Eco-Pave: Transforming Industrial Waste into Sustainable Paver Blocks

Mr. P. Ashok[1], Mr. S. Pradeep Reddy[1], Mr. K. Linganna[1], Mrs. V. Devi[1]
[1]Department of Civil Engineering.
[1]Sree Dattha Institute of Engineering and Science, Sheriguda, Hyderabad, Telangana

ABSTRACT

Rapid industrialization and urbanization have led to an alarming increase in industrial waste generation, posing serious environmental and disposal challenges. Landfills are reaching capacity, necessitating innovative and sustainable solutions for waste management. This study explores the potential of repurposing industrial waste—specifically fly ash and waste rubber—in the production of eco-friendly paver blocks. By partially replacing cement with 25% fly ash and coarse aggregates with waste rubber at varying levels (5%, 10%, 15%, 20%, and 25%), the research evaluates the mechanical properties of M30-grade concrete. The results aim to demonstrate the feasibility of using these waste materials to develop durable, cost-effective, and environmentally sustainable paver blocks. The adoption of such an approach could significantly reduce industrial waste accumulation while promoting green construction practices.

Key words: M30 Grade Concrete, Paver Blocks, Coarse Aggregate Substitution, Green Building Materials, Recycling in Construction.

1. INTRODUCTION

Concrete paving blocks has been extensively used in many countries for quite some time as a specialized problem solving technique for providing pavement in areas where conventional types of construction are less durable due to many operational and environmental constraints. This technology has been introduced in India in construction, a decade ago, for specific requirement namely footpaths, parking areas etc. but now being adopted extensively in different uses where the conventional construction of pavement using bituminous mix or cement concrete technology is not feasible or desirable. Concrete paver blocks were first introduced in Holland in the fifties as replacement of paver bricks which had become scarce due to the post-war building construction boom. These blocks were rectangular in shape and had more or less the same size as the bricks. During the past five decades, the block shape has steadily evolved from non-interlocking to partially interlocking to fully interlocking to multiply interlocking shapes. The main challenge before the Indian concrete industry now is to meet the demand of economical and efficient construction materials required by large infrastructure needs due to rapid industrialization and urbanization. All these call for use of good quality concrete with use of minimum resources (eg. Limestone, energy &money) and achieving maximization of strength, durability and other intended concrete properties. In recent years there has been an increasing worldwide demand of concrete paving blocks for the footpaths, roads and airfields which has led to a local depletion of aggregates. In some urban areas, the enormous quantities of aggregate that have already been used means that local materials are no longer available and the deficit has to be made up by importing materials from other locations. Most cities have areas of land covered by spoil heaps which are unsightly and prevent large areas of land being used for anything else. Concrete paving block is a versatile, aesthetically attractive, functional, and cost effective and requires little or no maintenance if correctly manufactured and placed.

2. LITERATURE REVIEW

Khushboo Tiwari, The experiment were conducted with the of proper utilization of the solid waste in construction of paver blocks without affecting the various mechanical properties such as compressive strength, flexure strength and split tensile strength. The waste which we are going to select is the waste generated by marble stone quarrying or at the time of its dressing. The paver blocks were constructed by using the waste marble products after replacing the coarse aggregate by some defined percentage. These blocks were tested by different tests like compressive strength test, flexural strength test, and split tensile strength test. The compressive strength found to be in between 47.35 N/mm2 to 44.98N/mm2 . But we observed that up to 40% replacement of coarse aggregate with marble stone generally does not show any major difference. The replacement of coarse aggregate with the marble stone generally does not affect the flexural strength of the paver blocks. In the same manner the split tensile strength of the paver blocks does not shows any effect by the replacement of coarse aggregate with marble stones. The approximate value is found to be 46.5 N/mm2 . Based on these experiment we concluded that the waste generated by the marble stone can be used as an alternative for the natural crushed stone used in paver blocks as the compressive strength, flexural strength and the split tensile strength of the testing blocks does not shown any major difference with its original standard mix paver blocks.

Yole, R.C. and Dr. Varma, M.B. , they used rounded steel aggregate as a partial replacement of aggregate and used rubber pad at bottom for testing. They designed a nominal m ix i.e., by weight having ration of 1:1.84:2.76 of cement aggregate and water respectively. They prepared 5 different type of paving block by percentage replacing of aggregate with 0%, 10%, 20%, 30% and 40%. The rubber pad used at bottom was of a thickness of 10 mm. They performed impact test on these blocks with and without rubber pads. They noticed that as there is an increase in percentage of steel ball bearings or rounded steel aggregate the average impact value increases from 4.33 for 0% replacement to 6.33 for 30% replacement when tested without using rubber pad below the paving block. On further increasing the replacement of ball bearing to 40% the average impact value decreases to 5. By using the rubber pad at the bottom of thickness 10mm at bottom impact value shows a drastic increase of 500 % to 600 %. The value of impact test changes to 23.33 to 35 for 10% to 40% replacement with steel ball bearings respectively. For the increasing impact value they justified that it was due to increase in the density of paver block.

Aarti Ghude et al The degradation of plastic is very long process, it may take thousands of years. Hence, project is helpful in reducing the plastic waste .In this project, they have used plastic waste in different ratio with fine and coarse aggregate. The paver blocks were prepared and tested .The water absorption capacity of plastic paver block is less. The results showed more strength as compared to paver blocks.

Dr. Bhavin G Patel et al Plastic is an innovative material for using it in construction purpose. Plastic paver block is a productive way of disposal of plastic waste. It shows better results such as strength. Compressive strength is higher compared to conventional paver block. The cost of paver block is reduced by utilizing the plastic waste and copper slag when compared to that of concrete paver block. This method is suitable for the country which has difficult to dispose recycled the plastic waste. The results of compressive test shows that strength of paver block increases with respect to the percentage of copper slag added by weight of fine aggregate. Addition of copper slag increases the density and thereby self weight and hence it is suitable for bearing like Paver block. The workability enhanced with the mixing of copper slag. As copper slag is a high density materials it increases the self weight of paver block there by increases the strength and toughness against the various kinds of loads. By this it can also be stated that the property of toughness and rigidness can be increased in the paver block by using copper slag in it.

Sukhada R H et al The study includes experimental tests on rubber and aggregates used in the Paver Blocks. The papers attempts to carry out the study on the use of industrial rubber waste at 5%, 10%, 15% and 20% in the production of concrete paver blocks. After preparing the specimen according to mix proportions of M40 mix, curing was done at 7 days. From the results obtained, it is observed that as the percentage of rubber increases the slump value also increases this means that workability increases. From the test results Compressive strength has decreased as the percentage of rubber has increased. Compressive strength feared well initially at 5% and 10%. Later it started slightly decreasing. So the conclusion drawn from the present study is, fully replacement of the rubber is not possible. But partially replacement of the rubber is possible up to certain percentages. From the literature review and experimental studies it is concluded that despite of decrease in strength of concrete there is a very high demand of concrete so it can be used as a partial replacement. Inspite of decrease in the strength, partial replacement of rubber is possible and is very much beneficial according to environmental concern and can solve many disposal related problems easily.

Mr. Neeraj Kumar Gupta, Dr. Ajay Swarup et al. The research has focused on using scrap tires where rubber powder is obtained from cryogenic milling of tires. The main objective of this paper was to use the rubber powder as partial replacement material with fine aggregates in concrete. Study involves the distortion work carried out which includes Mix design, casting, curing, and testing of specimen. Utilization of rubber powder into concrete mix was up to 10%, 20% and 30%. Various Laboratory test was performed and results obtained were, Fineness of the cement 7.6%, standard consistency of the cement 35%, Initial and Final setting time of the cement that is 35 minutes and 310 minutes and Crushing strength of the aggregate 13.93%. Casting and Curing of the specimen was done for 7 and 28 days. After curing compressive test was carried out by using Universal testing Machine (UTM) and results obtained were 35.13N/mm2 . Thus paper concludes that results obtained, satisfied as per IS Specifications.

Naveen Kumar N V, Naveen B M, Manjunatha R, Puru V, Darshan H A et al. As there is increase in the vehicles every year huge number of rubber tyre have hit the roads which is major environmental concern. Waste rubber tyres have caused serious problems all around the globe. So the alternative used in the study is to use crumb rubber in concrete as partial replacement material with fine aggregates. The paper aims at preserving natural resources such as cement and aggregates and to overcome this problem waste is utilized and made best use of it. Materials used in the experimental study are Ordinary Portland cement of 43 grade, fine aggregates, coarse aggregates, crumb rubber and water. Basic tests of these materials are carried out to check its properties and characteristics. The process involved in the experimental study is basic test, mix design, casting, curing and testing of specimen. In an order to prepare the specimen crumb rubber is replaced with fine aggregates in different percentages that are 0%, 5%, 10% and 20%. The workability test and compressive strength test was carried out for M25 grade of concrete by replacing fine aggregates with crumb rubber. The results obtained were high workable concrete and compressive strength which initially increased and then later decreased. Therefore the investigation concludes that use of partial replacement of crumb rubber with fine aggregates. But Inspite of open disposal of rubber waste it can be used in the study for environment concern as it has good workability, thermal resistance and sustainability.

Partha Saika, Owais Mushtaq, and A.Arunya et al. The investigation is carried out by using rubber chips as replacement with coarse aggregate. Paper also explains about the statistics of rubber waste produced every year. Since there is an increase in the rubber tyre every year it has become serious environment concern. So measures were taken to use rubber chips in the experimental trials. Rubber chips were replaced with coarse aggregates at different percentages and Compressive Strength test and Split Tensile test was carried out. Four specimens with various percentages at 0%, 4%, 8% and 12% replacement of rubber chips with coarse aggregates was done. Experimental works involved in the study are mix design proportion, casting, curing, and testing of specimen. Workability of concrete was also carried out but results feared well when compared to compressive strength and tensile strength. Therefore study concluded by suggesting using the rubber chips as replacement material up to certain percentages to control the pollution and decrease the waste for our environment purpose.

Rohit Sharma, shalika Mehta et al. The unique method is used to replace rubber with fine aggregates. The paper includes the experimental study done by using rubber at various percentage replaced with fine aggregates along with silica fumes to alter the bonding properties of rubber in the positive manner. The paper also aims that by using this rubber tyre waste it decreases the environmental related issues. The main objective of the paper was to find the Compressive strength, Split Tensile strength, and Flexural strength. To find the properties of rubberized concrete experimental test procedures are done. Procedure involves, mix proportion design, compressive test, flexural strength, and split tensile test. Mix design was done according to IS-Code 10262-2009 and mix was obtained. Crumb rubber at various percentages of 5%, 10%, and 15% was replaced with fine aggregates. Preparation and details of specimen includes casting, curing and testing. Thus paper concluded that workability of the concrete increased with increase in crumb rubber but Compressive strength, split tensile strength and flexural strength decreased with increase in crumb rubber. To overcome this problem and maintain positive way of using rubber in concrete silica fumes were added as admixture to strengthen the concrete and use it efficiently to maintain durability, suitability and control environment issues.

A. K. Gupta.et.al., They described uses of pervious use concrete in construction of pavement for improving their performance and they finally developed a strong and durable pervious concrete mixes for low-volume roads. The effects of two types of fine aggregates i.e. crushed stone and river sand, on various properties of pervious concrete was studied. The fine aggregate to coarse aggregate ratio was as 1:5.720, compared to conventional pervious cement concrete mixes. Cement content were varied from 300 kg/m3 to 340 kg/m3 with an increment of 10 kg/m3. In total 10 different pervious concrete mixes was prepared considering each level of cement content and each type of fine aggregate. In addition steel fibers were used to increase the strength parameter. The effect of such variation on the properties of pervious concrete mixes was studied.

Erdem Damci.et.al., They characterized the fly ash and its effects on the compressive strength, properties of Portland cement. They finally indicated that fly ash samples in the ratio of 15% in clinker markedly increases the compressive strength value (61.1 N/mm2) at 90 days and decreasing the particle size of fly ash in blended Portland cement causes an increase in compressive strength. This means that fineness is a more effective parameter than chemical composition in improving the strength development of fly ash mortars and it is suggested that fine fly ash can be used to obtain higher compressive strength values.

O. Kayali, studied about Fly ash lightweight aggregates in high performance concrete and obtained that concrete produced using fly ash aggregates is around 22% lighter and at the same time 20% stronger than normal weight aggregate concrete. Drying shrinkage is around 33% less than that of normal weight concrete. Moreover, the aggregates possess high durability characteristics that are required for high performance in structures. There are numerous research and journals which clearly explains behavior of fly ash and its properties in concrete that can help and guide many research areas like addition of fly ash to improve soil fertility and crop yield production which requires proper basic knowledge of fly ash.

Rafat Siddique, studied the behavior of fly ash by replacing sand and obtained result which says that compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity of fine aggregate (sand) replaced fly ash concrete specimens were higher than the plain concrete (control mix) specimens at all the ages.

Charles Berrymana .et.al., studied fly ash replacement for cement in reinforced concrete pipe with the water reducing admixtures and the results revealed that the maximum 7 days compressive strength was observed for the replacement of 35% Class C and 25% Class F fly ash. An increase of 15 % in durability and strength tests is observed in the concrete mixes containing 65% replacement of cement by Class C fly ash.

Niyazi Ugur Kockal .et.al., reveals the utilization of fly ash by replacing coarse aggregates with fly ash and concluded that durable high-strength air-entrained lightweight concretes could be produced using sintered or cold-bonded lightweight fly ash aggregates having comparable performance with the normal weight concretes. Fly ash aggregate lightweight concretes and the normal weight concrete, being air-entrained, were all highly resistant to freeze and thaw cycles, with a minimum durability factor.

Ritesh Mall et al, In this Compressive Strength analysis of Paver Block with 0%, 5%, 10%, 15%, 20%, 25%, 30%, fly ash are tested and graph shown that at 25% fly ash is partially replaced with OPC 43 grade give higher strength as compared to conventional mix i.e., is 0%. Then at 25% fly ash give economic value as compared to conventional mix i.e., is 0%. Replacement of cement by Fly Ash up to 25% by weight has a negligible effect on the reduction of any physical and mechanical properties like compressive strength, flexural strength etc. There is limitation in addition of Fly Ash in concrete to maintain the workability of concrete. There are 10-20% reductions in cost with the addition of 25% fly ash in concrete. Use of Fly Ash in Paver block can solve the disposal problem, reduce cost and produce a greener Eco friendly Paver Blocks for pavement.

3. PROPOSED SYSTEM

The Eco-Pave system focuses on developing sustainable paver blocks by incorporating industrial waste materials such as Fly Ash and Waste Rubber as partial replacements for traditional concrete components. This system aims to enhance the mechanical properties of paver blocks while promoting environmental sustainability through efficient waste utilization.

1. Materials and Mix Design

- **Binders:** Ordinary Portland Cement (OPC) is partially replaced with 25% Fly Ash to reduce cement dependency and improve sustainability.
- **Coarse Aggregate Replacement:** Waste rubber replaces coarse aggregates at varying levels (0%, 5%, 10%, 15%, 20%, and 25%) to assess its impact on strength and durability.
- **Water-Cement Ratio:** Optimized to ensure sufficient workability while maintaining strength.
- **Admixtures:** Superplasticizers are used to enhance workability due to rubber's lightweight and non-absorbent nature.

2. Workability Assessment (Slump Test)

The slump test is conducted to evaluate the workability of paver block mixtures containing different percentages of waste rubber. The results show a gradual reduction in slump as rubber content increases, requiring adjustments in the mix to ensure proper compaction and finishability.

3. Hardened Properties Evaluation

- **Compressive Strength Test:**
  - Paver block specimens are cast and tested at 7, 14, and 28 days to assess strength development.
  - Results indicate that compressive strength decreases with increasing rubber content, but up to 15% replacement achieves satisfactory strength for non-structural applications.
- **Water Absorption Test:**
  - Water absorption is analyzed to ensure durability and resistance to weathering.
  - Rubber-based paver blocks show lower absorption due to rubber's hydrophobic nature.
- **Flexural Strength Test:**
  - The bending resistance of paver blocks is evaluated to ensure they meet load-bearing requirements for pedestrian and light traffic applications.

4. Key Findings

- **Optimal Performance:** Paver blocks with 15% waste rubber and 25% fly ash exhibit the best balance of strength, durability, and sustainability.
- **Workability Adjustment:** Increased rubber content reduces slump, requiring modified mix designs for proper casting.
- **Sustainability Impact:** The system significantly reduces cement and natural aggregate usage, lowering CO_2 emissions and promoting industrial waste reuse.
- **Application Feasibility:** Rubber and fly ash-based paver blocks are suitable for footpaths, parking areas, and low-traffic zones, offering an eco-friendly alternative to conventional concrete pavers.

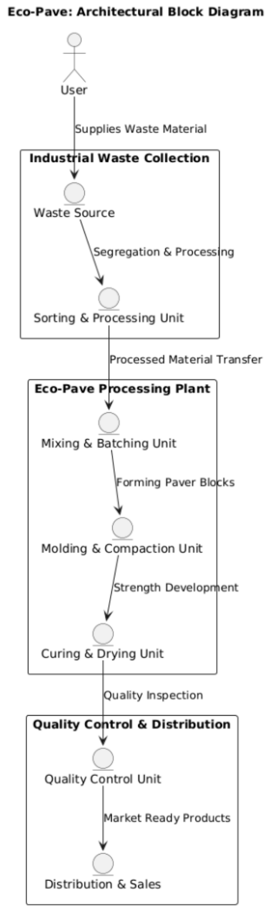

Figure 1 Presents the Block Diagram of Proposed System.

4. RESULTS AND DISCUSSIONS

As per experimental programmed results for different experiments were obtained. They are shown in table format or graph, which is to be presented in this chapter.

Table 4.1 Compression test results

Mix	Fly ash – crumb rubber (%)	Compressive strength (Mpa)		
		7 days	14 days	28 days

M1	0-0	21.7	31.0	34.8
M2	25 - 0	22.08	33.3	36.2
M3	25 – 5	25.26	36.5	40.1
M4	25 – 10	26.649	38.5	42.3
M5	25 – 15	27.7	42	45.4
M6	25 – 20	30	42.21	46.9
M7	25 -25	31.85	44.8	49
M8	25 - 30	28.5	40	47.5
M9	25 - 35	24.4	38.1	42.3

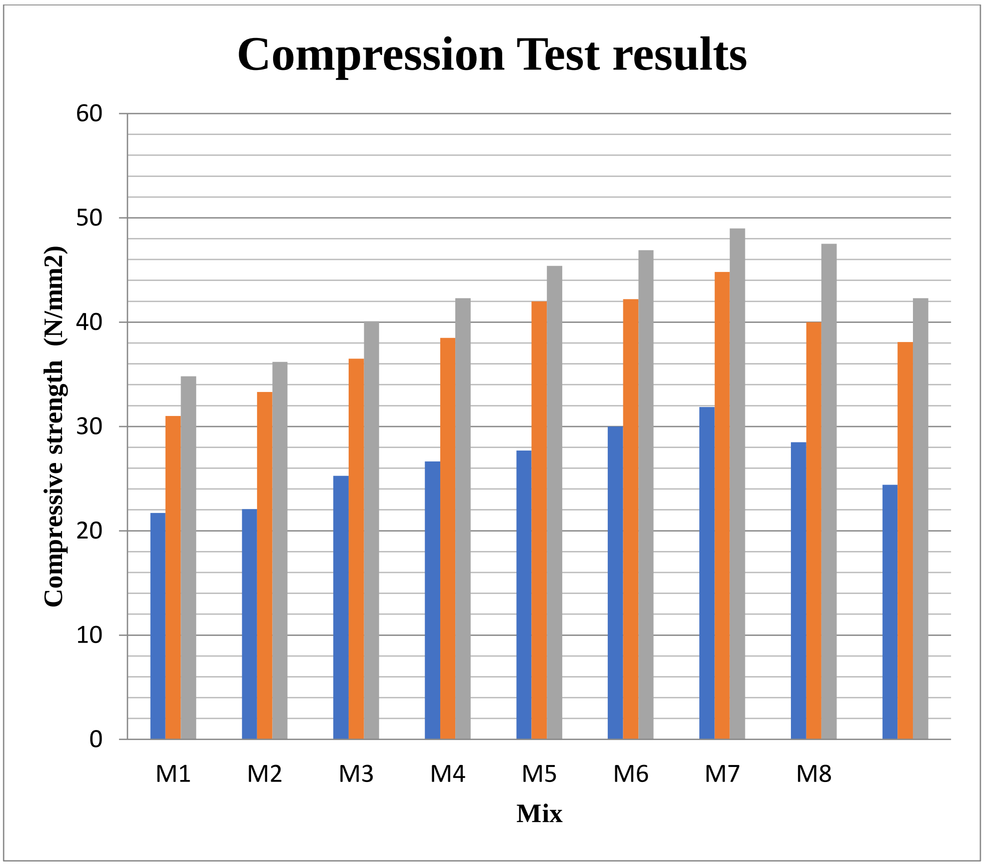

Fig 4.1 Compressive strength test results graph

The compressive strength is increasing with increasing in the crumb rubber as coarse aggregate replacement in the concrete Paver blocks preparation. The replacement of cement with fly ash (25%) and coarse aggregate with crumb rubber (Up-to 25%), the incremental concrete compressive strength comparison is mentioned below:

Table 4.2 Compression test results comparison

Mix	Fly ash – crumb rubber (%)	28 days Compressive strength (Mpa)	Increment / Decrement (%)
M1	0-0	34.8	-
M2	25 – 0	36.2	+4.02
M3	25 – 5	40.1	+15.23
M4	25 – 10	42.3	+21.55
M5	25 – 15	45.4	+30.46
M6	25 – 20	46.9	+34.77
M7	25 -25	49	+40.8
M8	25 – 30	47.5	+36.5
M9	25 – 35	42.3	+21.55

The compressive strength is higher for all different mixes as compare to the control mix of M1. The optimum dosage of Fly ash – crumb rubber (%) is 25 – 25 (%).

5. CONCLUSIONS

The Eco-Pave system successfully demonstrates the feasibility of utilizing industrial waste—specifically fly ash and waste rubber—in the production of sustainable paver blocks. Experimental results indicate that replacing cement with 25% fly ash and coarse aggregates with up to 15% waste rubber achieves a balanced mix with satisfactory compressive strength, durability, and workability for non-structural applications. While increasing rubber content reduces strength, optimized mix designs ensure that these paver blocks remain viable for footpaths, parking areas, and low-traffic zones. In addition to improving waste management, the Eco-Pave approach significantly reduces cement consumption, thereby lowering carbon emissions and promoting green construction. The study highlights that rubber and fly ash-based paver blocks not only support sustainable development but also offer cost-effective and eco-friendly alternatives to conventional concrete paving solutions. Future research can explore long-term durability, large-scale production feasibility, and alternative waste materials to further enhance the system's impact. By integrating industrial waste into construction, Eco-Pave contributes to a circular economy, reducing landfill dependency while promoting environmental responsibility in infrastructure development.

REFERENCES

[1]. IS 15658:2006, Precast concrete blocks for paving page, "Bureau of Indian Standard", New Delhi

[2]. Ritesh Mall, Sharda Shrama, Khalid Raza and Saurabh Dubey Study the properties of paver block by using waste material like Fly Ash. IJSRD - International Journal for Scientific Research & Development| Vol. 2, Issue 06, 2014 | ISSN (online): 2321-0613 [3] V. R. Patil, Prof. A. K. Gupta, Prof. D. B. Desai., 2011. "Use Of Pervious Concrete In Construction Of Pavement For Improving Their Performance" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684, PP: 54-56.

[3]. Ozlem Celika, Erdem Damcıa & Sabriye Piskin, "Characterization of fly ash and it effects on the compressive strength properties of Portland cement" Indian Journal of Engineering & Materials Sciences Vol. 15, October 2008, pp. 433-440.

[4]. O. Kayali, "Fly ash lightweight aggregates in high performance concrete", Construction and Building Materials 22 2393–2399, 2008.

[5]. Charles Berrymana, Jingyi Zhua, Wayne Jensena, Maher Tadros , "High-percentage replacement of cement with fly ash for reinforced concrete pipe", Cement and Concrete Research 35,108, 2005.

[6]. Niyazi Ugur Kockal , Turan Ozturan, "Durability of lightweight concretes with lightweight fly ash aggregates" , Construction and Building Materials 25 1430–1438, 2011

[7]. R.C. Yeole and Dr. M. B. Varma "Comparision of mix design of paver blocks using waste rounded steel aggregates and rubber pad" International Journal of Emerging Technology and Advance Engineering, ISSN 2250-2459, ISO 9001:2008, PP-523-527.

[8]. Ritesh Mall1 Sharda Shrama2 Prof. R.D.Patel3 , "Studies of the Properties of Paver Block using Fly Ash" IJSRD - International Journal for Scientific Research & Development| Vol. 2, Issue 10, 2014 | ISSN (online): 2321-0613

[9]. Khushboo Tiwari, An Experimental Study on Marble waste used in Paver Blocks, International Journal of Science and Research (IJSR) ISSN: 2319-7064 ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

[10]. Dr. Bhavin G Patel1 , Mohammed Hussain2, "Paver Block using Copper Slag and Plastic Waste" International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429 Volume 8 Issue IX Sep 2020- Available at www.ijraset.com

[11]. Aarti Ghude1 , Ram Kant2 , Parv Jaiswal3 ,Avish Dhomne4 ,Akash Thool5 ,Sanjal Nandanwar6 ,Neha Ghumde 7 ,Komal Bele 8, "UTILIZATION OF WASTE PLASTIC IN PAVER BLOCKS" Vol-5 Issue-2 2019 IJARIIE-ISSN(O)-2395-4396.

[12]. Mr. Neeraj Kumar Gupta, Dr. Ajay Swarup et al. 2017. "Use of Waste Tire Rubber in a partial replacement of aggregate in Concrete" ijariie.com vol-3 Issue-4 2017.

[13]. Mohammed Mudabheer Ahmed Siddiqui et al. 2016. "Study of Rubber aggregates in Concrete an Experimental Investigation" IJLRET Volume 02- Issue 12. December 2016. [15] Darshan H A, Puru V, Manjunath R, Naveen Kumar N V, Naveen B M et al. 2017. "An Experimental study on Rubberized Concrete" IJIRSET Vol. 6, Issue 7, July 2017.

[14]. T.C. Ling & Hasanan Md Nor "Properties of Crumb Rubber Concrete Paving Blocks with and without Facing Layer".

[15]. Xinyi Wang, Chee Seong Chin, Jun Xia et al. 2019. " Material Characterization for Sustainable Concrete Paving Blocks". MDPI Publications 21 March 2019.

[16]. Ratnadip Bhoi, Prof. R N Desai, Prof. B D Patel et al. 2016. "Double Layer Rubberized Concrete Paving Block". IJARIIE Vol-2 Issue-3 2016.

[17]. Partha Saika, Owais Mushtaq, A. Arunya et al.2016. "Experimental study of replacement of coarse aggregate by Rubber chips in Concrete". Sadgurupublications Int.J.Chem.Sci: 2016, 386-392.

[18]. P. Kirubagharan, R. Gowtham, Albert Duraisingh, Akshai B Nair et al 2017. "Experimental study on behavior of Paver Block using crushed rubber powder". IJCIET Volume 8, Issue, March 2017. IAEME Publications.

[19]. Rohit Sharma, et al. 2018. "Partial replacement of fine aggregate by waste tyre crumb rubber in concrete". IAEME Publications Volume 9, Issue 7, July 2018.

[20]. Shivradnyi Gaikwad, Sandesh Nalage, Namdev Nazare, Rajendra Joshi et al. 2019. "Use of rubber chips for the production of concrete Paver Block". IRJET Volume:06, Issue:03, March 2019.

[21]. Mufeed Sharholy, Kafeel Ahmad, Gauhar Mahmood, R.C.Trivedi. et al. 2007. "Municipal solid waste management in Indian cities- A review". Waste Management, www.elsevier.com/loacate/wasman. Science Direct. Published on 12 April 2007.

[22]. Utkarsh Patel 2019, " Solid waste management in India". ICRIER, New Delhi-4 th Janaury, 2019. CPCB, MoH&UA, Planning Comission. Task Force on Waste to Energy, Planning Commission.

[23]. Abhishek Nandan, Bikarama Prasad Yadav, Soumyadeep Baksi, Debajyoti Bose, et al. 2017. "Recent Scenario of Solid Waste Managemnet in India". World Scientific News, WSN 66 (2017) 56-74.

[24]. "Applications of Rubber in the concrete blocks". Canadian Science Publishing 2017. CPCB Board Annual Report