COMBINED EFFECTS OF WASTE CERAMICS AND WASTE FIBER METAL ON CONCRETE PAVEMENT

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ABSTRACT:- The manufacture of any kind of product produces waste. The ceramics industry in India came into existence about a century ago and has matured over time to form an industrial base. According to documents published "Ceramic Industry in India: A Trade Perspective", the Indian ceramic industry produces 2.5% of world's total products and is 3rd largest producer in the world. Among them only Gujarat produces 70% of total ceramic of India. This ceramic industry produces 5 to 10% of Ceramic Tiles Waste from total production. Rajkot has a strong manufacturing market contains small and medium industries like foundries, manufacture of oil engine, machine tools, engineering and automobile works, castor oil processing, gold and silver jewelry, handicrafts, readymade ladies garment, spices, medicines and wall clocks. A survey carried out in these industries reveals that waste production varies from 2 to 30% depending upon which type of ancillary received for the process. Ceramic industries are dumping these wastes in nearby pit or vacant space. This increases serious environmental pollution and occupation of the extensive land area. Waste Fiber Metal generated by industries are supplied to scrap vendors from which inferior quality of products are produced. Various researches have been done to find engineering properties and their effects on concrete with this waste separately. But research focuses on combined use of Ceramic Tiles Waste s and Waste Fiber Metal is not executed genuinely. No such provisions are made in International and Indian codes for utilization of these wastes and their consequences on pavement concrete.

Concrete is widely used in the construction of important projects in India. This leads to faster depletion of natural resources and increases the cost of construction of structures. It becomes necessary to search suitable alternative waste materials which could be used either as an additive or as a partial replacement to the conventional ingredients of concrete. This waste materials cause disposal crises and there by contributing to the environmental problems. So the use of waste in concrete has been done for safe and economical disposal of waste materials. The use of waste materials not only saves natural resources and dumping spaces but also it maintains a clean environment. Partial replacement of waste material in concrete is done to achieve the desired properties of concrete such as compressive strength, flexural strength, splitting tensile strength, durability and workability. In this research Ceramic Tiles Waste and Waste Fiber Metal are used as a substitute ingredient of concrete with a view to find combined effects of these wastes in pavement concrete.

1. INTRODUCTION

At present no construction activity is possible without using concrete. It is the most common material used in construction worldwide. The main reason behind this is because of its high strength, durability and workability. The total world consumption of concrete per year is about one ton for every living human being. Man consumes no materials except water in such tremendous quantities. Due to privatization and globalization, the construction of important infrastructure projects like Highways, Airports, Nuclear plants, Bridges, Dams etc. in India is increasing year after year. Such developmental activities consume large quantity of precious natural resources. This leads not only faster depletion of natural resources but also increase the cost of construction of structures.

In view of this, people have started searching for suitable other viable alternative materials which could be used either as an additive or as a partial replacement to the conventional ingredients of concrete so that the existing natural resources could be saved to the possible extent, and could be made available for the future generation. In this process, different industrial waste materials such as fly ash, blast furnace slag, quarry dust, tile waste, brick bats, broken glass waste, waste aggregate from demolition of structures, ceramic tiles, electronic waste of discarded old computers, TVs, refrigerators, radios, waste paper mill pulp, iron filling, waste coconut shell, rice husk ash, marble dust powder, hypo sludge, machine crushed animal bones, chicken feather, eggs shell, granite quarry sludge, palm oil fuel ash, copper dust, human hair etc. have been tried as a viable substitute material to the conventional materials in concrete.

II. LITERATURE REVIEW

Dr. Haider K. Ammash, et.al.[2]studiedon the possibilities Waste Glass of size up to 5mm as a fine aggregate in concrete. The waste glass was used as a partial weight replacement of sand with percentages of 10, 20, 30 and 40 %. They found that, waste glass aggregate can be satisfactorily substituted for natural fine aggregate at replacement levels up to 20%.

M. Iqbal Malik, et.al. [3] Studied the use of Waste Glass as partial replacement of fine aggregates in concrete. Fine aggregates were replaced by waste glass powder as 10%, 20%, 30% and 40% by weight for M-25 mix. The concrete specimens were tested for compressive strength, splitting tensile strength, durability and density at 28 days of age and the results obtained were compared with those of normal concrete. They discovered that 20% replacement of fine aggregates by waste glass showed 15% increase in compressive strength at 7 days and 25% increase in compressive strength at 28 days. Fine aggregates can be replaced by waste glass up to 30% by weight showing 9.8% increase in compressive strength at 28 days. With increase in waste glass content, percentage water absorption decreases. With increase in waste glass content, average weight decreases by 5% for mixture with 40% waste glass content thus making waste glass concrete light weight. Splitting tensile strength decreases with increase in waste glass content.

Gunalaan Vasudevan, Seri Ganis KanapathyPillay, [4] studied to investigate the effect of using Waste Glass Powder in concrete. Laboratory work was conducted to determine the performance of control sample and concrete with used waste glass powder. They concluded that concrete with using waste glass powder averagely had higher strength at 14 days but once the concrete reached at 28 days the control mix give more higher value compare to mix that contained waste glass powder but still give high value of the M 30 grade.

G.Murali, et.al. [5]concluded that the concrete with Steel Powder as waste material was found to be good in compression which had the compressive strength of 41.25% more than the conventional concrete. Better split tensile strength was achieved with the addition of the steel powder waste in concrete. The strength has increased up to 40.87% when compared to that of the conventional concrete specimen. In flexure the specimen with soft drink bottle caps as waste material was found to be good. While adding the soft drink bottle caps the flexural strength increased by 25.88% that of the conventional concrete.

Objectives

Following are the objectives of this research work:

- To evaluate the physical properties like specific gravity, water absorption, impact value, abrasion value, crushing value and chemical properties such as silicon dioxide, aluminium dioxide etc. of Ceramic Tiles Waste .
- To evaluate the physical properties like shape, length, thickness, density, appearance and chemical properties such as carbon, silicon, sulphur, magnesium etc. of Waste Fiber Metal.
- To replace the natural aggregate with cerarmic tiles waste and recron fiber with locally available Waste Fiber Metal for M25 grade to determine the optimum strength concrete mix by laboratory test and field test.
- To determine the compressive strength, splitting tensile strength and flexural strength of Waste Ceramic Metal Concrete (WCMC) and normal concrete of M25 grade in laboratory.
- To develop mathematical model for prediction of compressive strength of WCMC for M25 grade by Statistical/Mathematical tools.
- To investigate the temperature variations and curling for a stretch constructed on field for WCMC and normal concrete pavement of M25 grade on field condition.
- To determine the stress analysis by Finite Element based Software Tools for WCMC and normal concrete and their stress comparison at critical section for both WCMC and normal concrete of M25 grade.
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- To determine the compressive strength of core drilled from a constructed stretch of WCMC and normal concrete for M25 grade and compare it with normal concrete pavement to find the serviceability of pavement.
- To analyze cost benefit of WCMC per cubic meter per kilometer.

Material Sampling :-There are four major ceramic cluster in Vijayawada Modulu Ceramics Pvt Ltd Elurr Road ultra ceramics pvt ltd krishnalanka, sri Krishna tiles manufactures pvt ltd.., pantakalva road, Aparna enterprises ltd RR.Gardens.

Figure: 1 Prepared Ceramic Tiles and Insulator Wastes

Materials used for Mix Design Cement

Ordinary Portland cement (OPC) is the most important type of cement. After 1987 higher grade

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cements were introduced in India. The OPC was classified into three grades, namely 33 grade, 43 grade and 53 grade depending upon the strength of the cement at 28 days. The 28 days strength of cement for 33 grade, 43 grade and 53 grade is not less than 33N/mm2, 43N/mm2 and 53 N/mm2 respectively. But the actual strength obtained by these cements at the factory are much higher than the Indian Standard Specifications (38). Here, Ordinary Portland Cement of 53 grade was used. It was tested as per Indian Standard Specification IS 269-2015(39).

Fine Sand: Locally available natural sand available in krishna river region was used as fine aggregate. Its physical properties and sieve analysis was done confirming to Zone-III of IS 383-2015 are given in Table 17 and 18. As shown in Table 17 1.0 kg. of sand was taken to sieve analysis and its Fineness Modulus was 3.4.

Coarse Aggregate: Aggregate with 10 and 20 mm nominal size were used available from quarry near Vijayawada. Physical properties and sieve analysis were done according to criteria laid in the IS 383-2015 and it was shown in Table 14 and 15. Combined with 60% of 20mm size and 40% of 10mm size passing and comparison as per IS 383.

Ceramic Tiles Waste and Waste Fiber Metal

Waste ceramic collected from Morbi-Wankaner belt was used as a partial replacement of aggregate. Waste Fiber Metal collected from various industrial zones of Vijayawada City were examined for chemical composition and the chemical composition which found nearest , as it is directed in IS 1786-2008 was utilized for WCMC so as to avoid the reduction of concrete life. This waste metal fiber was used as a percentage by weight of concrete. Both the waste selected were usable in pavement concrete because their physical and chemical properties follows the criteria given in relevant Indian Standard Codes.

Water

Water is an important component of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked very carefully. Water was used for casting specimens and curing of pavement stretch conformed to the requirements of IS 456- 2000 (38).

Table: 1 Final Mix Proportion of Concrete

Materials	Qty./m3 (kg.)	Qty./Bag (kg.)
Cement	372.0	50.0
Water	186.0	25.0
Fine Aggregate (Sand)	642.0	86.3
20mm Aggregate	725.0	97.5
10mm Aggregate	484.0	65.0

Mix Composition: Based on the results of physical and chemical properties of both wastes with a range of 5% to Ceramic Tiles Waste and 0.10% on steel metal fibers 18 sets of cubes (Standard Size) of M25 grade were prepared for 28 days. These cubes are tested on compression testing machine (CTM) and from results of this pilot testing detailed testing with a narrow range of 1% on Ceramic Tiles Waste and 0.10% on steel metal fibers 66 sets of cubes of M25 grade were prepared.

Testing Procedure: After required period of curing, the specimens were taken out of the curing tank and their surfaces were wiped off. Besides measuring the fresh properties like workability, air content and concrete temperature following tests were performed on hardened concrete.

- Compressive strength (IS 516-2004 (41))
- Splitting tensile strength (IS 5816-2004 (42))
- Flexural Strength (IS516-2004)

Prediction of Compressive Strength using Mathematical Model:

Curve Fitting Toolbox of MATLAB was used for fitting curves and surfaces to data. The toolbox gives facility to perform exploratory data analysis, preprocess and post-process data, compare models, and remove outliers. It can conduct regression analysis using the library of linear and nonlinear models provided or specify given equations. The library provides optimized solver parameters and starting conditions to improve the quality required fits. The toolbox also supports nonparametric modeling techniques, such as splines, interpolation, and smoothing. After creating a fit, it is possible to apply a variety of post-processing methods for plotting, interpolation, and extrapolation, estimating confidence intervals, and calculating integrals and derivatives

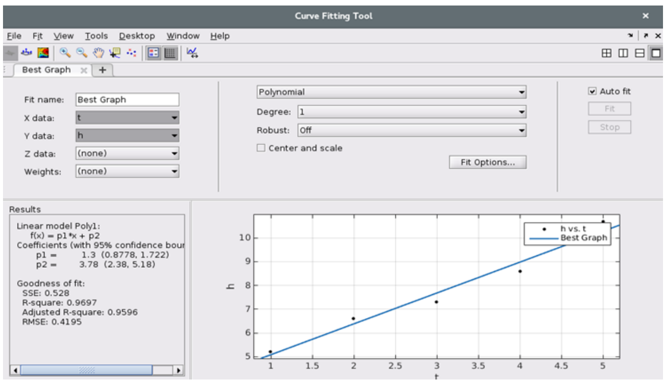

Figure: 2 Curve Fitting Tool Analysis

Table: 2 Compressive Strength of WCMC

Sr. No.	Days	Compressive Strength(N/mm2)
1	3	11.3
2	7	20.4
3	28	35.7
4	56	38.8
5	90	39.2

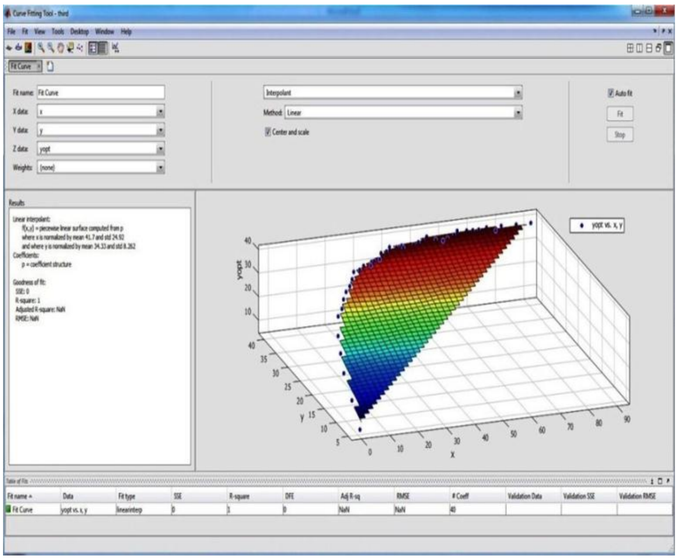

Figure: 3 Best Fit Curve by Exponential Regression for WCMC

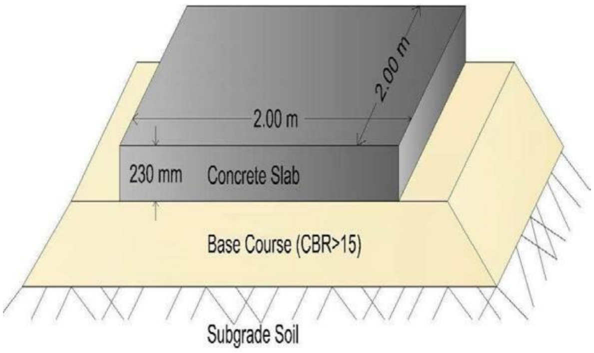

Figure: 4 Layout of Concrete Pavement Slab with Various Layers

Figure: 5 Waste required for Construction of WCMC

Figure: 6 Compaction with Needle Vibrator and preparation of Base Course

Figure7 Provision made for Measurement of Temperature at various Intervals

Figure: 8 Measurement of Pavement Curling with Extensometer

Field Test Temperature Variation :-To measure the temperature variation and curling of a stretch of 2m x 2m of pavement slab with normal M25 grade and with WCMC M25 grade were developed. The temperature was recorded at various critical locations throughout a day at every 2 hours interval. Critical locations HR (Horizontal Right), HL (Horizontal Left), C (Center), VL (Vertical Left) and VR (Vertical Right) were shown in Figure 9.

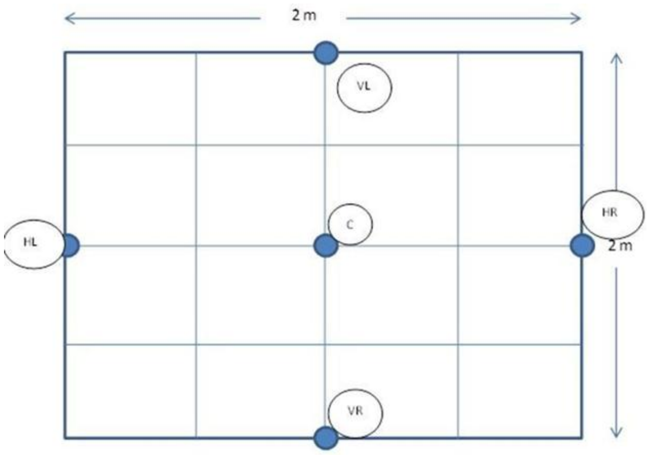

Figure: 9 Sketch showing location for temperature measurement

RESULTS AND DISCUSSION

Compressive Strength

To find out the optimistic compressive strength of WCMC a wide range of 20% to 50% replacement of waste ceramic and 0.30% to 0.50% of Waste Fiber Metal concrete was prepared. Six cubes with a range of 20%, 25%, 30%, 35%, 40%, 50% of Ceramic Tiles Waste and with 0.30% of Waste Fiber Metal were prepared. Similarly 6 cubes with 0.40% and 6 cubes with 0.50% Waste Fiber Metal were prepared. So, 18 cube sets of WCMC and 3 cube sets of normal concrete as a part of the pilot testing was casted and tested after 28 days on CTM of college laboratory. The 7 and 28 days compressive strength of cubes prepared with 25% to 35% of Ceramic Tiles Waste and 0.30% to 0.50% of Waste Fiber Metal as partial replacement of aggregate gives average 12% lesser compressive strength for 7 days and average 6% higher compressive strength for 28 days then the target mean strength of normal concrete for M25 grade.

Splitting Tensile Strength

Two sets of the standard size of the cylinder were casted with normal concrete to measure 7 and 28 days splitting tensile strength of concrete. With 30%, 31% and 32% of waste ceramic and 0.50% of Waste Fiber Metal four cylinders were casted with the equal combination for each to determined 7 and 28 days splitting tensile strength of concrete. Cylinders were properly cured and tested on CTM of college laboratory.

Flexural Strength

The cylinders which were casted for normal concrete and WCMC, same numbers of beams with the same combination of waste ceramic and Waste Fiber Metal were casted and cured. Beams were tested in manual operated flexural strength testing machine.

Result and Discussion (Field Condition) Field Test Temperature Variation: Temperature recording was started in summer season from 6:00 AM and it was measured at every 2 hours interval of 8:00 AM, 10:00 AM, 12:00 AM, 2:00 PM, 4:00 PM, 6:00 PM, 8:00 PM, 10:00 PM, 12;00 PM, 2:00 AM and 4:00 AM continuously. The depth of pavement slab was 230mm designed. So, temperature variations were taken at 0, 75, 150 and 230mm from top to bottom. The maximum temperature recorded was 45.4oC on top of VR section for WCMC at 4:00 PM which was shown in Table 34 while the maximum temperature observed on normal concrete was 46.1oC on top of VR section at 4:00 PM which was shown in Table 35. The minimum temperature recorded was 29.8oC on top of the surface of WCMC at 4:00 AM while the minimum temperature recorded was 29.9OC on a center top section of normal concrete in VR section.

Curling Measurement

Relative movement occurs in an upward and downward direction in concrete pavement because of variation in temperature throughout the day caused the curling in pavement slab. Both upward and downward curlings were measured by extensometer attached with aluminum frame.

Stress Analysis by Kenpave

Various parameters which were required to design of concrete pavements were properly analyzed. Here in this research concrete pavement for WCMC and normal concrete for M25 grade were casted and data required for this rigid pavement stress analysis such as type of foundation, number of layers, difference in temperature, co efficient of thermal expansion, thickness of slab, Poission's ratio, Youngs modulus, Modulus of subgrade reaction etc. were fed up and where it was required suitable data was assumed according to condition actual prevailed at casted site.

Results of Core Test for Hardened Concrete

Testing of hardened concrete plays a major role in controlling and confirming the quality of cement concrete works. Core test of hardened concrete is essential to identify and validate the compressive strength, and sometimes it becomes distinctive device to for accessing safety of concrete structure. Here in this research Six cores for each WCMC and normal concrete was drilled and it was prepared as per guidelines are given in IS 516-2004. Height of each core was measured, and their H/D ratio was measured according to that correction was applied. At the same time weight of each core was measured as shown in Plate 36, so with known volume, density was determined. To determine the compressive strength of cores it was tested on CTM of college laboratory, as shown in Plate 37. Observed strength after applying a correction factor of H/D ratio was measured. From that equivalent cubical compressive strength of calculated as per guidelines of IS

516-2004 and it was compared with 85% cube compressive strength as according to guidelines of IS 456- 2000.

CONCLUSION

Physical and Chemical Properties

Physical properties such as specific gravity, water absorption, impact value, abrasion value and the crushing value have shown better result for Ceramic Tiles Waste than that of ceramic insulators waste collected from various industrial areas of Krishna District.

Waste Fiber Metal collected from five different industrial zones of vijayawada City tested for chemical properties includes carbon, silicon, magnesium, sulphur, phosphorous in collage laboratory shown compatible results and it can be presumed that chemical composition required as per IS 1786-2008 are easily available from this Waste Fiber Metal which can be used as a part of fibrous concrete.

Specific gravity of normal aggregate was 2.94 while specific gravity of Ceramic Tiles Waste was found maximum 1.68. So, the percentage difference seems 57% declines and it can be concluded that with the use of this waste it is possible to produce light weight concrete.

Compressive Strength

The compressive strength of concrete mix increased due to partial replacement of waster ceramic and Waste Fiber Metal. So, compressive strength observed for M25 grade was appropriate for pavement concrete.

Based on the studies conducted on strength characteristic of WCMC using both waste materials it was found that concrete made with partial replacement of aggregate shows good compressive strength. The 7 and 28 days compressive strength of cubes prepared with 25% to 35% of Ceramic Tiles Waste and 0.30% to 0.50% of Waste Fiber Metal as partial replacement of aggregate gives average 12% lesser compressive strength for 7 days and average 6% higher compressive strength for 28 days then the target mean strength of normal concrete for M25 grade. It is also observed that by narrowing the percentage of waste in WCMC from 29% to 32% of Ceramic Tiles Waste and 0.30% to 0.50% of Waste Fiber Metal as partial replacement of aggregate gave consistent result in compressive strength which was very near to target mean strength of M25 grade concrete. It was found that waste in WCMC at 31% of Ceramic Tiles Waste and 0.50% of Waste Fiber Metal the compressive strength is 35.7 N/mm2 for 28 days which was approximately 13.0% higher that target mean strength of M25 grade of concrete.

Splitting Tensile Strength

It was observed that with 31% of waste ceramic and 0.5% of Waste Fiber Metal the splitting tensile strength for 7 days increases 8.39% than that of normal concrete. It was observed that with 31% of waste ceramic and 0.5% of Waste Fiber Metal the splitting tensile strength for 28 days increases 10.02% than that of normal concrete. According to ACI (American Concrete Institute), the estimated splitting tensile strength for M25 grade of concrete is about 3.15 N/mm2 and maximum observed splitting tensile strength for WCMC is 3.42 N/mm2.

Flexural Strength

It was observed that with same combination of wastes the flexural strength for 7 days increases by 17.4% than that of normal concrete. It was also observed that with same combination of wastes the flexural strength for 28 days increases by 5.33% than that of normal concrete. As per IS 456-2000 the flexural strength of M25 grade of concrete is 3.94 N/mm2 and observed maximum flexural strength for WCMC is 4.34 N/mm2.

Prediction of Mathematical Model for Compressive Strength

It was observed that mathematical model prepared by MATLAB computer program, the difference in the predicted compressive strength of WCMC was minimum 0.55% and the maximum is 4.5% to that actual compressive strength. It had also observed that the value of the coefficient of determination R2 is 99.16% with exponential regression. Hence, it can be concluded that mathematical model derived by the exponential regression gives better curve fit for WCMC. So, it was possible to predict nth day compressive strength of WCMC with this mathematical model.

Temperature Stress and Curling

If the temperature of the upper surface of the pavement slab is higher than the bottom surface, then top surface tends to expand, and the bottom surface tends to contract to result in compressive stress at the bottom, tensile stress at the top and vice versa.

During midday of summer, the surface of the slab, which is exposed to the sun, warms faster than the subgrade which is relatively cool. During night time the surface of the slab becomes cool when compared to the subgrade.

It was noticed that the maximum temperature was 45.4oC on the top of pavement concrete made by WCMC and minimum temperature was 29.8oC on the top of WCMC, while maximum temperature was 46.1oC on the top of pavement concrete made by normal concrete, and minimum temperature was 29.9oC on the top surface of the normal concrete.

Cost Benefit Analysis

As the ultimate aim in this research was to use the Ceramic Tiles Waste and Waste Fiber Metal in pavement concrete for its safe disposal with economic fabrication of M25 grade of concrete which was suitable to provide sustainable service. For this research 31% of Ceramic Tiles Waste was used as a partial replacement of 10mm and 20mm aggregates. At the same time 0.5% of Waste Fiber Metal was used as a percentage by weight of concrete. Thus, an aggregate which is a part of natural resources was conserved and reduced the cost of concrete and Waste Fiber Metal was introduced which increased the cost of concrete.

Availability and Usability of Waste Product

As it was found that WCMC needs 12 kg. of Waste Fiber Metal and approximately 560 kg. of Ceramic Tiles Waste of one cubic meter of concrete for pavement construction. It was also learnt from industry to industry visit that Vijayawada City itself generating about 50 to 500 tonnes of Waste Fiber Metal scrap daily depending upon slack to peak season, while it was also observed that about 5100 tonnes of ceramic tiles waste were generated annually by krishna District in the country.

It was estimated that approximately 210 cubic metre of pavement concrete is necessary for one taluka of A.P State per year. There are about 250 talukas in A.P. So, about 0.53 lakh cubic metre of pavement concrete approximately required to construct roads. Considering these data about 22% of wastes are available of total requirements for construction of WCMC.

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