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Critical analysis of Modified Paver Blocks Using Reclaimed Materials- An Experimental Approach

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Abstract:

Paver blocks are nowadays is a better answer for pavement surfaces bearing varied loads. Paver blocs are large in variety in terms of features ranging from enhanced engineered properties like better bearing capacity, multi functionality, varied shapes and locking features along with better visibility and porosity features, turned to be a better choice. The interlocking mechanism makes them easy to erect and quick to install almost in any surface having diversity in loading and traffic. The availability of recycled materials has further evolved the market and new range of novel materials is now available in wide spectrum. Various testes are done on the casted samples highlighting their novelty for use of recycled materials and not hampering or impacting their general properties. The maintenance of the casted paver blocks is least and repair and replacement is simple and fast. The versatility available in terms of shape, size, texture, thickness, interlocking, porosity and color along with visibility makes them a good material for use along the pavement. Paver blocks are different from loading condition like for heavy or medium traffic. This work is focused on use of recycled waste materials dumped into quarry and land fill sites and in the form of powder for materials reclamation and sustainable development. In this work replacement of cement is done by marble powder, granite powder, and m sand powder along with the quarried materials of the same recycled aggregates taken for lying the finished paver blocks. The work is focused on replacing the cement quantity with the waste marble, waste granite powder and m sand powder and least impacting the quality standards of the paver blocks. The main motto is to promote the use of recycled materials paver blocks and lower the waste generation issue. This work proved that 3 materials cannot be taken at the same time as replacement of cement, but partials replacement along 10 % marble powder and granite powder, 15 % m sand displayed good strength and results for casting medium traffic paver blocks with the concrete. These cheap blocks can reduce the cost and promote less usage of natural materials and increase use of recycled materials

Keywords **—paver blocks, urban pavements, waste granite powder, marble powder, recycled materials, m- sand powder, low-cost materials, loading.**

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I. INTRODUCTION

Rapid urbanization has raised the demand for land usage and demand of natural materials for the growth of the nations. India has turned itself into the 5th largest fast-growing economy. But this fast development has badly impacted the ecological balance of many parts of the country. The impact is felt in many areas like bad air quality, degraded water quality along with worsening flora and fauna depletion and making many things to go on the brink of disappearance. Due to human activities and ever-growing demand for this development, natural materials are almost being over harnessed and over utilized thereby making many calamities.

Global urbanization scenario in Oland area in Gujarat, India has made this port city into the graveyard of the ships of the world and has got good economic scope for India and worst impact on the surroundings of the city. Almost each water body is polluted due to the generated asbestos from the wrecked ships and recycled materials. The same is happening with the states generating tremendous amount of marble and granite and the states consuming it for its growth. The tiles generated are of many types and the dressing of stones cause dust and this dust is watered and flown into pits almost covered with slurry of waste marble and granite materials. The rapid urbanization scene has generated enormous waste and this is to be safely disposed else recycled or reduced or rejected for better natural solution of the same. The concept of globalization seems being misunderstood and the development has led to craving of paved surfaces and concrete jungles development. Each and every surface is being paved and concreted for smooth movement and we claim to be developed nation or fasting growing developing nation leaping many hurdles and thereby generating problems to our coming generations. The complicated pavement systems of the cities has raised the demand of paved roads and metal surface and paved systems for smooth movement of men and materials along with atheistic look for the same. Citizens spend countless hours over the pavement surfaces travelling from one corner to the other, thereby demanding for more comfort. Hence complicated roads network is the need of the hour for the over growing population and vehicles traffic. The lanes of the pavements are busied with multiple vehicles along with multiple choices of vehicles having varying loading and repetition conditions. The cases of rapid mass transit systems need special lanes for smooth movement of dedicated traffic and standalone vehicles meant for traffic in a particular section. These lanes then need special ambience like pedestrian sections for getting off and boarding smoothly.

There are many researches conducted across the globe which states that almost 40 % of global energy is consumed by the construction industry along with 35 % carbon dioxide release and pollution. The nonrenewable materials are limited in nature and green gases, causes global warming hence must be limited for use. Thus, green and sustainable construction must be promoted for reuse of exhausted materials and recycling rejected waste.

Many byproducts are available in various sectors of industry and they have good strength and properties although they are used once and are potentially suitable for reuse and reduced. Especially the materials which are to be used for the second time after their first economic use can be considered good once their feasible properties are properly evaluated. The byproducts of the crude oil industry like the asphalt is, or the residue of the furnace GGBS or alkaline slag or the silica fumes or the paper sludge can be having suitable properties once they are cautiously evaluated. The sanitary land filling of these materials can be justified once they are found

discarded in all aspects and still can be used for reclaiming waste and barren lands.

The paver's blocks are designated as per the codal provisions. They are graded as of three types viz. A, B, & C.

Specification of these paver blocks can be discussed below –

For Type-A paver blocks, they are designed in such a manner that they lock internally in an interlocking form and zigzag section fill each two pavers completely, without any gap in between. They have such geometry that the gap is used for locking each other and gripped properly so that they cannot slip from one another. The axis relative movements are cancelled in the transverse and in the longitudinal positions as per the locking symmetry. The resistance provided by the relative motion of opening each other is not present hence parallel motion is the cause of this force cancellation, thus they exhibit best grip among the interlocking paver blocks.

For Type-B paver blocks, locking among each other are exhibited as per the design itself and the zigzag pattern provides them a locking force and this avoids the opening when force is applied. The geometric formation provide resistance towards the opening once being locked through the puzzle format, thus their movement being in relative motion is just applicable to one axis only and is parallel to single axis.

For Type-C paver blocks locking among the zigzag pattern is not seen and provided**,** thus the symmetry, geometry and axis of plane where force is applicable depends to a smaller part upon the thickness of the paver (it means depth) and shape provided but is dependent more over on the locking mechanism, how they are locking among one another. How they are laid on the surface and how they are locked amongst.

Figure 1 types of paver blocks

II. MATERIALS TAKEN

Materials specifications: -

1. Cement, aggregates (fine and coarse), potable water, marble- granite and m sand powder
2. Admixture taken is laquor as suggested by the hardware shop owner and is in the category of BIS specifications.

Figure 2 paver blocks quick hardener/admixture

3. Super plasticizer or hardener which is locally taken from the hardware shop, the role of hardener is to avoid curing and helps in proper binding of the materials.

Figure 3 Hardener for paver blocks

A.) Quality and gradation of cement used: -

This shall be as per the specification laid in the BIS code 15658-2006 and available sub specifications are guided as per grades of cement of 53 or 43 or 33 grade. Grade 33 is not used. These BIS codes are followed as per 12269 for 53 grades of cement and BIS 8112 is followed for 43

grades of cement. The specific gravity of the cement taken and lab tested is found to be 3.16 and cement is of ordinary Portland cement of grade 43.

B) Quality and gradation and zoning of the aggregates taken:

Fine aggregates:

Particles passing the BIS grade sieves (4.75 mm) and holding over the 0.075mm BIS sieve comes under this category. The m sand taken is of zone II and having specific gravity as 2.61.

Coarse particles (aggregates)

They are as per the specifications laid in BIS 383 and are quarried and dressed chips. They are semi annular and hard. They are found to be (as per lab) having specific gravity of 2.70 and overall shape factor is 12 millimetres.

Quality of water taken:

The quality of water shall of potable grade and having pH of not lower than 6 and not higher than 8.0 and permissible silt content is 7 %.

Quality of the granite slurry powder:

1. Density is found as 2.63 to 2.78 g/cm^3.
2. Compressive strength found is 200 MPa.
3. Having a M.P. of 1216 till 1280 ^{0}C.
4. Having poor performance in permeability.

Table 1 : The chemical composition of the granite powder found is as below

Chemical composition	%
SiO_2	73.05
Al_2O_3	13.41
K_2O	4.15
Na_2O	3.66
CaO	1.80
Fe_2O_3	1.23
MgO	0.72

Features of waste marble powder-

Marble slurry is very fine having a particle dimension ranging from 75 micron to 150 microns. The density of marble powder is 2.70 grams per cubic centimeters and specific weight is between 2.50 to 2.81 grams per cubic centimeters. They contain high amount of calcium oxide lying between 30 to 69 %. It also contains good amount of silicon dioxide ranging from 1.5 % to 24 %. There are fewer amounts of other oxides also present like magnesium oxide, alumina, iron oxide and potassium oxide.

Combinations of materials taken:

Different combinations of granite powder, sun dried marble slurry powder, and m sand powder is taken in different proportions as per the nomenclature taken. These three materials are not taken at one time for replacing cement, but taken as per the combinations suitable for the mix criteria and minimizing the impact on the strength characters of the paver blocks. The minimum thickness of the casted paver blocks as per the mold is sixty millimeters. These paver blocks once casted will be tested in the lab and inferred as per the characteristics strength and properties thus obtained. The casted paver blocks will be used for least traffic or loading conditions and are to be put along sides the main traffic section. Bureau of Indian standards 15658- 2006 suggest guidelines for the casting, usage, and other allied mixing of recycled waste materials. In this work concrete of grade M 30 is used in all set of blocks having a standard mix proportion of one part cement or binder, 2.04 % fine particles and coarse aggregates in the ratio of 3.33. The aggregates taken are passing almost ten mm sieve are forty % and sixty % taken is of twenty millimeters. The m sand is good for compaction and packing hence river sand is not used. The aspect water cement ratio taken for the concrete is 0.40. The amount by weight of binder cement is just 2 % of super plasticizer.

Here A= Running number of paver blocks

B = Cement , D= Marble powder, E= Granite powder, M= M sand powder

Table 2 Character of the material proportions

Run no	%age of material
A1	100.00 % cement
A2	85.00 % cement (B) & 15.00 % marble powder(D)
A3	75.00 % cement (B) & 25.00 % marble powder (D)
A4	90.00 % cement (B) & 10.00 % granite powder (E)
A5	85.00 % cement (B) & 15.00 % granite powder (E)
A6	85.00 % cement (B) & 15.00 % M sand powder (M)
A7	75.00 % cement (B) & 25.00 % M sand powder (M)
A8	75.00 % cement (B) & 15.00 % marble powder (D) & 10.00 % granite powder (E)

A9	65.00 % cement (B) & 25.00 % marble powder (D) & 10.00 granite powder (E)
A10	70.00 % cement (B) & 15.00 % marble powder (D) & 15.00 % granite powder (E)
A11	60.00 % cement (B) & 25.00 % marble powder (D) & 15.00 % granite powder (E)
A12	70.00 % cement (B) & 15.00 % marble powder (D) & 15.00 % M sand powder (M)
A13	60.00 % cement (B) & 25 % marble powder (D) & 15 % M sand powder (M)
A14	60.00 % cement (B) & 15.00 % marble powder (D) & 25.00 % M sand powder (M)
A15	50.00 % cement (B) & 25.00 % marble powder (D) & 25.00 % M sand powder (M)
A16	60.00 % cement (B) & 15.00 % marble powder (D) & 10.00 % granite powder (E) & 15.00 % M sand powder (M)
A17	50.00 % cement (B) & 15.00 % marble powder(D) & 10.00 % granite powder (E) & 25.00 % M sand powder (M)
A18	50.00 % cement (B) & 25.00 % marble powder (D) & 10.00 granite powder (E) & 15.00 % M sand powder (M)
A19	40.00 % cement (B) & 25.00 % marble powder (D) & 10.00 % granite powder (E) & 25.00 % M sand powder (M)
A20	55.00 % cement (B) & 15.00 % marble powder (D) & 15.00 % granite powder (E) & 15.00 % M sand powder (M)
A21	45.00 % cement (B) & 15.00 % marble powder (D) & 15.00 % granite powder (E) & 25.00 % M sand powder (M)
A22	45.00 % cement (B) & 25.00 % marble powder (D) & 15.00 % granite powder (E) & 15.00 % M sand powder (M)
A23	35.00 % cement (B) & 25.00 % marble powder (D) & 15.00 % granite powder (E) & 25.00 % M sand powder (M)
A24	75.00 % cement (B) & 10.00 % granite powder (E) & 15.00 % M sand powder (M)
A25	65.00 % cement (B) & 10.00 % granite powder (E) & 15.00 % M sand powder (M)
A26	70.00 % cement (B) & 15.00 % granite powder (E) & 15.00 % M sand powder (M)
A27	60.00 % cement (B) & 15.00 % granite powder (E) & 25.00 % M sand powder (M)

III. RESULTS OBTAINED

A total of 27 concrete mixes are created and four replica of each paver is casted. Then the quantity of water, admixture, and hardener are added to the mixture. The aggregate and cement or the binder materials is mixed and water is added for a slump of 0. The aggregate to binder ratio is taken as **4.62**as suggested by a paver block manufacturer. The mixture is transferred to the mold. The mold is made up of hard plastic. The paver block thus formed is demolded after 24 hours and cured for next 28 days age

Table 3compressive strength test results

	Compressive Strength Values in N/mm^2	
Run No. Of Paver Block	Strength at 7 day age	Strength at 28 day age
A1	22.34	31.12
A2	22.67	32.89
A3	15.02	22.08
A4	20.89	31.15
A5	19.18	28.22
A6	19.98	31.15
A7	20.96	32.18
A8	19.07	29.78
A9	18.14	29.29
A10	10.87	22.40
A11	9.67	19.21
A12	15.10	23.15
A13	16.78	27.99
A14	20.17	30.60
A15	15.10	22.21
A16	14.97	21.69
A17	12.19	19.51
A18	17.38	29.16
A19	10.72	20.86
A20	17.30	28.17
A21	12.11	18.14
A22	12.19	18.15
A23	9.17	22.08
A24	21.91	32.71
A25	18.17	31.10
A26	17.19	29.16
A27	18.19	19.92

Table 4 Flexural strength of the sample blocks

Run No. Of Paver Block	**Flexural Strength Values in N/mm^2**
A1	2.37
A2	2.49
A3	1.48
A4	2.43
A5	1.72
A6	2.47
A7	2.52
A8	1.91
A9	1.84
A10	1.39
A11	1.26
A12	1.60
A13	1.78
A14	2.45
A15	1.49
A16	1.57
A17	1.30
A18	1.82
A19	1.39
A20	1.64
A21	1.17
A22	1.21
A23	1.46
A24	2.54
A25	2.39
A26	1.89
A27	1.91

Table 5 abrasion resistance of the paver blocks

Run No. Of Paver Block	**Abrasion happened in cubic mm after 16 cycles**
A1	833.3333
A2	833.3333
A3	1250.00
A4	416.6677
A5	416.6677
A6	0
A7	416.6677
A8	833.3333
A9	833.3333
A10	416.6677
A11	1250.00
A12	833.3333
A13	1250.00
A14	833.3333
A15	1250.00
A16	833.3333
A17	1250
A18	1666.6677
A19	2083.3434
A20	1666.6767
A21	2500.00
A22	2500.00
A23	3333.3431
A24	416.6667
A25	416.6667
A26	833.3333
A27	833.3367

Table 6 water absorbed data obtained after the testing

Run No. Of Paver Block	Percentage of water absorbed
A1	5.6
A2	6.5
A3	8.1
A4	2.09
A5	1.71
A6	2.73
A7	1.77
A8	3.29
A9	3.87
A10	1.67
A11	2.93
A12	2.62
A13	5.29
A14	2.76
A15	4.33
A16	2.022
A17	1.62
A18	2.39
A19	3.78
A20	3.19
A21	2.29
A22	3.90
A23	2.90
A24	1.76
A25	1.50
A26	1.30
A27	1.55

Table 7 UPV test result

Run No. Of Paver Block	Pulse velocity in metre/second (age taken after 28 day)
A1	4.72
A2	4.7
A3	4.6
A4	4.71
A5	4.43
A6	4.63
A7	4.28
A8	3.81
A9	3.71
A10	2.98
A11	2.89
A12	3.13
A13	3.62
A14	4.44
A15	3.13
A16	3.34
A17	2.90
A18	3.89
A19	2.89
A20	3.98
A21	2.71
A22	2.70
A23	2.98
A24	4.87
A25	4.89
A26	4.4
A27	4.4

Table 8 rapid moisture permeability tests values

Run no	RCP values after age of 7 day	Comment	RCP values after age of 28 day	Comment
A1	3257	Moderate	2676	Moderate
A19	2166	Moderate	1502	Moderate
A23	2512	Moderate	2398	Moderate
A24	1698	Low	1387	Low

IV. CONCLUSIONS

1. Adding marble dust in concrete increase the strength of the material and when the casted paver blocks are tested for various strength values then strength increased as compared to the normal concrete at 15 percent partial replacement of cement.

2. Good compressive stamina is obtained when marble dust is used and heaviness is also obtained making it less prone to sink, but when this material is used in structural work they can cause weight issues.

3. Marble dust is fine, and hence helps in achieving good finish over the textured surface.

4. Granite powder can be good in concrete and in making paver blocks but this is suitable at addition on only 10 percent, when more addition is done it causes strength reduction and other parameters impact is also seen.

5. Paver block turn resistant to fire and acid attack and spilling of chemicals when m sand powder is partially replaced with cement at 15 percent. Strength gain is also visible from results.

6. When all three materials, marble powder, granite powder and M sand are used at once and partially replacement of cement is done, then strength and other parameters are impacted and is less useful, least strong, highest permeable as compared to the normal concrete. Thus, this combination is fatal to the pavers and concrete.

7. All mix combinations when taken into account, only 15 percent of m sand and 10 percent of granite powder is found optimal and given better strength and other parametric values, as found from this work.

8. Reduction in cost is achieved by using the recycled materials, and saving the nature from dumping of pollutants causing various pollution and marble powder, granite powder and m sand can be easily available and obtained from the dumping sites.

9. Silicosis is a TB like disease when marble powder is inhaled for long is caused, thus this issue can be reduced when recycling of the dust is properly done.

10. The paver blocks of the recycled materials will be safe, eco-friendly and cost effective along with shape freedom and use at ease facility.

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