Investigation On the Effects of Oyster Shell in Interlocking Paver Blocks & RC Beam

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Abstract*— Oyster Shells are the Hard, Protective outer coverings of Oysters, which are marine molluscs found in coastal areas, which is also a disposed waste from sea shore areas that are rich in Calcium Carbonate (CaCO3). To pursue for a chance to recover this waste as building ingredients this study investigates the Effects of Crushed Oyster Shell as Full & Partial Substitute for traditional aggregates in the Production of Interlocking Paver Blocks as per IS Code 15658-2021 and also examines the Impact of Oyster Shell on the flexural strength of Reinforced Concrete Beams by replacing. This research fully involves that preparing Interlocking Paver Blocks with 100 % replacement of Coarse Aggregate & Fine Aggregate by Crushed Oyster Shell according to Grade Designations & Traffic Categories & Other Requirements given in IS Code 15658-2021 and also evaluating their performance based on key parameters given in IS Code such as Size & Shapes, Visual Appealing, Strength, Surface Texture and Finish, Low Water Absorption, Durability. In parallel, Reinforced Concrete Beams incorporating oyster shell as a partial replacement for fine aggregate are subjected for flexural strength tests to assess their structural integrity and potential applications in load-bearing elements. This innovative approach not only provides a sustainable solution for managing oyster shell waste but also offers new opportunities for eco-friendly Construction Practices.

I. INTRODUCTION

India has a coastline of 7516.6km – 5422.6km of mainland coastline & 2094km island territories. As it touches 9 states of india – Tamilnadu, Kerala, Karnataka, Gujarat, Goa, Maharashtra, Andra Pradesh, Odisha, West Bengal. In these Oyster shells are found along both the eastern and western coastlines they are primarily found in areas such as the Gulf of Kutch and the Gulf of Khambhat in Gujarat, as well as parts of Kerala and Tamil Nadu on the western coast. These areas are also rich in huge quantity of oyster shell waste which is disposed every day. Oyster shells are rich in calcium carbonate, making them valuable for a variety of applications. India exports oyster shells primarily for use in various industries such as agriculture, aquaculture, and construction. India's coastal regions, particularly on the east and west coasts, produce a significant amount of oyster shells that can be exported. Major ports such as Mumbai, Chennai, and Kochi facilitate the export of these shells to international markets. To pursue this waste & to reuse this as a building ingredients these oyster shell is to be crushed and to be Fully & Partially replaced as both Fine & Coarse aggregate in Interlocking Paver Blocks as per the IS Code 15658-2021 and also evaluate how the oyster shell in behaving in Reinforced Beam Concrete by means of flexural strength.

SCOPE AND OBJECTIVE:

A. To Introduce India's First Full Oyster Shell Paver Block made with with complete replacement of both coarse aggregate & fine aggregate by Oyster shell & also in two different C.A & F.A replacement patterns.
B. The main objective of this study is to formulate a low-cost and eco-friendly Interlocking Paver Blocks & Construction Practices.
C. Oyster shell are waste from sea food industry. Utilizing them in paver blocks helps to reduce sea waste and encourages recycling of natural materials to construction industry.
D. By using oyster shell as an aggregate in paver blocks, the demand for traditional aggregates such as sand and gravel is reduced. This leads to a more sustainable approach to construction

MATERIAL CEMENT*:*

The cement that is Portland Pozzolana Cement a fly ash based cement as per the Standard Specifications of the country that conforming to Indian specification of IS code IS 1489 is used. Ramco Supergrade PPC cement in the specific gravity of 2.87 with good workability, early hardening, high msand compatibility cement which is one of best from the cement industry is used in this project

PROPERTIES OF CEMENT:

S.NO	DESCRIPTION	RESULT
1.	Specific gravity	2.90
2.	fineness	2%
3.	consistency	31%
4.	Initial Setting time	30 minutes

M- SAND:

Fine aggregate conforming the requirements of IS383 is used. M-sand that meets the requirements of IS code in the sieve size of 2.36mm to 150 micron is used. M-Sand is used as the fine aggregate in the project, exhibits a specific gravity of 2.67, reflecting its density concerning water and essential for assessing its compactness and overall quality

PROPERTIES OF M- SAND:

S.NO	DESCRIPTION	RESULT
1.	specific gravity	2.67
2.	Fineness modulus	2.76

COARSE AGGREGATE:

For Paver Blocks 10mm Size & 4.75mm Size Aggregate are Used

Coarse aggregate conforming the requirements of IS383 is used. Two different size of coarse aggregates are used. As per the code for wearing face (faces the atmosphere) retained 10mm sieve sized aggregates are used and for wearing layer (upper face of paver block) that passes from 4.75mm sieve sized coarse aggregates are used. The specific gravity test yields a result of 2.75, indicating its density, while the fineness modulus is determined to be 2.66, providing insights into its particle size distribution.

For RC Beam 20mm Size Aggregates are Used

Coarse aggregate conforming the requirements of IS383 is used. For the beam, coarse aggregate with a maximum size of 20 mm is utilized. The specific gravity test yields a result of 2.76, indicating its density, while the fineness modulus is determined to be 7.50, providing insights into its particle size distribution

PROPERTIES OF COARSE AGGREGATE:

S.NO	DESCRIPTION	RESULT
1.	Specific gravity	2.73
2.	fineness	7.80
3.	Surface moisture	0.08%
	Water absorption	1.36%

10mm Retained C.A Aggregate

4.75mm Passed C.A Aggregate

ADMIXTURE (FOR BEAM)

Superplasticizer Tec Mix 550 is a crucial component in our project aimed at enhancing the performance of concrete through water reduction. Its advanced formulation facilitates significant reduction in the water-to-cement ratio, thereby improving the workability and durability of concrete structures. The incorporation of Tec Mix 550 enables us to achieve higher levels of compressive strength while minimizing the risk of segregation and bleeding during the casting process.

STEEL FOR REINFORCEMENT (FOR BEAM)

For beam reinforcement, this project utilizes four 10mm diameter steel bars for primary reinforcement, complemented by ten 8mm diameter stirrups spaced at 160mm intervals. This configuration ensures optimal structural support and integrity, reinforcing the beam against bending and shear forces, enhancing its load-bearing capacity and durability.

OYSTER SHELL:

Oyster shells are abundant in coastal areas. Repurposing these shells as a replacement for sand can reduce reliance on finite sand resources. Oyster shells are primarily composed of calcium carbonate, similar to limestone. This calcium carbonate present in oyster shells reacts with cementitious materials in concrete

mixture such as cement and also exhibit pozzolanic properties, meaning they react with chemical reaction in the hydration process of cement that produce Calcium Silicate Hydrate (CSH) gel, which is primarly binding agent in concrete. This formation of additional CSH gel contributes to the development of strength and stiffness & durability in the concrete over time in construction applications. Proper crushing & mixing proportions techniques, curing methods are crucial to maximizing the benefits of these shells.




PROPERTIES OF OYSTER SHELL:

S.NO	DESCRIPTION	RESULT
1.	specific gravity	2.84
2.	Fineness modulus	2.54

CHEMICAL PROPERTIES OF OYSTER SHELL:

CHEMICAL COMPONENTS	OYSTER SHELL
$CaCO_3$	89.56
SiO_2	4.04
MgO	0.649
Al_2O_3	0.419
SrO	0.33
P_2O_5	0.204
Na_2O	0.98
SO_3	0.724

PAVER BLOCK MOULDS:

The paver blocks are manufactured in two layers for wearing layer & wearing face area, these are only done with the moulds in different sizes & thickness. In this project a plastic mould in the shape of Damru in 60mm thickness is used for casting of Concrete Paver Blocks.

REINFORCEMENT BARS:

Reinforcement bars is a steel bar or mesh of steel wires used as a tension device in reinforced concrete and reinforced masonry structures to strengthen and hold the concrete in tension. In this project 10mm for main reinforcement & 8mm for stirrups with 20mm cover is used.

MIX DESIGN:

OBJECTIVE OF MIX DESIGN:

- For the Paver Blocks M35 mix under the traffic category of Light in thickness of 60mm for the traffic application of Rural Roads with low volume traffic, Local Authority footways residential roads given in the is code 15658:2021 is designed.
- For the RC Beam same M35 mix is used.

Cement = 500kg/m^3
Fine Aggregate = 914kg/m^3
Coarse Aggregate = 776kg/m^3
Water = 189kg/m^3

M35 Grade	Cement	Fine Aggregate	Coarse Aggregate	Water
For One Paver Block	500	914	776	189
Mix Ratio	1	1.552	1.661	0.37

FOR SIZE OF 60mm PAVER BLOCK MOULD
= 0.254 X 0.1066 X 0.05 m

SIZE OF BEAM
= 500 X 100 X 100 mm

EXPERIMENTAL PROCEDURES: -

DIFFERENT TYPES OF OYSTER SHELL REPLACEMENT IN PAVER BLOCKS IN BOTH LAYER 1 & 2

IDENTIFICATION	CEMENT	C.A - (10mm-4.75mm Retained) For Layer 2	C.A - (4.75mm Passed) For Layer 1	F.A - (2.36mm Passed 150 mic Retained)
NORMAL PB	Cement	Normal Aggregate	Normal Aggregate	M Sand
PBT1	Cement	Oyster Shell	Oyster Shell	Oyster Shell
PBT2	Cement	Oyster Shell	Oyster Shell	M Sand
PBT3	Cement	Normal Aggregate	Normal Aggregate	Oyster Shell

TYPE 1 - FULL REPLACEMENT OF BOTH FINE & COARSE AGGREGATE BY OYSTER SHELL

Top Wearing Layer 10mm

Bottom Wearing Face 50mm

TYPE 2 – FULL REPLACEMENT OF COARSE AGGREGATE BY OYSTER SHELL

Top Wearing Layer 10mm

Bottom Wearing Face 50mm

TYPE 3 – FULL REPLACEMENT OF FINE AGGREGATE BY OYSTER SHELL

Top Wearing Layer 10mm

Bottom Wearing Face 50mm

RCC BEAM by 10%, 20%, 30% REPLACEMENT OF F.A BY OYSTER SHELL

IDENTIFICATION	CEMENT	20mm C.A	(2.36mm Passed– 150 mic Retained)-F.A
CONVENTIONAL BEAM	Cement	Aggregate	100% M Sand
RC BEAM 1	Cement	Aggregate	10% Oyster Shell + 90% M Sand
RC BEAM 2	Cement	Aggregate	20% Oyster Shell + 80% M Sand
RC BEAM 3	Cement	Aggregate	30% Oyster Shell + 70% M Sand

Mechanical Properties

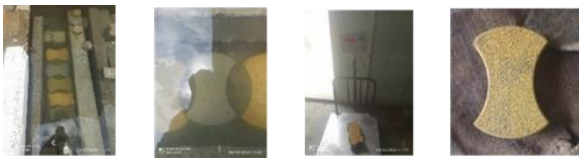
Determination of Compressive Strength

The Compression test for the concrete paver blocks is done as per the ANNEX D given in the IS CODE 15658-2021. For this the samples are taken after cured for 28 days and dried it for 24hrs as given in code book. The 3 Different types of casted paver blocks are taken for this test. Procedure the blocks shall be stored for 24 ± 4 h in water maintained at a temperature of 27 ± 2°C. The specimens are aligned with those of the bearing plates. The maximum load applied to the specimen shall be noted in N

Determination of Water Absorption

The Water absorption test for the concrete paver blocks is done as per the ANNEX C given in the IS CODE 15658-2021. For this the samples are taken after cured for 28 days. The test specimen shall be completely immersed in water at room temperature for 24 ± 2 h. Visible water on the specimens shall be removed with a damp cloth. The specimen shall be immediately weighed as Ww. Subsequent to saturation, the specimens shall be placed at a distance of 15 mm from each other and subsequently dried in a ventilated oven at 105 ± 5 ° C for not less than 24 h and until two successive weighing at intervals of 2 h show an increment of loss not greater than 0.2 percent of the previously determined mass of the specimen. The dry weight of each specimen, Wd shall be recorded in N to the nearest 0.01 N.

W percent = (Ww —Wd)/ Wd × 100



Determination of Flexural Strength

The Flexural Strength test for the concrete paver blocks is done as per the ANNEX G given in the IS CODE 15658-2021. For this the samples are taken after cured for 28 days and dried it for 24hrs as given in code book. This test is done by Universal Testing Machine and the load is applied in point load as given in code.

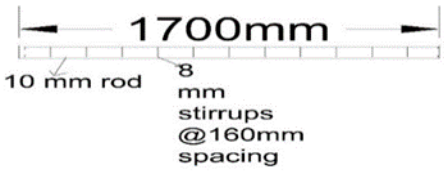
$$Fb = 3Pl / 2bd2$$

Where Fb = flexural strength, MPa; P = maximum load, N; l = distance between central lines of supporting rollers, mm; b = average width of block, measured from both faces of the specimen, mm; and d = average thickness, measured from both ends of the fracture line, mm.

Reinforcement Details of Beam

Steel reinforcement with a diameter of 10 mm is utilized as longitudinal steel, while 10 nos of 8 mm

diameter steel are employed as shear reinforcement spaced at 160 mm intervals.



Flexural Strength

A total of four beams underwent flexural testing. One beam was tested conventionally. Three beams on the partial replacement of oyster shell in the 10%,20%,30% as fine aggregate. The beams are tested and evaluated.

TEST RESULTS

COMPRESSIVE STRENGTH TEST

TABLE REPRESENTING THE PBT1 COMPRESSIVE STRENGTH OF PAVER BLOCKS

S.NO	TYPE OF BLOCK	AREA OF BLOCK IN MM	LOAD IN NEWTON	STRENGTH N/mm2	INDIVIDUAL STRENGTH	AVERAGE STRENGTH
1	Conventional PB	41330	$1550X10^3$	37.503	37.503	37.502
2	Trial1-PBT1	41330	$1600X10^3$	38.712	38.712	41.535
3	Trial2-PBT1	41330	$1750X10^3$	42.342	42.342	
4	Trial3-PBT1	41330	$1800X10^3$	43.551	43.551	

TABLE REPRESENTING THE PBT2 COMPRESSIVE STRENGTH OF PAVER BLOCKS

S.NO	TYPE OF BLOCK	AREA OF BLOCK IN MM	LOAD IN NEWTON	STRENGTH N/mm2	INDIVIDUAL STRENGTH	AVERAGE STRENGTH
1	Conventional PB	41330	$1550X10^3$	37.503	37.503	37.502
2	Trial1-PBT2	41330	$1600X10^3$	38.712	38.712	40.324
3	Trial2-PBT2	41330	$1650X10^3$	39.922	39.922	
4	Trial3-PBT2	41330	$1750X10^3$	42.342	42.342	

TABLE REPRESENTING THE PBT3 COMPRESSIVE STRENGTH OF PAVER BLOCKS

S.NO	TYPE OF BLOCK	AREA OF BLOCK IN MM	LOAD IN NEWTON	STRENGTH N/mm2	INDIVIDUAL STRENGTH	AVERAGE STRENGTH
1	Conventional PB	41330	$1550X10^3$	37.503	37.503	37.502
2	Trial1-PBT3	41330	$1700X10^3$	41.132	41.132	42.343
3	Trial2-PBT3	41330	$1750X10^3$	42.342	42.342	
4	Trial3-PBT3	41330	$1800X10^3$	43.555	43.555	

WATER ABSORPTION TEST

TABLE REPRESENTING THE PBT1 WATER ABSORPTION OF PAVER BLOCKS

TYPE OF BLOCK	WW	WD	W% (INDIVIDUAL)	W%(AVERAGE)
Conventional PB	4.935	4.705	4.882	4.882
Trial 1 - PBT1	4.792	4.601	4.151	4.385
Trial 2 - PBT1	4.840	4.635	4.422	
Trial 3 - PBT1	4.846	4.715	4.240	

TABLE REPRESENTING THE PBT2 WATER ABSORPTION OF PAVER BLOCKS

TYPE OF BLOCK	WW	WD	W% (INDIVIDUAL)	W%(AVERAGE)
Conventional PB	4.935	4.705	4.882	4.882
Trial 1 – PBT2	4.692	4.516	3.897	3.935
Trial 2 – PBT2	4.768	4.983	4.132	
Trial 3 – PBT2	4.863	4.686	3.777	

TABLE REPRESENTING THE PBT3 WATER ABSORPTION OF PAVER BLOCKS

TYPE OF BLOCK	WW	WD	W% (INDIVIDUAL)	W%(AVERAGE)
Conventional PB	4.935	4.705	4.882	4.882
Trial 1 – PBT3	4.859	4.632	4.900	4.624
Trial 2 – PBT3	4.923	4.712	4.478	
Trial 3 – PBT3	4.720	4.530	4.194	

FLEXURAL STRENGTH TEST

TABLE REPRESENTING THE PBT1 FLEXURAL STRENGTH OF PAVER BLOCKS

TYPE OF BLOCK	d (mm)	l (mm)	b (mm)	P (TF)	P (N)	Fb=3Pl/2bd² (IND)	Fb=3Pl/2bd² (AVG)
Conventional PB	60	225	205	1.98	19417	8.87	8.80
Trial 1 - PBT1	60	225	205	1.94	19024	8.70	8.83
Trial 2 – PBT1	60	225	205	2.00	19613	8.96	

TABLE REPRESENTING THE PBT2 FLEXURAL STRENGTH OF PAVER BLOCKS

TYPE OF BLOCK	d (mm)	l (mm)	b (mm)	P (TF)	P (N)	Fb=3Pl/2bd² (IND)	Fb=3Pl/2bd² (AVG)
Conventional PB	60	225	205	1.98	19417	8.87	8.80
Trial 1 - PBT1	60	225	205	1.93	18926	8.65	8.51
Trial 2 – PBT1	60	225	205	1.87	18338	8.38	

TABLE REPRESENTING THE PBT3 FLEXURAL STRENGTH OF PAVER BLOCKS

TYPE OF BLOCK	d (mm)	l (mm)	b (mm)	P (TF)	P (N)	Fb=3Pl/2bd² (IND)	Fb=3Pl/2bd² (AVG)
Conventional PB	60	225	205	1.98	19417	8.87	8.80
Trial 1 - PBT1	60	225	205	2.04	20005	9.14	8.98
Trial 2 – PBT1	60	225	205	1.97	19319	8.83	

FLEXURAL STRENGTH TEST ON BEAM

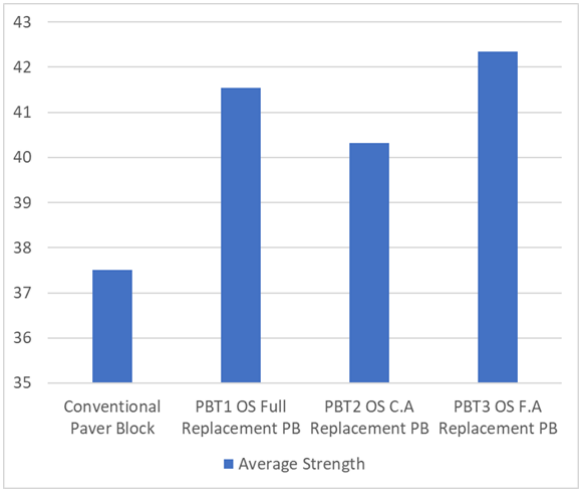
TEST RESULT ON LOAD-CARRYING CAPACITY

S.NO	SPECIMEN	INITIAL CRACK	FINAL CRACK
1	Conventional Beam	24	54.20 KN
2	RC Beam 1	29	58.36 KN
3	RC Beam 2	33	62.05 KN
4	RC Beam 3	38	67.13 KN

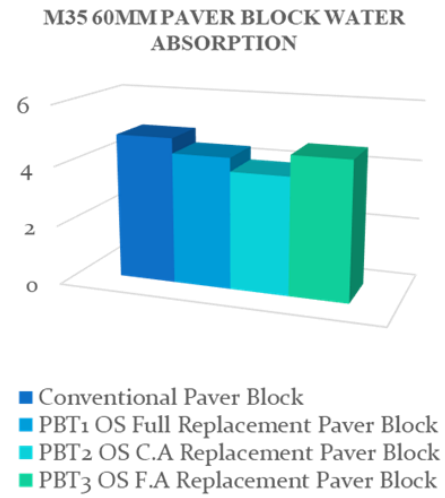
TEST RESULTS OVERALL COMPARISON

IDENTIFICATION	CEMENT	C.A - (10mm-4.75mm Retained) For Layer 2	C.A - (4.75mm Passed) For Layer 1	F.A - (2.36mm Passed 150 mic Retained)
NORMAL PB	Cement	Normal Aggregate	Normal Aggregate	M Sand
PBT1	Cement	Oyster Shell	Oyster Shell	Oyster Shell
PBT2	Cement	Oyster Shell	Oyster Shell	M Sand
PBT3	Cement	Normal Aggregate	Normal Aggregate	Oyster Shell

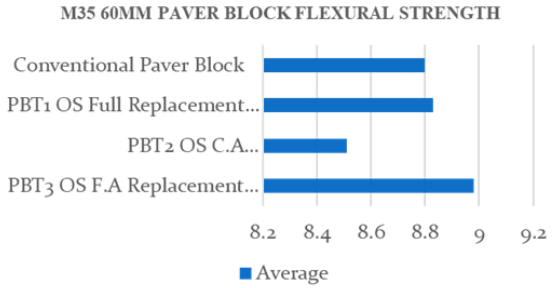
OVERALL COMPARISON OF COMPRESSIVE STRENGTH OF PAVER BLOCK



OVERALL COMPARISON OF WATER ABSORPTION OF PAVER BLOCKS

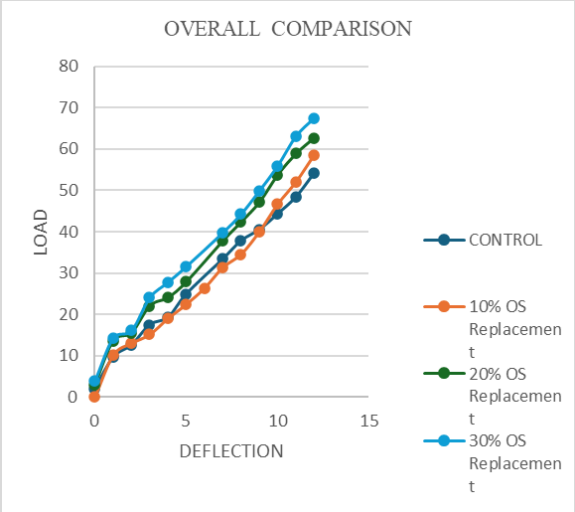


OVERALL COMPARISON OF FLEXURAL STRENGTH OF PAVER BLOCK



RCC BEAM by 10%, 20%, 30% REPLACEMENT OF F.A BY OYSTER SHELL OVERALL COMPARISON

IDENTIFICATION	CEMENT	20mm C.A	(2.36mm Passed– 150 mic Retained)-F.A
CONVENTIONAL BEAM	Cement	Aggregate	100% M Sand
RC BEAM 1	Cement	Aggregate	10% Oyster Shell + 90% M Sand
RC BEAM 2	Cement	Aggregate	20% Oyster Shell + 80% M Sand
RC BEAM 3	Cement	Aggregate	30% Oyster Shell + 70% M Sand



II. RESULTS AND DISCUSSION

INTERLOCKING PAVER BLOCKS

In this study, three different types paver blocks in M35 mix namely PBT1 (Full replacement of both Fine & Coarse aggregate by Oyster shell), PBT2 (Full Replacement of Coarse aggregate by Oyster shell) and PBT3(Full Replacement of Fine aggregate by Oyster shell) cast with full and partial replacement of 10mm & 4.75mm & 2.36-150mic sizes of coarse and fine aggregate and also results are compared with normal paver blocks. The Compressive Strength, Water Absorption and Flexural Strength tests are conducted at 28days as per the IS Code 15658 : 2021. Based on the experimental results, the following conclusions were drawn.

- In M35 grade concrete, Compared to all the Paver Blocks, Compressive Strength, Adequate Water absorption & Flexural Strength of PBT3 (Full Replacement of Fine Aggregate by Oyster Shell) shows greater than the PBT1 and PBT2.
- In the Compressive Strength of PBT3 – (Full Replacement of Fine Aggregate by Oyster Shell) shows 12.9% higher than the control concrete & PBT1, PBT2, which is higher than the individual & average compressive strength of paver block given in the IS code 15658:2021.
- In the water absorption test the PBT3 shows nearly equals the water absorption rate of 4.624 % compares to the normal paver block (4.882 %) and PBT1(4.385 %) & PBT2(3.935 %), which is also limits the max water absorption of paver block given in the IS code 15658:2021.
- In Flexural strength the PBT3 shows higher strength MPa compares to normal blocks and PBT1 & PBT2, which is higher than the individual & average compressive strength of paver block given in the IS code 15658:2021.
- Compressive Strength of PBT1 – (Full replacement of Coarse and fine aggregate by Oyster Shell) yielded 10.75% higher than the control concrete.
- Compressive Strength of PBT2 - Full Replacement of Coarse by Oyster Shell) shows minimum of 7.5% of increase in strength compared to Control concrete and PBT1 & PBT3. Even though the compressive strength of PBT2 lower than the PBT1 and PBT2 but the same time higher than the control concrete.

REINFORCED CONCRETE BEAM

Three different types of reinforced beams are partially replaced in the percentage of 10%, 20%, 30% by Oyster Shell as fine aggregate in the size 2.36mm – 150mic along with conventional beam, these are tested after 28 days of curing

- In the testing of 30% replacement of oyster shell RC Beam optimized maximum load of 67.456KN compared to the 20% & 10% also greater compared to conventional beam.
- In the testing of 20% replacement of oyster shell RC Beam optimized maximum load of 62.730KN compared to the 10% also greater compared to conventional beam.
- For the Reinforced beam when the higher percentage of oyster shell replaced as fine aggregate shows increase in flexural strength & withstanding max .
- Its noted that Calcium Carbonate ($CaCO_3$) present in oyster shells reacts with cementitious materials in concrete mixture with cement and also exhibit pozzolanic properties, meaning they react with chemical reaction in the hydration process of cement that produce Calcium Silicate Hydrate (CSH) gel, which is primarily binding agent in concrete.
- Whenever the Oyster Shell used in the sizes of 4.75mm to 150mic or as fine aggregate in any concrete applications, this oyster shell shows a better alternative for M Sand as well as River sand.
- Based on this experimental study it is concluded that the Crushed Oyster Shell from sea waste is better replacement for both Fine & as well as Coarse aggregate in the Paver Block & Hollow Blocks Production industry and in the construction application.

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