Road Aggregates from Industrial Polymer-Waste

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Abstract— **Considerable amount of polymer waste is being generated during filtration stage in manufacturing process of recycled rigid PVC pipes. Locally this waste is called as *Jaali Gola.* It contains stone and metal particles along with major portion of crude, non-recyclable polymer waste. This waste is great environmental nuisance. The present work has attempted to investigate the feasibility of this polymer waste to be used as aggregates in road work applications. The pipe industry polymer wastes are cut in a cutting machine and particles like natural coarse aggregate are obtained. These particles are called Waste Polymer Aggregates (WPA). These are subjected to different tests recommended by IS codes and the test result indicates that WPA are suitable to be used in bituminous road as a substitute to traditional coarse aggregates. Efforts are also taken to calculate cost of materials per kilometre length of a bituminous road of 3.7 metre width, considering WPA as coarse aggregates for road construction. Calculations show that, total cost of materials in case of waste polymer aggregate road is considerably less than that for a usual stone aggregate road. Further, WPA are also tried with bitumen, as a mix, in an experimental work of repairing of pot holes of an existing bituminous road pavement. The repaired road was under observation for a period of more than one year. It is found that WPA-Bitumen mix is intact in the pot holes and no considerable damage has occurred to it due to traffic. Since WPA-Bitumen mix is performing well in the repaired pot holes, WPA can further be used on large scale in construction of bituminous road pavement. Thus, the outcome of the entire work shows a way to solve the problem of disposal of pipe industry polymer waste in an eco-friendly manner. There will be added advantage of its use since the natural aggregates are getting scarce day by day. Their over exploitation is not only creating environmental nuisance but is also creating socio-economic and political conflicts. The present work thus attempts to solve a twofold problem with single stroke.**

Keywords— **Waste Polymer, Coarse Aggregates, Recycled pipe, Jaali Gola, Bituminous Road, Pot Hole.**

I. INTRODUCTION

Plastics are being extensively used now-a-days almost in all walks of life due to the advantages availed from their different varieties and amazing properties. Since plastics are comparatively affordable material due to their low cost and suitability at most of the places of its intended use, it is gaining popularity day by day. Due to rapid growth in population and industrialization, use of plastics has constantly increased during past years all over the world, particularly in developing countries like India. In the present era, use of plastics has increased to such an extent that, one can't even think life without using plastics. Such an extreme use of plastics naturally gave rise to generation of high volume of its waste. Studies have shown that thousands of tons of waste plastics are being generated every day across the world. Since plastic is not a green (eco-friendly) material, the question of its proper disposal should be viewed seriously. It is not even easily biodegradable and takes more than thousands of years for its complete natural decomposition.[1] Scientists, environmentalists and researchers have consistently warned people against direct dumping of waste plastics in open ground or into the available water bodies due to its catastrophic effects on the entire ecosystem. Studies have shown that open burning of waste plastics or using the same for area reclamation or land filling is even more dangerous to the environment, since this leads to further increase in soil (land) pollution, water pollution and air pollution through high degree. So the question is what to do with such a tremendous amount of plastic waste which is getting generated every day. [10] One of the answers to this question may be to utilize this waste in some appropriate and innovative manner.

Considering the benefits, efforts are being taken to utilize waste materials as alternative aggregates in preparation of cement concrete that is used for different construction works. Significant research is made on the use of many different materials as aggregate substitute such as coal ash, blast furnace slag, fibre glass waste materials, waste plastics, rubber waste, sintered sludge pellets and others. [3], [14]

II. SOURCE OF POLYMER WASTE

Many pipe factories use required type of plastic scrap as their raw material to manufacture rigid pipe. Therefore such pipes are called as recycled plastic pipes. In filtration stage of manufacturing process of these recycled plastic pipes, the pulverized plastic scrap is melted and injected through steel wire mesh in hot condition at a temperature 170-200 ^{0}C. When the filter mesh gets completely blocked because of impurities and other foreign particles present in plastic scrap, the injected material further ceases to flow out of filter mesh. The blocked mesh is then replaced by a new one and filtration process is continued. When the blocked mesh and mass of polymer waste (adhered to mesh) cools down they are separated out from each other. This separated mass of impure plastic waste is locally called as *Jaali Gola*. It contains usually stone and metal particles along with major portion of impure and non-recyclable polymer waste. In a day considerable amount of such polymer waste is getting generated and there is a big question of its disposal. [9] Since non-recyclable polymer waste is a great nuisance to environment, it is taken for study in the present work in a view to make an attempt to find a safe way of its disposal. Particles like natural coarse aggregate are obtained when *Jaali Gola* (mass of waste polymer) are applied to the cutting machine. Thus required quantity of Waste Polymer Aggregates (WPA) is derived through cutting machine available at the manufacturing plant. [14]

Fig.1 *Jaali Gola* Material (Mass of Waste Polymer) [14]

III.PREPARATION OF WASTE POLYMER AGGREGATES (WPA)

In production of recycled pipes, plastic scrap is used as main raw material. In the process of hot filtration of manufacturing of this pipes, a non recyclable mass of waste is generated which contains crude polymer constituent along with foreign bodies like stone and metal pieces. This mass of waste polymer (Jaali Gola), is allowed to cool to room temperature. Considerable amount of such waste is getting generated in pipe factories during the filtration process and stacked aside as non recyclable solid waste [9], [10]. This waste polymer is taken for producing coarse aggregates. To satisfy this requirement, the mass of waste polymer are applied to the hopper of cutting machine to cut it into small pieces of size less than 25mm. [15] Thus, with the help of cutting machine required quantity of cut pieces are obtained from solid mass of waste polymer (Jaali Gola). These cut pieces of waste polymer are called as Waste Polymer Aggregates (WPA).

Fig. 2 Waste Polymer Aggregates (WPA) derived from *Jali Gola*.

IV.ENGINEERING PROPERTIES OF WPA [14]

Aggregates obtained from mass of polymer waste are subjected to different tests to determine their engineering properties. The tests which are suggested by Indian Road Congress and Indian Standards are conducted on WPA to judge their suitability as a substitute to natural aggregates. [4]-[8]

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A. Particle size and Appearance of WPA -

While obtaining WPA from *Jaali Gola*, the size of screening attached from underside of a cutting machine decides the range of particle size. The particle size may be changed as per requirement by adopting appropriate size of screening. In the present work a major portion of WPA was of particle size ranging between 10mm to 12.5mm. The surface texture of WPA is rough like natural stone aggregate and shape of the particles is irregular.

B. Specific gravity determination -

Indian Standard Specification IS 2386 (Part III) of 1963 gives various procedures to find out the specific gravity. In the present work specific gravity of WPA is determined using Standard Pycnometer bottle.

C. Percentage water absorption -

This is determined following the guidelines given in IS 2386 (Part III) of 1963. Oven drying of WPA at prescribed temperature of 110 ^{0}C is avoided purposely. Instead Waste Plastic Aggregates are oven dried at a temperature of 65 ^{0}C for 24 hours and then percentage water absorption is calculated.

D. Determination of aggregate impact value -

To determine toughness of WPA, this test is conducted as per the steps given in IS 2386 (Part IV) 1963.

E. Determination of aggregate crushing value –

This test provides a relative measure of the resistance of an aggregate sample to crushing under gradually applied compressive load. The test is carried out referring the procedure given in IS 2386 (Part IV) 1963.

F. Determination of abrasion value –

Testing of aggregate for its resistance to wear is of importance for aggregates to be used for road construction. WPA are also subjected to this test to determine their performance in wear by Los Angeles abrasion value method, following the guidelines given in IS 2386 (Part IV) 1963.

G. Stripping test (with bitumen of grade 80/100) –

This test is conducted to determine the effect of moisture upon the adhesion of the bituminous film to the surface particles of WPA. This test is of significant value to ascertain the suitability of the two materials for satisfactory biding action. The test is conducted referring the guidelines given in IS 6241-1971.

H. Marshall Stability test –

This test determines the optimum bitumen content corresponding to the maximum load supported by test specimen before failure. The specimen is a compacted mixture of aggregate and bitumen prepared in cylindrical shape in specified manner. This test is conducted following the procedure given by ASTM D 1559. Thus Marshall Stability of a test specimen is the maximum load required to produce failure when the specimen is preheated to a prescribed temperature placed in a special test head and the load is applied at a constant strain of 5 cm per minute.

V. RESULT OF LABORATORY TESTS [14]

Above tests are conducted taking three different samples of WPA for each test. The average test results obtained are tabulated below. Little changes regarding weight and volume of the sample, oven temperature, percentage addition of bitumen, etc. in some tests are required, as base material of the test sample was polymer.

TABLE I [14]
ENGINEERING PROPERTIES OF WPA

Sr. No.	Type of property	Specifications	Test Results	Recommendation for N.A.
1	Particle size	IS 2386 (Part I) 1963	10mm-12.5mm	Recommended size.
2	Specific Gravity	IS 2386 (Part III) 1963	1.5	1.5to2.9
3	Water Absorption	IS 2386 (Part III) 1963	1.55%	Should not be more than 2%
4	Impact Value	IS 2386 (Part IV) 1963	1.47%	Should not be more than 30%
5	Crushing Value	IS 2386 (Part IV) 1963	1.7%	Should not be more than 30%
6	L.A. Abrasion Value	IS 2386 (Part IV) 1963	2.24%	Should not be more than 30%
7	Strippig Test	IS 6241-1971	17%	Should not be more than 25%

8	Marshall Stability Value	ASTM D 1559	848 Kg	Should not be less than 340 Kg

VI. REPAIRING OF POT HOLES USING WPA

In the present study, efforts are also taken to observe actual performance of WPA (Waste Polymer Aggregates) in an experimental work of repairing of pot holes of an existing bituminous road pavement. For this purpose an existing bituminous road is selected, where the upper layer of the road was damaged at intermittent locations along its stretch. At some places along the road, pot holes were also developed due to stripping out of road material. Among these a few pot holes were decided where repair and maintenance work was required to be done. In the beginning approximate size (length, width and depth) of every pot hole is measured using ordinary ruler scale. Loose stone particles, soil and dust are removed completely from each pot hole, using a small broom and a cleaning brush. Thus the inner part of every pot hole was kept dry, clean and dust free before repairing. To prepare required WPA-Bitumen mix, percentage addition of bitumen was decided from the results of previously conducted Marshall Stability Test. Referring this percentage, estimated weight of bitumen is taken and it was heated to 90-110 ^{0}C. Similarly, required weight of Waste Polymer Aggregates was taken and they are slightly heated to 60-65 ^{0}C and added to previously heated bitumen. Care is taken for the molten bitumen to get evenly applied on the surfaces of all WPA particles. Thus, the required type of bituminous concrete was prepared by thorough and careful mixing of WPA with bitumen. After this, molten (hot) bitumen was applied on the inner side and base area of pot holes using a small steel wire brush. This is done in view to provide good scope for development of strong bond between old and new materials. Just after finishing bitumen painting, pot holes were completely and carefully filled adopting WPA-Bitumen mix. The poured mix was well compacted flush with the existing road surface using hand rammer. In this way all the pot holes were repaired one by one using WPA-Bitumen mix [4].

Fig. 3 Typical Pot Hole in Pavement before Repairing

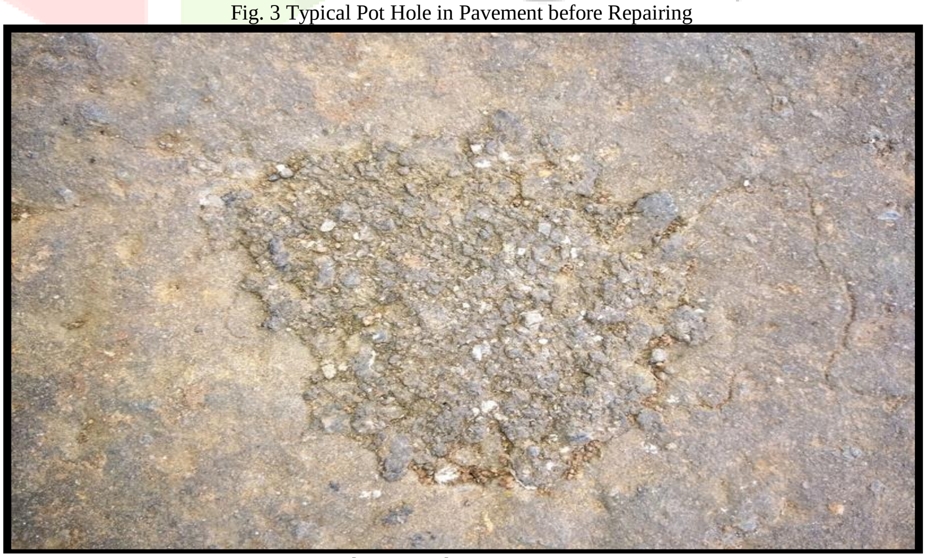

Fig.4 Pot Hole Repaired using WPA-Bitumen Mix.

VII. OBSERVATIONS OF REPAIRED POT HOLES

The compacted mix exhibits similar kind of surface texture as that of the ordinary bituminous pavement. The repaired road is observed for a period of more than a year under normal traffic condition. It is found that no considerable damage has occurred to the WPA-Bitumen mix in the repaired pot holes. A negligible number of fine particles from the top portion of some pot holes are stripped out and removed away may be due to road traffic or weathering agencies. However maximum portion of WPA-Bitumen mix in the repaired pot holes is stable and intact.

VIII. COST ANALYSIS [15]

Considering the importance of money in every sector of life in this era of critical thinking and implementation, it becomes essential for any project, before its actual execution to check its economical feasibility. In the present study it is proposed that, Waste Polymer Aggregates (WPA) will be used as substitute to natural stone aggregates for construction of bituminous road pavement. The optimum percentage of bitumen is taken as determined in Marshall Stability test.[8] The road can either be in the form of premix carpet or surface coats (black top surfacing or painting). In the beginning, cost required for usual type of bituminous road, where stone aggregates are used is determined, and after that cost required for that bituminous road, wherein waste polymer particles (WPA) will be used as coarse aggregate, is obtained. [11]

Assumptions in Cost Analysis:

1. On experimental basis the cost analysis is conducted per kilometer length of road having 3.7m as its width.
2. Only waste polymer aggregates (WPA) are to be used to prepare bituminous mix. It will not contain any stone aggregates.
3. Cost analysis involves only cost of material required for bituminous layers.
4. Other conditions like foundation, construction procedure, laying material and compaction (rolling) etc. for WPA road are similar to that for the usual bituminous road.

Considering all these assumptions cost analysis is carried out separately for the two different cases of road pavements.

TABLE II [15]
COST OF MATERIAL FOR USUAL BITUMINOUS ROAD

Particulars	**Material required**	**Proportion**	**Total quantity**	**Rate**	**Amount in Rs.**
First coat	Stone grit (20 mm gauge)	1.35 cu. m per 100 sq. meter	50 cu. M	900 / cu.m.	45000
	Binder (Road Tar No. 3)	220 kg per 100 sq.m	8.14 tonne	2900/tone	23606
Second coat	Stone grit (12 mm gauge)	0.75 cu. m per 100 sq. meter	28 cu. M	900/cu.m.	25200
	Binder (Asphalt)	120 kg per 100 sq.m	4.44 tonne	2900/tone	12876
Total amount for materials only					**106682**

TABLE III [15]
COST OF MATERIAL FOR WASTE POLYMER AGGREGATE (WPA) BITUMINOUS ROAD

Particulars	**Material required**	**Proportion**	**Total quantity**	**Rate**	**Amount in Rs.**
First coat	WPA (20 mm gauge)	1100 kg.per 100 sq. m. (according to 1.35cu.m of grit)	40.70 tonne	1000/tone	40700
	Binder (Road Tar No. 3)	11 % by weight of WPA	4.477 tonne say 4.5 tonne	2900/tone	13050
Second coat	WPA (12 mm gauge)	620 kg.per 100 sq.m. (according to 0.75cum)	17.36 tonne	1000/tone	17360
	Binder (Asphalt)	11 % by wt. of WPA	1.91 tonne say 2 tonne	2900/tone	5800
Total amount for materials only					**76910**

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IX. OUTCOME OF COST ANALYSIS [15]

The above cost analysis clearly indicates that cost of materials per kilometre length in case of WPA bituminous road is **less by Rs. 29772/-** than the cost of materials required for traditional bituminous road. In percentage it is **27.9% less**. Since WPA are comparatively light in weight (specific gravity is 1.5) their mixing, placing and transportation will be comparatively easy, fast and convenient and transporting given volume of WPA will require lesser powered vehicles. Due to all these reasons there is further scope to reduce the cost of construction of bituminous road pavement.

X. CONCLUSION

The pollution concerns associated with waste plastics and reducing availability of the natural aggregate has forced the researchers to look for alternatives. The present work has successfully proved the feasibility of pipe industry polymer waste as road pavement aggregates. The WPA has qualified all the relevant tests prescribed by IS codes. [14] Also the WPA-Bitumen mix in pot holes is found to be performing well like usual pavement material. This indicates that WPA could be used as an alternative material to natural stone aggregates. When added with bitumen in proper manner, they produce usable quality of pavement mix. Moreover, cost analysis also show that the material cost of bituminous road is comparatively lesser if waste polymer aggregates are used in road construction. This has opened a new dimension for the road construction industry of Jalgaon region. The present work is a laboratory scale study. Of course the work needs to be extended to the field scale trials also. However the technological feasibility of using WPA for road pavements has been well proved by the present work. Now it is up to the field engineers to carry forward the work for the environmental protection and economic benefit of the road construction industry.

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