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Quarry Dust Based Cement Mortar with Inclusion of Bacteria A Waste Utilization Approach for Next Generation

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Abstract: *In the fast developing era urbanization takes place very rapidly and it is directly or in directly harmful for environment. Most common construction material cement mortar contains sand which is natural resource and as demand of sand (fine aggregate) increases scarcity of natural sand is the main concern. On the other hand aggregate crushing plant has a byproduct "Quarry Dust". Replacement of quarry dust by natural sand in cement mortar is done after comparing physical and chemical properties of natural sand and quarry dust. The results shows that it has almost similar properties so in this research natural sand is 100% replaced by quarry dust and in addition inclusion of bacteria (Bacillus Pesteurii) in different concentration like; 10^5 , 10^6 , 10^7, 10^8 cell/ml is done. As Bacillus Pesteurii can produce calcium carbonate ($CaCO_3$) as a filler material and serve as a binding factor in cement mortar. This study shows that the compressive strength is increases of the bacterial mortar than the standard mortar or sustainable mortar. The results of compressive strength test are higher of the cell concentration 10^7 cell/ml that is 31.01 N/mm^2. So a sustainable cement mortar which is economical can be used to utilize waste and protection of environment can be done.*

Keywords: *Cement Mortar, Quarry Dust, Waste Utilization, Bacterial Mortar, Environment*

1. INTRODUCTION

This study has a concept of quarry dust based cement mortar with the inclusion of bacteria. Quarry dust can be defined as residue, tailing or other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 4.75mm. Usually, quarry dust is used as a surface filler material in highway constructions. Quarry dust is abundantly available to the extent of 200 million tons per annum which has a landfill disposal problems and environmental hazards. In present study replacement of sand by quarry dust is an attempt to utilize waste and reduce the use of natural sand. As this is an attempt to use sustainable and economical cement mortar for the fast developing infrastructures.

In addition, by using new invention of bacterial mortar bacteria (Bacillus Pesteurii) added to have better strength results. Bacterial mortar is a science of precipitation of calcite carbonate ($CaCO_3$) and it has ability to heal the cracks of cement mortar. So this study introduces a new sustainable cement mortar which is more durable than standard cement mortar.

2. EXPERIMENTAL MATERIALS

Following are the experimental materials for the research experimental work.

2.1. Quarry Dust

The Quarry Dust was taken from the Sahjan and Quarry Works, Sevaliya, Gujarat state, India. Quarry Dust is collected from its disposal site on the Quarry site. The quarry dust is in a powdered form having the size less than 4.75mm. Quarry Dust was tested for checking the physical and chemical properties. The Figure 1 shows Quarry Dust.

Figure1. *Quarry Dust*

Quarry dust has almost similar properties of Fine aggregate (natural sand). The comparison of natural sand and quarry dust properties (physical and chemical) is shown in Table 1 and 2.

Table1. *Physical Requirement of Quarry Dust and Fine aggregate* (*Natural Sand)*

Property	Quarry dust	Fine aggregate (Natural sand)	Test method
Specific gravity	2.54-2.60	2.60	IS2386(Part III)- 1963
Bulk density (kg/m^3)	1720-1810	1460	IS2386(Part III)- 1963
Absorption (%)	1.20-1.50	Nil	IS2386(Part III)- 1963
Moisture Content (%)	Nil	1.50	IS2386(Part III)- 1963
Sieve analysis	Zone-II	Zone-II	IS 383 -1970

Table2.*Chemical Requirement of Quarry Dustand Fine aggregate*(*Natural Sand)*

Compounds	Quarry dust (% by weight)	Fine aggregate(Natural sand) (%by weight)
Lime	3.28	02.93
Silica	64.84	88.25
Alumina	0.12	00.71
Iron Oxide	0.94	00.93
Potassium Oxide	00.07	00.30
Sodium Oxide	00.15	00.01
Sulphite	00.22	00.08
Magnesia	8.49	00.17

2.2. Fine Aggregate

Fine aggregate is a naturally occurring granular material composed of finely divided rock and mineral particles. Those fractions from 4.75 mm to 150 microns are termed as fine aggregate. The Figure 2 shows fine aggregate.

Figure2. *Fine Aggregate*

(Source: Galaxy India Pvt ltd.)

2.3. Bacteria

Bacillus species are aerobic, sporulating, rod-shaped bacteria that are ubiquitous in nature. Majority of Bacillus species are harmless. Bacillus is a type of bacteria that can produce calcium carbonate ($CaCO_3$) as a filler material and serve as a binding factor in cement mortar. Calcium carbonate ($CaCO_3$) can reduce capillarypores of concrete and improve durability and compressive strength. The Figure 3 shows Bacillus Pesteurii NCIM 2477.

Figure3. *Bacillus Pesteurii NCIM 2477*

(Source: ARIBAZ laboratory New Vallabh Vidyanagar)

2.4. Cement

The cement utilized for the present examination was Ordinary Portland Cement (OPC) Grade-53 (Hi-bond 53). It is conformed to the requirement of Indian Standard specification BIS 12269 - 1987. Figure 4 shows Hi-bond 53 Grade Ordinary Portland Cement.

Figure4. *Hi-bond 53 Grade OPC*

3. DESIGN MIX

Design Mix of Cement Mortar as shown in table 3.Material required for casting of cubes: (for 1 cube size 70.7 mm x70.7 mm x70.7 mm)

Table3. *Design Mix of Cement Mortar*

Materials	Cement	Natural Sand / Quarry dust	Water
Weight	190 gm.	640 gm.	90 ml

4. EXPERIMENTAL METHODOLOGY

4.1. Compressive Strength Test

Procedure for casting: take the sand and cement as per required weight mix thoroughly on the non-porous surface until it gets mix well. Now add water and mix until its get uniform color. In bacterial mortar bacteria of different concentration is added into the distilled water and that water is added into the sand cement mixture. This paste is poured into the mortar mould and vibrated for 2 minute for the compaction. After 24 hours demould that mortar cube after it gets harden and cure that cube into a clear water for 28 days.

Figure5. *Casting and curing of cement mortar cube*

(Source: Sadbhav consultancy at nana bazar, Vallabh Vidyanagar)

Testing Methodology for compressive strength test after 7 days, 14 days, 28 days cubes were taken out and tested under compression testing machine. The results of the compression tests at 7, 14, 28 days are given in Table4 and Figure6.

Table4.*Comparative Experimental Results for Compressive Strength Test for all Mixes in Cement Mortar at 7, 14 and 28 Days*

Description	Cement Mortar Mixes	Average Compressive Strength (N/mm^2)		
		7 days	14 days	28 days
Fine Aggregate (Natural Sand) based	A	8.14	10.80	17.87
Quarry Dust based	B	11.00	12.40	17.87
Quarry Dust +Bacteria based (Bacillus Pesteurii)	B1(10^5cells/ml)	12.00	14.27	24.41
	B2(10^6cells/ml)	20.27	23.54	28.81
	B3(10^7cells/ml)	22.81	24.14	31.01
	B4(10^8cells/ml)	19.34	22.27	23.54

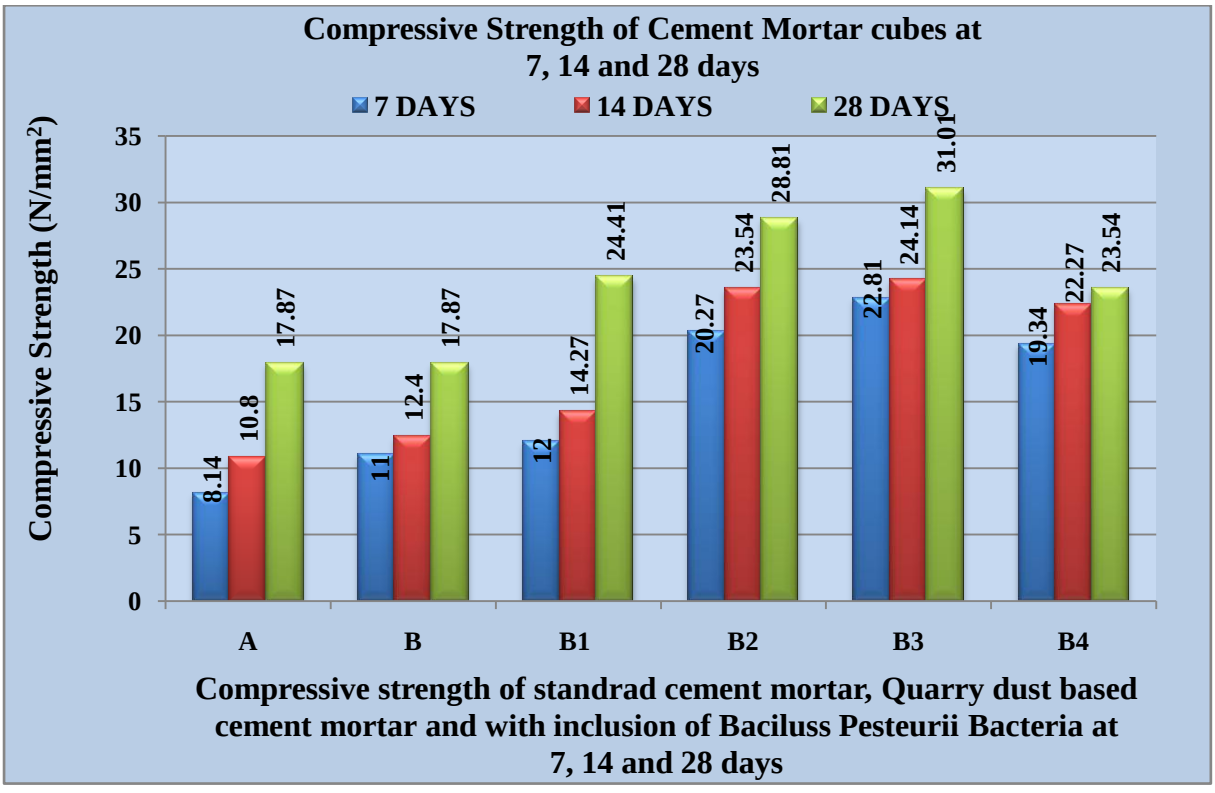

Figure6. *Compressive Strength Test*

From above figure 6, it can be said that compressive strength of cement mortar is increasing as the

concentration of bacteria is increasing but decreases at the cell concentration 10^8cells/ml (B4). So comparing the standard cement mortar strength with quarry dust based mortar it gives higher strength but the highest strength is achieved at B3 (10^6cells/ml) bacterial concentration that is 31.01 N/mm^2 at 28 days.

4.2. Water Absorption Test

For water absorption, after curing for 28 days put the cubes into oven at 85°c temperature for 24 hours drying. Weight the dried cubes and again put it in the water for 24 hours. Next day take the wet weight of the cubes. The results of the Water Absorption Test at 28 days are given in Table5 and Figure7.

Table5. *Average Water Absorption Test Results for all Cement Mortar Mixes at 28 Days*

Description	Cement Mortar Mixes	Average Water Absorption (%) at 28 days
Fine Aggregate (Natural Sand) based	**A**	0.84
Quarry Dust based	**B**	1.40
Quarry Dust + Bacteria based (Bacillus Pesteurii)	**B1(10^5cells/ml)**	2.14
	B2(10^6cells/ml)	1.45
	B3(10^7cells/ml)	1.26
	B4(10^8cells/ml)	1.65

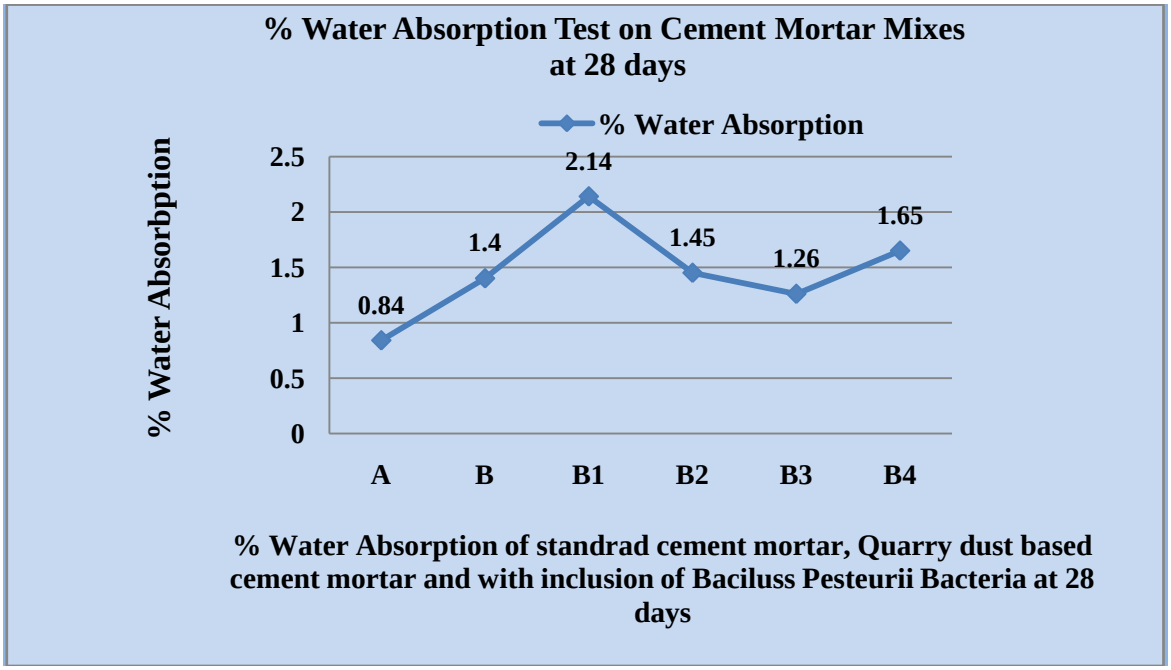

Figure7. *Water Absorption Test*

From the above figure 7, it can be said that water absorption is quite high compare to standard mortar but is lesser at B3 (10^7 cells/ml) concentration that is 1.26.

5. CONCLUSIONS

From this study following conclusion can be drawn:

a) The compressive strength of bacteria mortar is higher than standard mortar cubes so bacterial mortar is a sustainable, economical and more durable.

b) The water absorption is lesser where the compressive strength is higher.

c) It can be concluded that the B3 type of mortar is a new invention as it is quarry dust based bacterial mortar and having a highest compressive strength 31.01 N/mm^2 and water Absorption is 1.26.

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