrete cubes were formed for each set of beam sample-types to study 28 days compressive strength, with a mix ratio of 1:2:4 for the crushed stone aggregate concrete cubes and a mix ratio of 1:2:3 for the clam-shell aggregate concrete cubes. The concrete cube samples were cured andtested to failure at 28 days

III. RESULTS AND DISCUSSION

This section illustrates the experimental results of the different tests carried out on a two-layer reinforced concrete beam with one-layer of clam-shell aggregate concrete. Table 1 presents the direct test results, cracking load, ultimate load carrying-capacity and the mode of failures of a two-layer of clam-shell aggregate reinforced concrete beam. Table6 presents the compressive strength of types MC, M1, M2, M3 and MP. Table 2,3,4 and 5 show the computed cracking capacity, bending capacity, tensile stress and shear stress of test beam samples.

Table 1. Direct observation of samples

Sample Type	Number of samples	First crack load (kN)	Failure load(kN)	Deflection at failure(mm)	Mode of failure
MC	Sample 1	29.31	36.64	4.69	Flexure/crushing
	Sample 2	29.31	32.97	2.88	Flexure/crushing
	Sample 3	27.48	36.64	4.05	Flexure/crushing
M1	Sample 1	21.98	36.64	5.92	Shear/crushing
	Sample 2	25.65	32.97	4.29	Shear /crushing
	Sample 3	23.65	34.79	5.12	Shear /crushing
M2	Sample 1	21.98	32.97	5.10	Flexure/crushing
	Sample 2	25.65	32.97	4.22	Flexure/crushing
	Sample 3	23.58	31.65	4.66	Flexure/crushing
M3	Sample 1	29.31	36.64	4.59	Shear /crushing
	Sample 2	21.98	32.97	3.55	Shear/Flexure/crushing
	Sample 3	24.85	35.56	4.21	Shear /crushing

Ultimate Failure Loads: Ultimate failure loads of R.C. beam Types are described in Table 1 and their modes of failure can be noticed in Figure 4. Out of the four beam types tested, Type-MC was a control R.C. beam and was cast completely of crushed stone aggregates concrete. The initial crack becomes visible at a load of 28.70 kN at the middle of the beam. The crack occurred as a result of flexural stresses. The beam Type-MC failed at a load of 34.82 kN, a result of a flexure–crushing failure.

Beam Type-M1 was formed with crushed stone aggregate concrete 1:2:4 mix with a depth of 75mm at the compression layer and clam-shell concrete 1:2:3 mix with a depth of 75mm at the tension layer. The first crack was noticed at a load of 23.78kN. The crack developed was observed to be flexural. As loading continued, shear cracks appeared and became visible. The beam finally failed at a load of 34.82 kN (it had load-carryingcapacity as the control beam, type-MC). Deflection at failure was 26% more that was reached in Type-MC

Table 2. Cracking Capacity of the Beams

Sample Type	Number of samples	First crack load (kN)	Cracking Capacity (kNm)
MC	Sample 1	29.31	5.37
	Sample 2	29.31	5.37
	Sample 3	27.48	5.04
M1	Sample 1	21.98	4.03
	Sample 2	25.65	4.70
	Sample 3	23.65	4.33
M2	Sample 1	21.98	4.03
	Sample 2	25.65	4.70
	Sample 3	23.58	4.32
M3	Sample 1	29.31	5.37
	Sample 2	21.98	4.03
	Sample 3	24.85	4.56

.**Table 3.** Bending Capacity of the Beams

Sample Type	Number of samples	Failure load(kN)	Bending Capacity (kNm)
MC	Sample 1	36.64	6.72
	Sample 2	32.97	6.05
	Sample 3	36.64	6.72
M1	Sample 1	36.64	6.72
	Sample 2	32.97	6.05
	Sample 3	34.79	6.38
M2	Sample 1	32.97	6.05
	Sample 2	32.97	6.05
	Sample 3	31.65	5.80
M3	Sample 1	36.64	6.72
	Sample 2	32.97	6.05
	Sample 3	35.56	6.52

Beam Type-M2was produced with clam-shell aggregate concrete 1:2:3 mix with a depth of 75mm at the compression layer and 75mm of crushed stone aggregate concrete 1:2:4 mix at the tension layer. The first crack seemed right at the middle of the beam at a load of 25.38kN. Beam Type-M2 as well exhibited shear cracks as the load increases. The Shear cracks developed near the left support and propagated along the flexural deformed steel bars towards the centre of the beam. The failure occurred at a load of 32.53kN. The beam failed as a result of deformed steel bars yielding together with concrete splitting at the compression face of the beam. Comparison of Beam Type-M2 with control beam Type-MC confirms that the ultimate load-carrying capacity was 6.6% less than that of Type-MC. Deflection at ultimate failure load was 16.8% greater than that control beam Type-MC.

Beam Type-M3 are beams with clam-shell aggregate concrete 1:2:3 with a depth of 50mm at the tension layer and 100mm of crushed stone aggregate concrete 1:2:4 mix at the compression layer. Initial cracking originated due to flexural stresses at a load of 35.38kN. The beam completely failed at a load of 35.06kN. The results show that the load-carrying capacity of beam Type-M3 is higher than Type-M1, Type-M2 and Type-MC.

Table 4. Tensile Stress of the Beams

Sample Type	Number of samples	First crack load (kN)	Tensile Stress (MPa)
MC	Sample 1	29.31	14.33
	Sample 2	29.31	14.33
	Sample 3	27.48	13.43
M1	Sample 1	21.98	10.75
	Sample 2	25.65	12.54
	Sample 3	23.65	11.56
M2	Sample 1	21.98	10.75
	Sample 2	25.65	12.54
	Sample 3	23.58	11.53
M3	Sample 1	29.31	14.33
	Sample 2	21.98	10.75
	Sample 3	24.85	12.15

Table 5. Shear Strength of the Beams

Sample Type	Number of samples	Failure load (kN)	Shear Strength (kN)
MC	Sample 1	36.64	18.32
	Sample 2	32.97	16.49
	Sample 3	36.64	18.32
M1	Sample 1	36.64	18.32
	Sample 2	32.97	16.49
	Sample 3	34.79	17.40
M2	Sample 1	32.97	16.49
	Sample 2	32.97	16.49
	Sample 3	31.65	15.83
M3	Sample 1	36.64	18.32
	Sample 2	32.97	16,49
	Sample 3	35.56	17.78

Load–deflection behaviour: The researched results in Table 1 and the load against the deflection curve in Figure 1 confirm that the control beam, Type-MC, was noticeably stiffer than all the two-layer beams. The deflections of all the two-layer beams at ultimate failure load were higher than that of the control beams cast completely of crushed stone aggregates concrete. The highest deflection was reported in beam Type M1, with crushed stone aggregate concrete 1:2:4 mix with a depth of 75mm at the compression layer and clam-shell concrete 1:2:3 mix with a depth of 75mm at the tension layer. In the course of loading, it was observed that MC, M1, M2 and M3 beams failed in a fairly ductile manner; this could be for the reason that the load capacity of MC, M1, M2 and M3 would have been reached with a small amount of inelastic distortion.

Table 6: 28-Day Compressive Strength

Specimen Type	Size of Cube (mm)	Weight of Specimen (kg)	Applied Compressive Load (kN)	28-Day Compressive Strength (MPa)
Type-MC	150x150x150	8	643.3	28.60
Type-M1	150x150x150	8.5	302.5	13.44
Type-M2	150x150x150	7.8	390	17.33
Type-M3	150x150x150	8	387.5	17.22
Type-MP	150x150x150	8.8	276.67	12.30

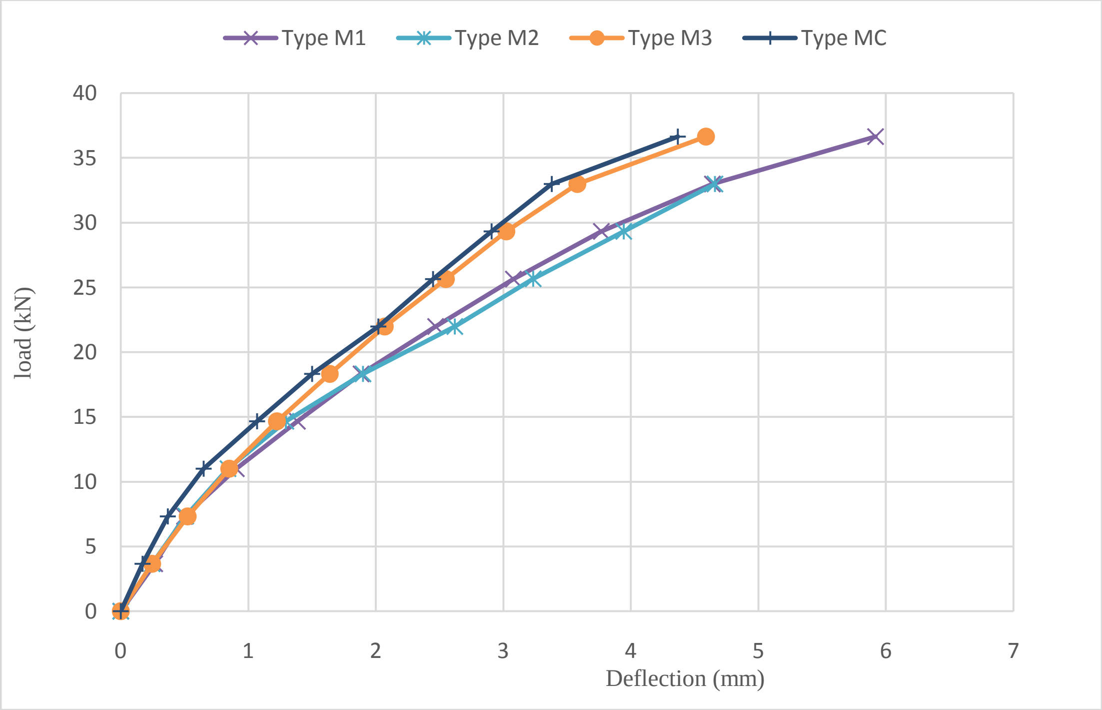

Fig. 1. Load - deflection curve of experimental results of beam Type-MP, M1, M2, M3

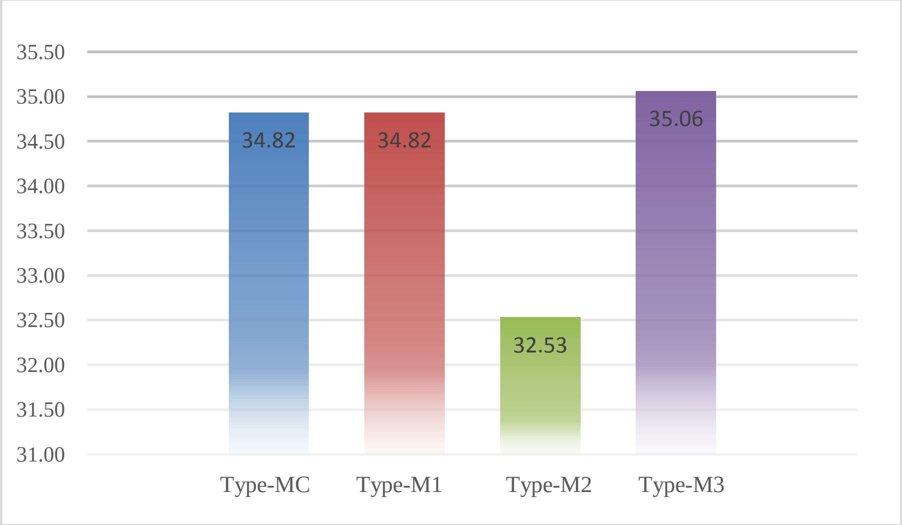

Fig. 2 Failure load of the RC beams sample Types

Bending capacity: The researched results presented in Table 3 showed that the two-layer beams with clam-shell aggregate concrete 1:2:3 with a depth of 50mm at the tension layer and 100mm of crushed stone aggregate concrete 1:2:4 mix at the compression layer had higher bending capacity than the control beams produced completely of crushed stone aggregate concrete of 1:2:4 mix. While two-layer beams with crushed stone aggregate concrete 1:2:4 mix with a depth of 75mm at the compression layer and clam-shell concrete 1:2:3 mix with a depth of 75mm at the tension layer was observed to have the same bending capacity as the control beams produced completely of crushed stone aggregate concrete of 1:2:4 mix. Two-layer beams produced with clam-shell aggregate concrete 1:2:3 mix with a depth of 75mm at the compression layer and 75mm of crushed stone aggregate concrete 1:2:4 mix at the tension layer had lower bending than the control beams produced completely of crushed stone aggregate concrete of 1:2:4 mix.

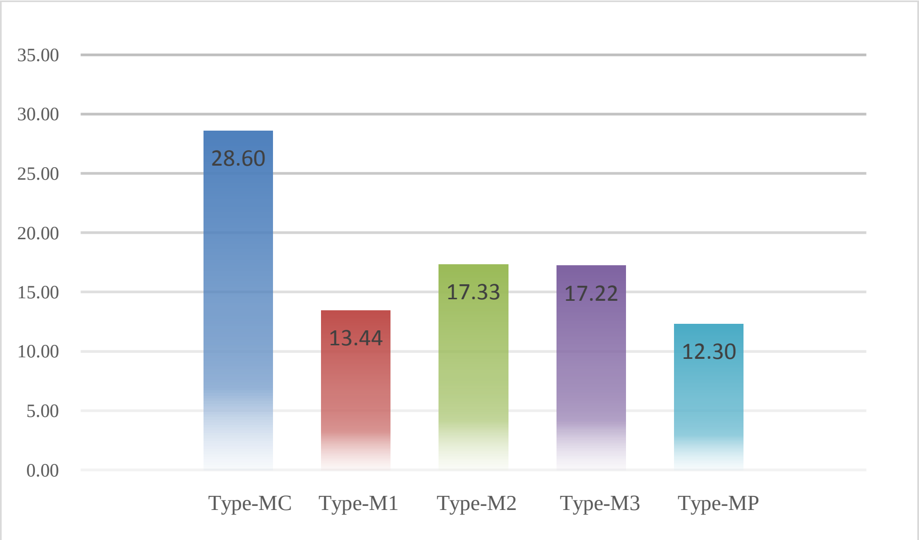

Fig. 3 Compressive strength at 28-day for Cube Type-MC, M1, M2, M3 and MP

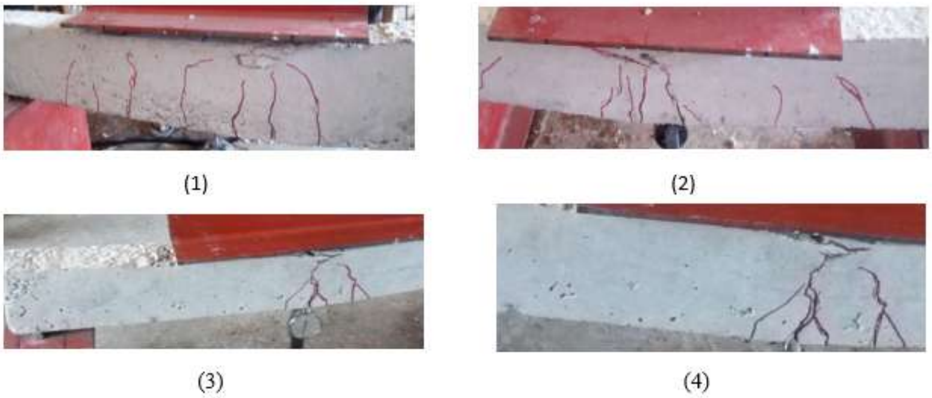

Fig. 4. Crack Pattern of test specimen: (1) Type-MC, (2) Type-M1, (3) Type-M2, and (4) Type-M3

IV. CONCLUSION

In this article, a two-layer reinforced concrete beam with one layer of Clam-shells aggregate concrete has been investigated experimentally. Based on the research results and discussions reported in the article, the following conclusions may be drawn:

i. Two-layer reinforced concrete beam with one-layer of Clamshell aggregates concrete reveals significant performance in load-carrying capacity.

ii. The crushed stone aggregate concrete layer of depth 0.5x the depth of the beam at the compressive zone and Clam-shell aggregate concrete with a depth of 0.5x the depth of the beam at the tensile zone has the same load-carrying capacity as beams produced entirely of crushed stone aggregates concrete.

iii. Clam-shell aggregate concrete with a depth of 0.5x the depth of the beam at the compressive layer and 0.5x the depth of the beam of crushed stone aggregate concrete at the tensile layer has a lower load-carrying capacity than the beams produced entirely of crushed stone aggregates concrete.

iv. Clam-shell aggregate concrete with a depth of $\frac{1}{3}$ x the depth of the beam at the tensile layer and $\frac{2}{3}$ x the depth of the beam of crushed stone aggregate concrete at the compressive layer has higher load-carrying capacity than the beams produced entirely of crushed stone aggregates concrete.

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