CONSERVATION OF NATURAL SAND BY USING BYPRODUCT OF STONE QUARRY AND WASTE PLASTIC AS FINE AGGREGATE FOR IMPROVING DURABILITY OF CONCRETE

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Abstract

The scope of this study is to enhance the industry understanding of the sustainable utilization of quarry dust, and to identify any gaps in current knowledge. The term sustainable utilization implies the use of quarry dust to their full potential to meet the needs of the present, while at the same time conserving natural resources and finding ways to minimise the environmental impacts associated both with quarry fines production and use. Concrete mixes were casted using ordinary river sand and compared with 25%,50%,75%, 100% replacement with quarry dust in combination with waste plastic in fabriform. The addition of quarry dust along with waste plastic significantly improved the concrete matrix properties in terms of strength and permeability resistance. The addition of fine quarry dust with ldpe as waste plastic in concrete resulted in improved matrix densification compared to conventional concrete. Matrix densification has been studied qualitatively through petro graphical examination using digital optical microscopy. The structure was evaluated using SEM in quarry dust and ldpe composites.

Keywords: Natural Sand, Quarry Dust, Waste Plastic, SEM Analysis, RCPT, Cracked Permeability.

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1. Introduction

In recent years, incredible efforts have been made in the area of concrete technology to investigate the utilization of industrial waste materials in the production of concrete. Quarry dust is a powder waste obtained during the crushing process of parent granite rock. It has recently gained good attention to be used as an effective filler material instead of fine aggregate. The successful utilization of these materials will result in the reduction of environmental load, waste management cost and concrete production cost, besides enhancing the properties of concrete in both fresh and hardened states. Most often the durability of concrete is assessed under no ideal condition without stressing. The durability of concrete is one of the most important properties because it is essential that concrete should be capable of withstanding the conditions for which it has been designed throughout the life span of a structure [1, 2]. Lack of durability may be caused by external environmental reasons or internal causes within the concrete itself [3,4]. As for alternative materials used as aggregate fillers in concrete, numerous types of byproducts such as recycled concrete aggregate, quarry dust, fly ash, and slag, as well as several types of manufactured aggregates have been studied by many researchers. Several experimental studies showed that the influence of partial replacement of fine aggregate with crushed stone dust at varying percentages resulted in the improved properties of fresh and hardened concrete [4]. It can be observed that the permeability of concrete increased significantly when the stress level exceeds up to 40% of the ultimate strength of the concrete specimens [5]. Investigations on the influence of supplementary cementing materials in concrete demonstrated an increased resistance of concrete; in another study it was found that the decrease in the coefficient of permeability occurred with time, which is expected due to continuous hydration in the specimen as well as potential pore-blocking [9]. The loss of the concrete durability may be caused by the severity of the environment to which it is exposed or by internal changes within the matured concrete itself [10]. Durability evaluation of concrete using gas permeability test can be an appropriate technique for measuring the permeation properties of concrete [11].The addition of micro fillers showed improved pore filling effects at lower water-to-binder ratio and also showed better performance in gas permeability. It can be observed that the permeability of concrete can be reduced by adding mineral admixture like silica fume up to 8%, which makes the microstructure of concrete denser [12]. Also, the previous experimental study signifies that the durability of concrete depends on the long-term effects of concrete sustainability towards adverse environmental conditions as well as during operational loads when the structure is put in use. It can be summarized from the previous studies that the concrete structure put in use is subjected to initial loading due to self weight which in turns produces cracking. This necessitates for testing permeability of concrete in stressed condition to evaluate the significant performance of concrete under cracked condition.

Research Significance

The scope of this study is to enhance the industry understanding of the sustainable utilisation of quarry dust, and to identify any gaps in current knowledge. The main objective of the present work was to systematically study the effect of percentage replacement of natural sand by quarry dust & waste plastic (ldpe) in fabriform as 0%, 25%, 50%, 75%, and 100% respectively on the strength properties of concrete. The study also focuses on evaluating the performance characteristics of quarry dust substituted concrete and to assess the durability properties of concrete. Durability measurements were quantified using cracked permeability test. Cracked permeability of concrete is an important measure determined in this study which provides an actual estimation on the permeability properties of concrete under stressed conditions. This serves as a real quantification of concrete durability subjected to initial crack opening when subjected to service loading. In this regard, the concrete specimens were tested by giving an initial stress up to 40% of its ultimate load and measuring the weight gaining of concrete kept in concrete permeability equipment.

2. MATERIALS

Cement

Portland Pozzolana cement conforming to IS 1489 (part 1) -1991 was used. The physical properties are tabulated in Table 1.

Table. 1 Physical properties of Portland Pozzolana cement

Property	**Portland cement**	**IS:1489-1991**
Specific gravity	3.1	3.10 - 3.14
Fineness, m2/kg	321	≥300
Soundness, mm	1.5	< 10
Normal consistency, %	30.5	----
Initial setting time, min	164	≥30
Final setting time, min	224	≤600

Fine Aggregate

Natural sand obtained from the river and normally available in the market was used. The quarry dust obtained from a local crusher was used. The physical properties of the natural and quarry dust are table.2.

Quarry rock dust

The Quarry Rock Dust obtained from local resource Siddheswar’s Crushers (P) Ltd., Umred road, Nagpur was used in concrete to cast test cubes, beams and cylinder. The physical and chemical properties of Quarry Rock Dust obtained by testing the samples as per Indian Standards are listed in Tables 2 and 3, respectively.

Table 2 Physical properties of quarry rock dust and natural sand.

<table>
<tr><th>Property</th><th colspan="2">Quarry rock dust</th><th>Test method</th></tr>
<tr><td>Specific gravity</td><td colspan="2">2.61</td><td rowspan="8">IS 2386 (Part III) 1963</td></tr>
<tr><td>Bulk relative density (kg/m3)</td><td colspan="2">1118</td></tr>
<tr><td rowspan="2">Moisture content (%)</td><td>Wet</td><td>24.25</td></tr>
<tr><td>Dry</td><td>2.1</td></tr>
<tr><td>Fineness modulus</td><td colspan="2">3.18</td></tr>
<tr><td>Effective size(mm)</td><td colspan="2">0.2</td></tr>
<tr><td>Coefficient of uniformity</td><td colspan="2">4.5</td></tr>
<tr><td>Coefficient of gradation</td><td colspan="2">2.2</td></tr>
<tr><td>Fine particles less than 0.075mm (%)</td><td colspan="2">15-Dec</td><td>IS 2386 (Part I) 1963</td></tr>
<tr><td>Sieve analysis</td><td colspan="2">Zone II</td><td>IS 383 - 1970</td></tr>
</table>

Table 3 Typical chemical composition of quarry rock dust and natural sand

Constituent	Quarry rock dust (%)	Natural sand (%)	Test method
SiO2	62.48	80.78	IS: 4032-1968
Al2O3	18.72	10.52	
Fe2O3	06.54	01.75	
CaO	04.83	03.21	
MgO	02.56	00.77	
Na2O	Nil	01.37	
K2O	03.18	01.23	
TiO2	01.21	Nil	
Loss of ignition	00.48	00.37	

Fig.1 Quarry dust at Siddeshwar's crushing plant, Waste plastic fibers

Waste Plastic

Waste plastic represents the discarded Low Density Ployethylene (LDPE) as post consumer plastic waste in concrete collected from CHEMECH plastic manufacturing plant located in the MIDC area of Hingna road, Nagpur having the properties as in table 4.

Table 4. Physical and mechanical properties of waste plastic

Properties	Values
Density (g/cc)	0.910-0.980
Particle size	5.00-50.0µm
Water absorption	0.0100%
Max. moisture content	0.100
Tensile strength	2.80-56.5Mpa
Modulus of elasticity	0.11-0.449Gpa
Flexure modulus	0.0248-1.38Gpa

Coarse aggregate

Natural aggregate having density of 1620 kg/m^3 and fineness modules (FM) of 7.57 was used. The specific gravity was found to be 2.60 and water absorption as 1.32%.

Admixture

Workability is the essence of good concrete and due to presence of quarry fines and plastic fibres concrete losses its workability. To improve additional workability to the modified concrete a super plasticizer, AC-PLAST-BV-M4 was being used. It is a concrete admixture with less than 0.05% chloride content and conforms to IS: 9103-1999. The super plasticizer was added to 0.6% by weight of cement for all mixes.

Cracked Permeability of Concrete

The concrete permeability in this study was tested in cracked concrete specimens with an initial load (40% of ultimate load) applied on it and later checked for the water permeability under constant pressure. From the experimental test results shown in Figures 2,3 for M30 grade it can be noted that the coefficient of permeability values of conventional river sand concrete mixes was found to be decreasing. However, in the case of quarry dust-substituted concrete the permeability coefficient was found to be reduced appreciably for all as compared to conventional river sand-substituted concrete as shown in table 5 .This essentially shows that quarry dust substituted concrete had improved matrix strengthening due to efficient granular packing and provided crack resistance for the initial stress levels. Also, it can be noted that compared to conventional river sand concrete mixes, the quarry dust concrete showed a reduction in permeability. It can be understood from the results that the incorporation of finer quarry dust-waste plastic particles in place of river sand had shown a significant crack-resisting properties at initial loading. Concrete petrography studies were conducted using digital microscope of 50x magnification to identify the interfacial properties of conventional river sand concrete mixes compared to those of quarry dust-substituted concrete mixes. Concrete slices of size 25 × 25mm were cut from different regions of casted concrete sections of actual size of 100mm× 100 mm. The micrograph shown in Figure 4 was captured for controlled concrete mix without initial stress which revealed the weak interfacial zone between aggregate and large void formations in the matrix. In the case of initial stress applied to conventional concrete, the cracking near the voids occurred rather than in the interfacial region which can be seen in Figure 4 (b). However, in the case of quarry dust-substituted concrete mix the distribution of finer sizes of particles was able to increase the matrix densification as evidently seen in Figure 5(a). Also, it can be concluded from Figure 5. (b) that upon the application of initial loading the aggregate cracking at the interface occurred rather than matrix cracking due to higher elastic modulus of matrix. The micro structural results also confirm that the improvement of matrix properties are better realized in quarry dust substituted concrete compared to conventional river sand concrete mixes.

3. RESULTS

The experimental test results shown in Table5 for M30 grade and it can be noted that the coefficient of permeability values of conventional river sand concrete mixes was found to be decreasing.

Table 5. Coefficient of permeability for M30 concrete

Grade of concrete	Mix Identification	28 days	90 days
		Coefficient of permeability (10^{-12} m/s)	
M30	M100-0-0	4.500	2.500
	M75-25-0	4.450	2.450
	M75-23-2	4.300	2.300
	M75-21-4	4.250	2.250
	M75-19-6	4.100	2.100
	M75-17- 8	4.000	2.000
	M50-50-0	3.950	1.950
	M50-48-2	3.800	1.800
	M50-46-4	3.750	1.750
	M50-44-6	3.650	1.650
	M50-42-8	3.550	1.550
	M25-75-0	3.450	1.450
	M25-73-2	3.250	1.250
	M25-71-4	3.150	1.150
	M25-69-6	3.000	1.000
	M25-67-8	3.000	1.000
	M0-100-0	3.000	1.000
	M0-98-2	2.950	0.955
	M0-96-4	2.750	0.950
	M0-94-6	2.650	0.850
	M0-92-8	2.35	0.750

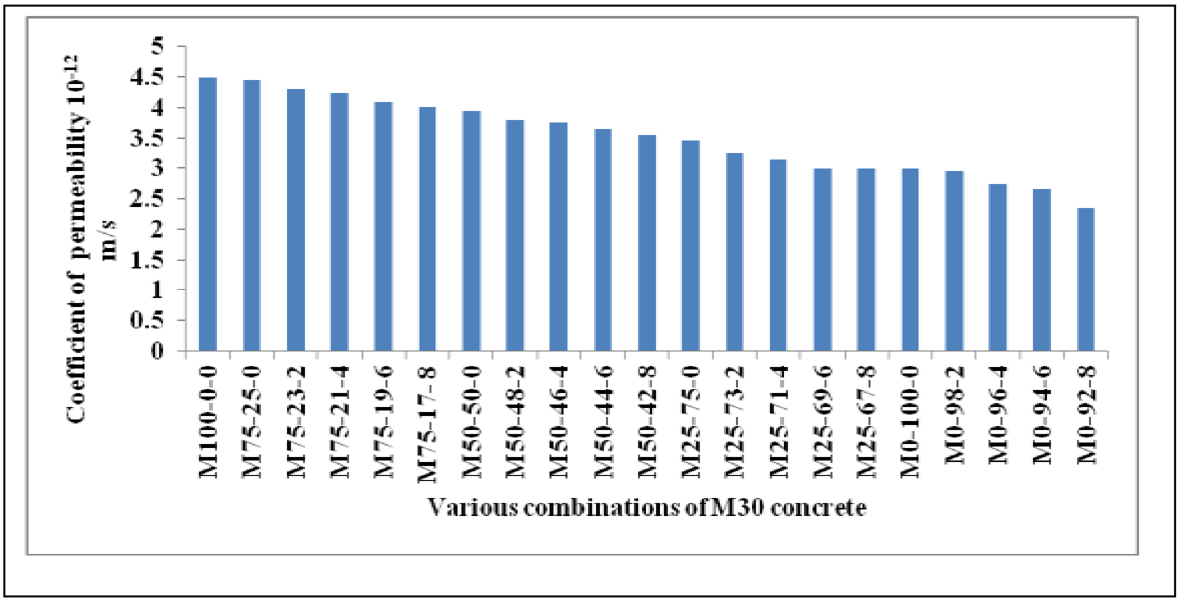


Fig. 2 Coefficient of cracked permeability for M30 concrete at 28days

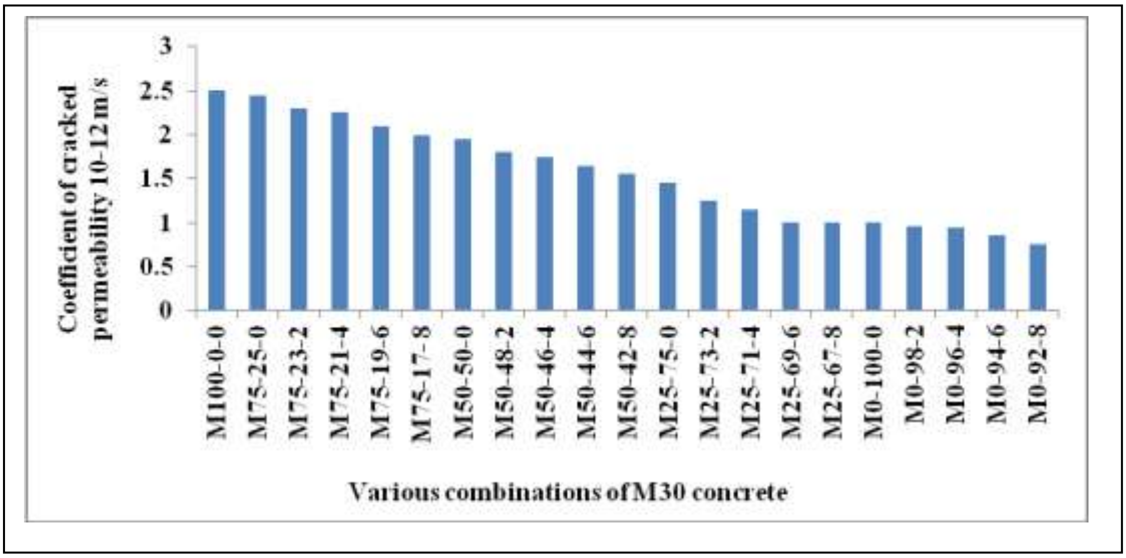
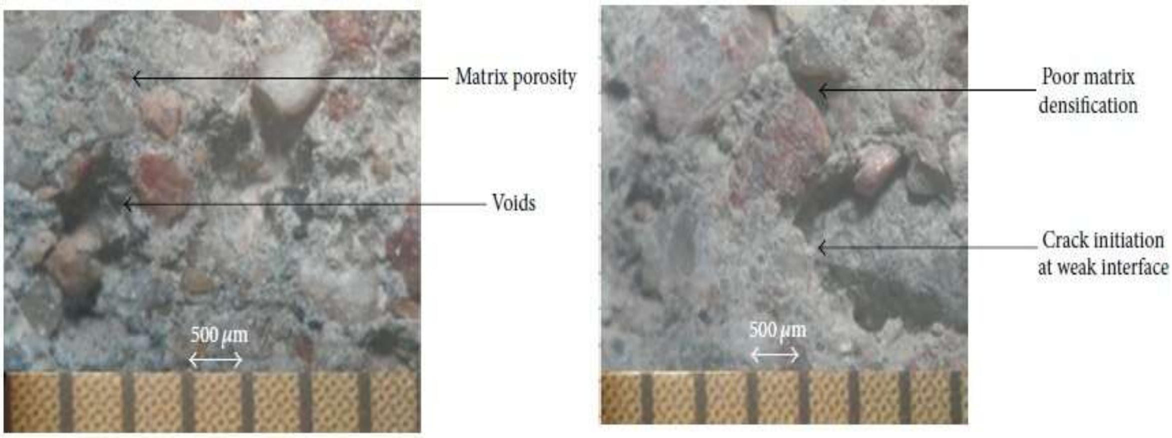
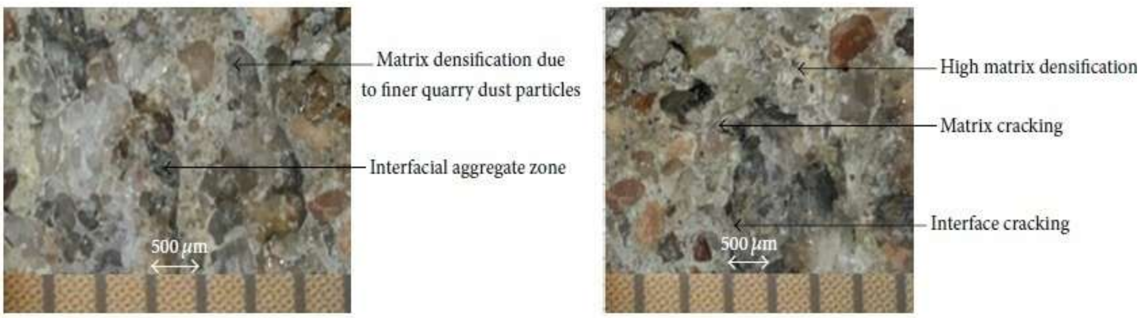


Fig. 1 Coefficient of cracked permeability for M30 concrete at 90days



a) b)

Figure 4(a) Microscopic view of conventional concrete without initial stress (50x magnification). (b) Microscopic view of conventional concrete at 40% load (50x magnification).



a) b)

Figure 5 (a) Microscopic view of quarry dust concrete without stress (50x magnification). (b) Microscopic view of quarry dust concrete at 40% load (50 x magnifications).

4. Discussion

Effect on Durability Properties

- The cracked permeability experimental test results showed that the addition of the quarry dust improved the permeation resistance of concrete. This can be seen from the concrete mixes containing 100% quarry dust instead of river sand for M30 which showed a substantial reduction in the coefficient of permeability values up to 40%, and the reduction was significant for higher cement content 450 kg/m^3) as well as for F/C ratio of 0.5.
- This is evident from the cracked water permeability test results as well as chloride permeability test results. Compared with natural sand, 100% quarry dust replacement in concrete showed the considerable reduction in cracked permeability and chloride permeability at higher cement content and higher F/C ratio.
- It is also understood from the particle size analysis that the fineness of quarry dust led to the improved pore structure properties leading to matrix densification properties. This is evidently seen from the digital microscopy studies that the porosity of conventional concrete mixes were more and resulted in matrix cracking whereas a refined matrix densification is achieved with the quarry dust substitution.

5. Conclusion

1. The cracked permeability test results showed that the addition of quarry dust and waste plastic improved permeation resistance of concrete. The reduction in permeability coefficient values was found to be up to 20.91% and the reduction was significant for M0-92-8 mix for all grades of concrete. Thus it can be inferred that the quarry dust and waste plastic led to the improved pore structure leading to matrix densification.
2. The study also signifies that the durability of concrete is dictated due to initiation of micro cracks upon initial stress applied and becomes adverse due to capillary movement of water.
3. Further it can be concluded from the test results that the addition of alternative fine aggregate material such as quarry dust in concrete can be a potential application form as concreting works in order to reduce the river sand depletion.

4. Reference

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