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CONSTRUCTION OF LOW-COST RIGID PAVEMENT BY USING CERAMIC WASTE

[1]Arvind Kumar, [2]Ravindra Kumar
[1]M. Tech scholar, Vivekananda Global University, Jaipur
[2]Assistant Professor, Vivekananda Global University, Jaipur

Abstract: Constructing a low-cost rigid pavement using ceramic waste is an innovative and environmentally friendly approach to waste management and infrastructure development. Rigid pavements are typically made of concrete and are known for their durability and strength, making them suitable for heavy traffic loads. By incorporating ceramic waste into the mix. By using the ceramic waste, we can reduce the cost of materials and minimize the environmental impact of construction.

Here is a general outline of the steps we can follow to construct a low-cost rigid pavement using ceramic waste:

1. Collect and Prepare Ceramic Waste:

Gather ceramic waste materials from construction sites, ceramic industries, or recycled tiles. Ensure that the waste is clean and free from contaminants, as these impurities could affect the strength and durability of the pavement.

2. Material Testing:

Before proceeding with construction, it's essential to conduct laboratory tests on the ceramic waste to determine its suitability for pavement construction. Test its physical properties, such as particle size distribution, density, and compressive strength, to understand how it will interact with the concrete mix.

3. Design Concrete Mix:

Work with civil engineers to design a concrete mix that incorporates ceramic waste as a partial replacement for traditional aggregate. The mix design should optimize the proportions of cement, sand, aggregate, and ceramic waste to achieve the desired strength and performance.

4. Batching and Mixing:

Once the mix design is ready, batch the concrete components according to the specified proportions. Properly mix the ingredients to ensure uniform distribution of ceramic waste particles within the concrete mix.

5. Pavement Preparation:

Prepare the area where the rigid pavement will be constructed. Clear the site of any debris, level the ground, and compact the subgrade to create a stable foundation for the pavement.

6. Placing and Compacting Concrete:

Pour the prepared concrete mix onto the prepared surface and spread it evenly. Use appropriate compaction equipment to compact the concrete and eliminate air voids, ensuring proper bonding and strength.

7. Curing:

Curing is a critical step to achieve the desired strength and durability of the pavement. Cover the newly placed concrete with wet burlap or use curing compounds to maintain moisture for a specific duration as per the mix design requirements.

8. Finishing:

After the curing period, finish the surface of the rigid pavement to achieve the desired texture and skid resistance. Techniques like brooming or using a trowel can be used for finishing.

9. Regular Maintenance:

To ensure the longevity of the pavement, schedule regular maintenance, and repair any cracks or damages that may occur over time.

It is essential to conduct quality control tests during the construction process to monitor the performance of the pavement. Additionally, this project can contribute to sustainable development by reducing the disposal of ceramic waste in landfills and conserving natural resources.

***Index Terms* - Rigid Pavement, Ceramic Waste, Concrete.**

I. INTRODUCTION- road surface or road pavement, is a hard, durable material that is constructed on an area intended to support the movement of vehicles or pedestrians. Pavements can be found on roads, highways, streets, sidewalks, and other pathways where traffic is expected.[1]

The primary purpose of a pavement is to provide a smooth, safe, and durable surface for vehicles and pedestrians to travel on. Different types of materials are used for pavement construction, including asphalt, concrete, brick, stone, and various composite materials [2]. The choice of pavement material depends on factors such as traffic volume, climate conditions, and budget considerations.

Properly constructed and maintained pavements are essential for ensuring the safety and efficiency of transportation networks and providing a comfortable experience for pedestrians. Regular maintenance, such as repairs and resurfacing, is required to extend the lifespan and functionality of the pavement [3].

II. CONCRETE MIX DESIGN

Method recommended for concrete mixes design (IS 10262-1982) according to Indian standard was introduced during year 1982. To revise in IS 10262 of 1982 a number of changes were introduced in IS 456:2000. A committee was set up to review the method of mix design in conformity with IS 456:2000. The committee took long time and come up with a new guideline for concrete mix proportioning.

The weight of the entire ingredient in kg/m3 can be found out.

The weight of coarse aggregate and fine aggregate are in saturated and surface dry condition. Depending upon the absorption characteristic or presence of surface, moisture, make the field correction as worked out in the earlier mix design example. In the laboratory carry out trial number.

Observe the workability bleeding and segregation characteristic and cohesiveness of concrete etc. The measured workability in terms of slump or flow value is different from stipulated value, the water and/ or admixture content may be adjusted suitably. With the adjustment, the mix proportion will be recalculated, keeping the w/c ratio at the pre-selected value, which will compromise trial mixture 2. In addition, two more trial mixes number 3 and 4 shall be made with water content same as trial mix number 2 and varying the w/c ratio by ±10 percent of the preselected value.

Mix number 2 to 4 normally provides sufficient information; include the relationship between compressive strength and w/c ratio.

Design a concrete mix for M45 grade of concrete with following data

Type of cement- OPC 43 grade

Maximum size of aggregate- 20mm

Exposure condition- Severe

Workability- 125 mm slump

Minimum cement content- 320kg/m3

Maximum w/c ratio-0.45
Method of placing concrete-pumping
Degree of supervision- good
Type of aggregate- crushed angular agg.
Super plasticizer will be used
Specific gravity of coarse aggregate- 2.80
Specific gravity of fine aggregate- 2.70
Water absorption- Coarse aggregate- 0.5%, Fine aggregate- 1.0%
Free surface moisture- Coarse aggregate- nil, Fine aggregate- nil
Grading of coarse aggregate conforming to table 2 of IS 383
Grading of fine aggregate conforming to grading zone 2

Target mean strength
Characteristic strength (fck)=40
Target mean strength f 'ck= fck+ 1.65×5
= 40+ 1.65×5 = 48.25 N/mm2
Where S is the standard deviation taken as 5 N /mm2 Water/cement ratio
Water/cement ratio is taken from the experience of the mix designer based on his experience of similar work elsewhere.
W/C= 0.42
This water cement ratio is to be selected both from strength consideration and the maximum w/c denoted in table 5 of IS 456 and lesser of the two is to be adopted for durability requirement.
w/c ratio mention in table IS 456 is 0.45. W/C proposed is 0.42. This being lesser than 0.45,
we should adopt W/C ratio as 0.42 Selection of water content
Maximum water content as per table is 186 litres. This is for 50 mm slump. Estimated water content for 125 mm slump = 186×9/100+186
(3% increase for every 25 mm slump over and above 50 mm slump) = 203 litre
The efficiency of super plasticizer used as 25%. Therefore, actual water is to be used = 203×0.75=152 litre.

Calculation of cement content
W/C ratio = 0.42 Water used = 152 litre Cement content = w/c
C =152/0.42 = 36.2 kg/mm2
Calculation of coarse and fine aggregate content
From the above table volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate Zone 2, for w/c ratio is found out to be 0.62.
In the present case w/c 0.42 i.e. it is less by 0.08. As the w/c is reduced it is desirable to increase the coarse aggregate proportion to reduce the fine aggregate content.
The coarse aggregate is increased at the rate of 0.01 for every decrease in w/c ratio is 0.05 0.01/0.05 × 0.08 = 0.016
Volume of C.A. = 0.62= 0.016/0.636
Therefore, Corrected proportion of volume of CA =0.636
Since it is angular aggregate and the concrete is to be pumped, the coarse aggregate can be reduced by 10%.
Therefore, final volume of coarse aggregate = 0.636×0.9 = 0.572
Therefore, volume of fine aggregate = 0.43

Calculation of mix proportion
Volume of concrete = 1 m3
Absolute volume of cement = 362/3.15 × 1/1000 m3 = 0.115 m3
Volume of water = 152 litre = 0.152 m3
Volume of chemical admixture = 1.2×362/100×1=3.94
= 3.94/1000= 0.004 m3
(Assuming dosage of 1.2% by weight of cementitious material and assuming specific gravity of admixture as 1.1)
Absolute volume of all the material except total aggregate = 0.115 + 0.152 + 0.004 = 0.271 m3 Absolute volume of total aggregate = 1 – 0.271 = 0.729 m3
Weight of coarse aggregate = 0.729 × 0.57 × 2.80 × 1000 = 1163 kg/m3

Weight of fine aggregate = 0.729 × 0.43 × 2.70 × 1000 = 846 kg/m3 Therefore, wet density of concrete = 2527 kg/m3 w/c ratio is 0.42
The above quantity of aggregate is on saturated and dry surface condition. At the site it is given in the problem that the aggregate is absorptive and there is no surface moisture. It is required to make the necessary correction for the actual site condition of the aggregates, with respect to absorption characteristics.

Site correction
Absorption of fine aggregate = 1.0%
= 1/100 × 846 = 8.46 litre
Absorption of coarse aggregate= 0.5/100 × 1163 = 5.82 litre Total absorption= 14.28 litre
Therefore, Actual amount of water to be used = 152 + 14.28 = 166.28 kg/m3
Actual weight of fine aggregate to be used = 846 – 8.46 = 837.5 kg/m3 Actual weight of coarse aggregate to be used = 1163 – 5.82 = 1157.20 Admixture = 4.0 kg/m3
With the above proportion of material carry out trial mix number 1 and see the quality of concrete. If it is not satisfactory carry out trial mix number 2, 3 and 4 as indicated earlier under trial mixes. Arrive at the final proportion of concrete mix to satisfy the required parameters.

Table-1 TRIAL MIX DESINGS FOR M40 PQC IN CONVENTIONAL METHOD OF 1m³

GRADE OF CONCRETE	M45 (PQC)
CEMENT OPC (43) GRADE (kg)	332/168 kg cement and fly ash
Aggregate 20mm (kg)	712
Aggregate 10mm (kg)	516
SAND (kg) (Zone I)	641
ADMIXTURE (CONPLANT PC – 50) (SUPERPLASTICIZER)	2.66
WATER (liter)	149
CEMENT (BRAND)	Prism OPC - 43

III. RESULTS AND DISCUSSION
AGGREGATE IMPACT VALUE
Objective: To determine the aggregate impact value, which is a relative measure of the resistance of an aggregate to sudden shock or impact.

TABLE- 2 AGGREGATE IMPACT VALUE TEST (AS PER IS 2386 PART IV)

Trial No.	1	2	3
Wt of sample measure	320	317	322
Wt of crushed material retrain is sieve 2.36mm(gm)	256	261	258
Wt of crushed material passing is sieve 2.36mm(gm)	64	56	64
Aggregate impact value	20	17.66	19.87
Average Impact Value	19.17		

FINENESS OF CEMENT-
The fineness of cement is an important property that can affect its hydration rate and overall performance in concrete. The fineness of cement is usually determined using a sieve analysis, which involves passing the cement through a set of sieves with progressively smaller openings to determine the particle size distribution. The most common standard used for this test is the ASTM C 204 standard.

TABLE-3 FINENESS OF CEMENT (IS 4031/ PART- IV)

TRIAL NO	IS SIEVE (mm)	Wt of sample (gram)	Wt of cement retained	% of retained	Average retained	Permissiblelimit is:8112
1	90mic	100	3	3%	3.33%	less than10% on 90 mic sieve
2	90mic	100	3	3%		
3	90mic	100	4	4%		

STANDARD CONSISTENCY TEST OF CEMENT

The consistency of cement is the minimum water requirement to start the chemical reaction between water and cement.

Table- 4 STANDARD CONSISTENCY TEST OF CEMENT (IS: 4031/ PART - IV)

Trial No	Wt. of cement (gm) = A	Penetration of the plunger from the bottom of vicat mould (mm)	Is the penetration between 5 to 7mm (yes/no)	Standard consistency P=B/A×100	Wt. of Water (gm)=B
1	400	7	yes	29%	116

COMPRESSIVE STRENGTH OF CONCRETE-

The compressive strength test of concrete is a widely used procedure to determine the ability of concrete to withstand axial loads, or in simpler terms, how much weight or force it can bear before it fails. The test involves applying a load to a cylindrical or cubical specimen of concrete until it fractures.

Table- 5 Compressive Strength of Trial Mixes

Cube No.	Age	Weight of Cube (gm)	Density of Cube (gm/m3)	Load in KN	Strength.N/mm2	Average compressivestrength (N/MM2)
				Days	Days	
1	28 days	8443	2.502	1050	46.67	46.8 N/mm2
2	28 days	8550	2.520	1000	47.55	
3	28 days	8418	2.494	1040	46.22	

FLEXURAL STRENGTH OF CONCRETE

The flexural strength of concrete, also known as the modulus of rupture or bending strength, is a measure of a concrete's ability to withstand bending forces. It's an important property when assessing the structural integrity of concrete elements like beams and slabs. The procedure to determine the flexural strength of concrete involves performing a test called the "Three-Point Bending Test" according to ASTM C78 or the "Center-Point Loading Test" according to ASTM C293.

TABLE 6 FLEXURAL STRENGTH OF TRIAL MIX

FLEXURAL STRENGTH OF PQC (IS: 516)								
Grade of Concrete- M40								
Sr.No .	ID Mark	Age/ Days	Dimension CM L*B*D	Flexural Distance "a" (cm)	Weight (Gm)	LOAD "P" (KN)	Flex Strength N/mm2	Avg Flex StrengthN/mm2
1	1	28 days	60x15x15	27	38936	28	4.98	4.92
2	2	28 days	60x15x15	26	38839	28	4.98	
3	3	28 days	60x15x15	25	38796	27	4.98	
1. Fn= P*L/B*D2, Where a>20 CM for 15cm Specimen or Where a> 13.3 cm For 10 cm Specimen								
2. Fn= 3P*a/B*D2, Where 20>a>17 CM Specimen or Where a 13.3 >a> 11cm For 10 cm Specimen								
3. Discard Where a> 17 CM 15 CM Specimen or Where a > 11cm For 10 cm Specimen								

IV. PROPERTIES OF CERAMIC WASTE

The specific gravity is estimated to be 2.717 and 98.5 % of ceramic dust passed through the sieve of 0.075mm (75 micron). The chemical properties were given in with the compliance oftest method IS 3812.

TABLE- 7 TEST DESCRIPTION

S.NO.	Test description	Result
1	Aluminium oxide	32.43%
2	Calcium oxide	2.16%
3	Ferric oxide	1.152%
4	Magnesium oxide	0.251%
5	Potassium oxide	0.009%
6	Silicon oxide	60.21%
7	Sodium oxide	0.093%

Fig. 1 Ceramic Waste in Dust Form

TABLE 8 TRIAL MIX IS DONE AS PER IS 10262:2009 FOR CERAMIC WASTE WHICHREPLACE CEMENT WITH 10%,20% AND 30%

GRADE OF CONCRETE	M40(PQC) WITH10% REPLACEMENT OF CEMENT WITH CERAMIC WASTE MIXING IS DONE AS PER IS: 10262:2009	M40(PQC) WITH20% REPLACEMENT OF CEMENT WITH CERAMIC WASTE MIXING IS DONE AS PER IS: 10262:2009	M40(PQC) WITH30% REPLACEMENT OF CEMENT WITH CERAMC WASTE MIXING IS DONEAS PER IS: 10262:2009
CEMENT OPC (43) GRADE (kg)	298.8+33.2+168 CEMENT+CERAMIC WASTE+FLYASH	266+66+168 CEMENT+CERAMIC WASTE+FLYASH	236+96+168 (CEMENT+CERAMI CWASTE+FLYASH)
20mm (kg)	712	712	712
10mm (kg)	516	516	516
SAND (kg)	641	641	641
ADMIXTURE (CONPLAN T PC – 50)	2.66	2.66	2.66
WATER (liter)	149	149	149
CEMENT	OPC-43	OPC-43	OPC- 43

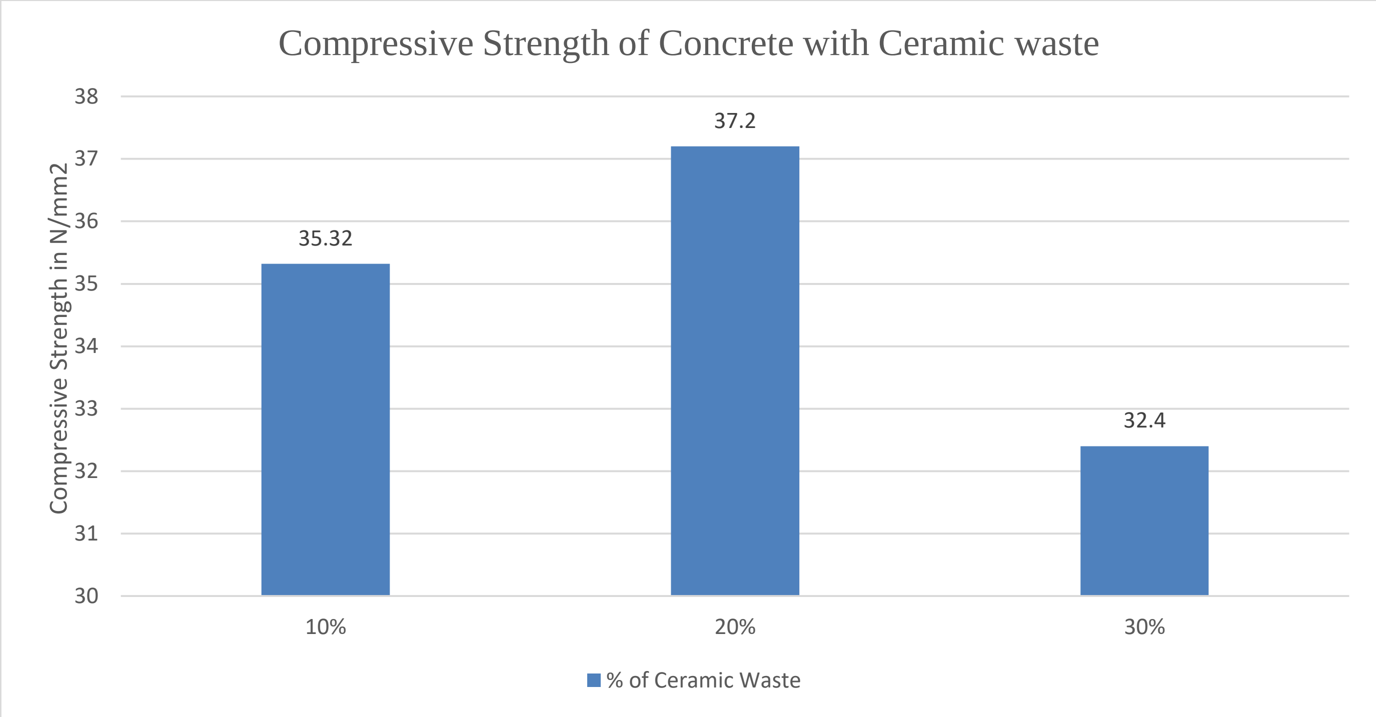

Fig. 2 Showing Compressive Strength Graph When Ceramic Waste Is Added inConventional Form of Trial Mix In 28 Days

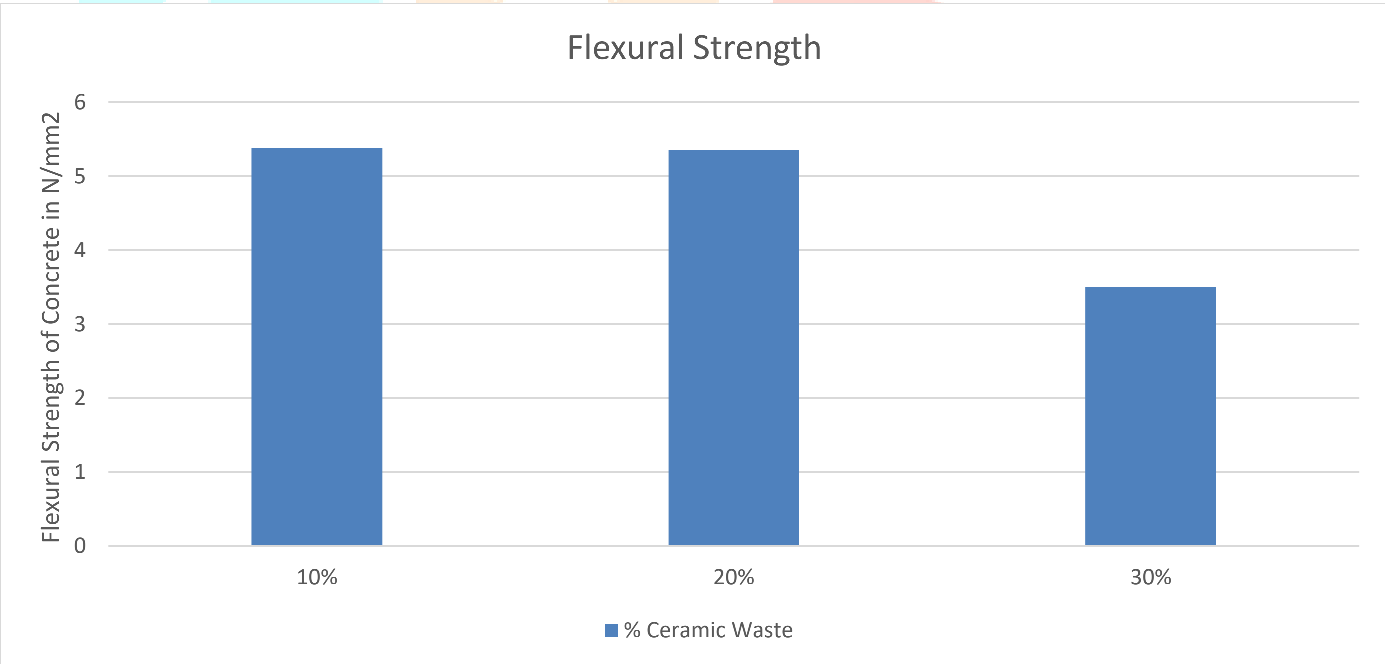

FIG. 3 SHOWING FLEXURAL STRENGTH GRAPH USING CERAMIC WASTE IN CONVENTIONALTRIAL MIX IN 28 DAYS

V. COMPARISION OF COST OF CEMENT, FLY ASH, CERAMIC WASTE

As we know that PQC cost approximately 85000 Rs per 10 cubic meter i.e. 8500Rs per 1 cubic meter and for dry lean concrete (DLC) it cost approximately 4000Rs per cubic meter.
We take labour charge as 400rs for 8-hour work.

Table 9 Comparison of Cost of Cement, Fly Ash, Ceramic Waste

MATERIALS (COST)	M40 PQC	M40 PQC WITH 20% REPLACEMENT WITH CERAMIC WASTE
CEMENT/FLY ASH/ CERAMIC WASTE (KG)	332/168 332×8 + 168×1 = 2824 RS	266/168/66 2494RS
SAND (KG)	641×0.65 = 416.65	416.65
20mm (KG)	712×0.7 = 498.4	498.4
10mm (KG)	516×0.66 =340.56	340.56
ADMIXTURE (KG)	2.66×90 = 239	239
TOTAL COST	4318.61 RS	3988.61RS

VI. CONCLUSION-

The result show we can save 330 Rs by using ceramic waste as a partial replacement of cement in Concrete mix design for PQC and experimental show significance result by using ceramic as partial replacement of cement.
Ceramic waste show good cementitious property. Trial mix design is done as per IS 10262: 2009.
Test is being conducted with the help of trial mix table in which cement is replaced with the ceramic waste and after conducting the test the compressive strength is being tested on cube casted with replacement of ceramic waste and compressive strength is taken which is shown in graph and showed a satisfactory result as well as flexural test is done and result is shown in the graph and result is satisfactory as well.

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