# Replacement of Waste Material in Concrete using Recycled Plastic

**M. Prakash, B. Hemalatha**

***Abstract:*** ***Disposal of waste plastic has become a major environmental issue in all parts of the world. Every year millions plastic are discarded, thrown away or buried all over the world, representing a very serious threat to the ecology. It is estimated that every month almost 100000 million plastic waste end their service life and more than 50% are discarded without any treatment. This experimental study was based on the utilization of waste plastic as a partial substitute for natural fine aggregates in cement concrete. The properties of concrete like compressive strength, flexural tensile strength, abrasion resistance, pull-off strength, water permeability, water absorption, resistance to acid attack and sulphate attack, carbonation, depth of chloride penetration, corrosion of steel reinforcements were tested and SEM test was performed to study the micro structure.***

***Keywords: Plastic Aggregate: Fine Aggregate, Partial Replacement.***

## I. INTRODUCTION

Solid waste disposal is a worldwide problem. With urbanization, industrialization and technological innovations in different fields, large amount and variety of solid waste materials have been generated by the industrial, agricultural, mining and domestic activities. Fly ash, marble sludge waste, incineration ash, rice husk-bark ash, bagasse ash, bottom ash, stone wastes, ceramic waste, copper slag, agricultural wastes, copper tailings, carbon steel slag, coal waste, mine waste, construction and demolition waste, ceramic waste, foundry slag, limestone waste, wood ash, furnace slag, welding slag, phosphor gypsum slag, ISF slag, wollastonite, waste plastic etc, are some of the examples of solid waste materials that pollutes the environment.

Due to the huge increase in the population and the uplift in the living standards of people, there was a big growth in the number of vehicles. As a result of this, lots of plastic are ending as waste every day. Disposal of waste plastic has become a major environmental issue in all parts of the world. It was estimated that 1.5 billion plastic are manufactured in the world per day every year millions of plastic are discarded, thrown away or buried all over the world, representing a very serious threat to the ecology. It is estimated that every year almost 100000 million plastic end their service life and out of that, more than 50% are discarded to landfills or garbage, without any treatment. By the year 2030, the number would reach to 12000000 million yearly. Including the stockpiled plastic, there would be 50000000 million plastic to be discarded on a regular basis If the Indian scenario is considered, it is estimated that the total number of discarded plastic would be 1120 million per month after retreading The Discarded municipal plastic which are disposed to landfills constitute one important part of solid waste. The plastic are bulky and 75% space that a occupies is void and these spaces provide the potential sites for the breeding of rodents. There is a tendency for the plastic to float or rise in a land-fill and come to the surface Stockpiled plastic also present many types of, health, environmental and economic risks through air, water and soil pollution. The plastic store water for a longer period because of its particular shape and impermeable nature providing a breeding habitat for mosquitoes and various pests. Use of discarded plastic as a fuel has been banned due to environmental issues

Plastic burning, which was the easiest and cheapest method of disposal, causes serious fire hazards. Temperature in that area rises and the poisonous smoke with uncontrolled emissions of potentially harmful compounds is very dangerous to humans, animals and plants. The residue powder left after burning pollutes the soil. Once ignited, it is very difficult to extinguish as the 75% free space can store lot of free oxygen. Plastic melt due to the high temperature and generate oil that pollutes soil and water. It was reported that a serious fire hazard happened in Wales on an area where 1000 million plastic were dumped. The plastic have been burning continuously for at least 15 years causing serious health and environmental problems

For the last some years, construction industry is taking up the challenge to incorporate sustainability in the production activities by searching for more environmental friendly raw materials or by the use of solid waste materials as aggregates in concrete. One of the possible solutions for the use of waste plastic is to incorporate into cement based materials, to replace some of the natural aggregates. This attempt could be environmental friendly (as it helps to dispose the waste plastic and prevent environmental pollution) and economically viable as some of the costly natural aggregates can be saved

## II. THE OBJECTIVES OF THIS RESEARCH WORK ARE AS FOLLOWS

1. If we can use plastic as a partial substitute for aggregates in concrete, the environmental pollution caused by the discarded plastic can be prevented to a great extend.
2. Lot of the natural fine aggregates can be saved due to the substitution with the waste plastic in concrete.
3. This could be an effective method to dispose the discarded plastic.
4. The cost of construction project can be reduced by reducing the use of the costlier natural fine aggregates.
5. A light weight concrete that can be used for some specific works can be developed.

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6. The waste accumulation, that destroys the natural beauty can be prevented to a great extend.

Mix design procedure

In order to achieve the best proportions of the constituent materials, trial mixes were cast and tested at every step.

(a) The grade of concrete (for severe exposure condition) was fixed as M30. OPC 43 grade cement conforming to IS 8112 was selected. Maximum size of

Aggregates was 20 mm. Minimum cement content was 320 kg/m$^3$ and maximum was 450 kg/m$^3$. Maximum water-cement ratio as per IS 456:2000 was 0.45.

(b) The water-cement ratio was fixed as 0.40 and target strength for M30 grade obtained as 38.25 N/mm$^2$. The water content was fixed based on the trial mixes using super plasticizer. Water content divided by water-cement ratio gives the cement content. It should be greater than the minimum content as specified in the code.

(c) The volume of aggregate was divided into fine aggregates and coarse aggregates. As per the sieve analysis, the coarse aggregate were divided to 20 mm (60%) and 10 mm (40%). They are mixed in a proportion in a way that the final gradation matches with that given in IS: 383-1970 for 20 mm well graded aggregates.

(d) Thus, the mass of constituent materials (cement, water, aggregate and chemical admixture) for one cubic meter concrete was obtained.

Trial mix was done to check for workability and compressive strength (3 days and 7 days)

Mixture proportions of fresh concrete (control mix) with w/c 0.4, 0.45 and 0.5

| Water-cement ratio | Cement kg/m | Water kg/m | Coarse Aggregate 10 mm kg/m$^3$ | Coarse Aggregate 20 mm kg/m$^3$ | Fine Aggregate kg/m$^3$ | Admixture % |
|---|---|---|---|---|---|---|
| 0.4 | 388 | 155 | 465 | 737.2 | 698.4 | 0.65 |
| 0.45 | 388 | 174.6 | 465 | 737.2 | 698.4 | 0.3 |
| 0.5 | 388 | 194 | 465 | 737.2 | 698.4 | 0 |

**TESTING OF CONCRETE IN FRESH STAGE**

## III. WORKABILITY OF CONCRETE BY COMPACTING FACTOR TEST

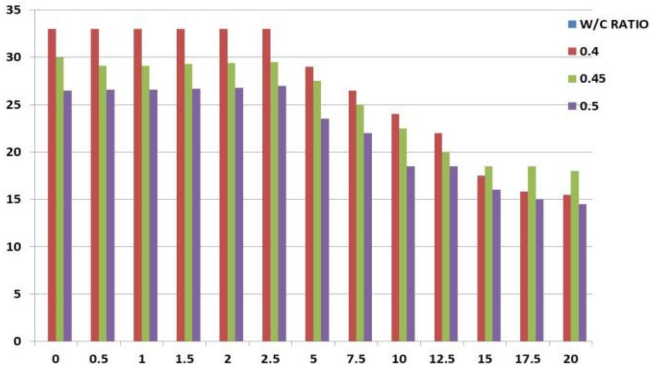
Workability of concrete was determined by compacting factor test. This test was preferred to slump test because it gives more precise results in case of low water-cement ratios. It consists of two hopper vessels A and B with a hinged bottom and a bottom cylinder, C. After cleaning and oiling the three vessels, the vessel A was filled with concrete sample. The hinge door of A was opened and concrete falls in to vessel B. Hinge door of B was opened, so that concrete falls to cylinder, C. The surplus concrete in the cylinder was struck off with steel float and the weight of concrete W1 was calculated as the weight of concrete with cylinder minus the weight of the empty cylinder. The cylinder with concrete was vibrated to have full compaction and concrete was filled completely. New weight W2 was taken by the weight of fully compacted concrete with cylinder minus the empty weight of cylinder. Compacting factor = W1/W2

| % of Plastic | 0 | 2.5 | 5 | 7.5 | 10 | 12.5 | 15 | 15.5 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| w/c=0.4 | 0.95 | 0.95 | 0.96 | 0.98 | 0.97 | 0.97 | 0.96 | 0.98 | 0.97 |
| w/c=0.45 | 0.95 | 0.94 | 0.94 | 0.95 | 0.96 | 0.95 | 0.95 | 0.95 | 0.94 |
| w/c=0.5 | 0.95 | 0.95 | 0.95 | 0.96 | 0.96 | 0.95 | 0.95 | 0.95 | 0.96 |
| w/c=0.3 | 0.94 | 0.94 | 0.95 | 0.94 | 0.95 | 0.94 | 0.94 | 0.95 | 0.94 |

### A. Compressive Strength

The compressive strength of the specimens was taken after 7, 28 and 90 days of curing. The variations in the compressive strength with respect to their water-cement ratios and with respect to the percentage of crumb plastic are taken. The limit for compressive strength was kept as 30N/mm$^2$ for M30 grade concrete and 60 N/mm$^2$ for M60 grade concrete. 100mm concrete specimens were used as per IS: 516-1959, clause 2.8.Crumb Plastic was partially substituted for fine aggregates by weight from 2.5% to 20% in multiples of 2.5%. Water-cement ratios of 0.45 and 0.5 were also studied. In the case of water-cement ratio 0.45, the amount of water was 174.6 kg/m$^3$ and admixture was 0.3% by weight of cement. In the case of water-cement ratio 0.5, the amount of water was 194.0 kg/m$^3$ and no admixture was used.

In the compressive strength, flexural tensile strength and pull-off strength tests, gradual decrease in strength was noticed as the amount of crumb plastic was increased in concrete. The reduction in compressive strength of the mix with 20% crumb plastic was more than 50% than the value of the control mix. The reduction in flexural strength for the mix with 20% crumb plastic was only 25-27% for all the mixes when compared to the control mix. Results obtained from the Pull-off strength followed the similar pattern of that of the compressive strength




### B. Abrasion Test

From the abrasion test, it was observed that the plasticized concrete specimens showed better resistance to abrasion when compared to the control mix specimens.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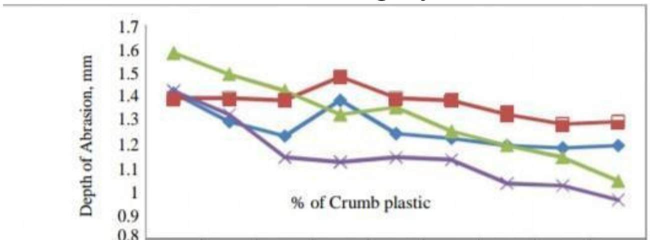
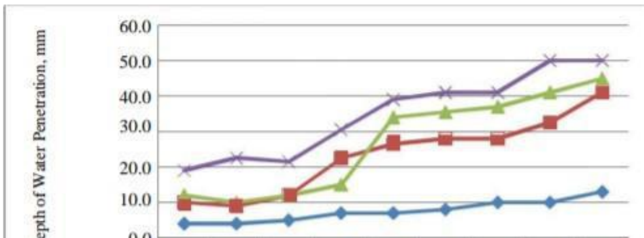
During the abrasion test, the crumb plastic particles present in the plasticized concrete have projected beyond the smooth surface of the concrete and restricted the grinding/rubbing of the concrete surface by acting like a brush. This minimized the action of abrasive powder on the surface of concrete and hence the plasticized concrete became more resistant to abrasion when compared to the control mix The plastic particles can improve the abrasion resistance of concrete, and this can ensure its application in pavements, floors and concrete highways, or in places where there are abrasive forces between surfaces and moving objects




| | 0 | 2.5 | 5 | 7.5 | 10 | 12.5 | 15 | 17.5 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| W/C=0.4 | 1.41 | 1.29 | 1.23 | 1.38 | 1.24 | 1.22 | 1.19 | 1.18 | 1.19 |
| W/C=0.45 | 1.39 | 1.39 | 1.38 | 1.48 | 1.39 | 1.38 | 1.32 | 1.28 | 1.29 |
| W/C=0.5 | 1.58 | 1.49 | 1.42 | 1.32 | 1.35 | 1.25 | 1.19 | 1.14 | 1.04 |
| W/C=0.3 | 1.42 | 1.32 | 1.14 | 1.12 | 1.14 | 1.13 | 1.03 | 1.02 | 0.96 |

### C. Water Penetration Test

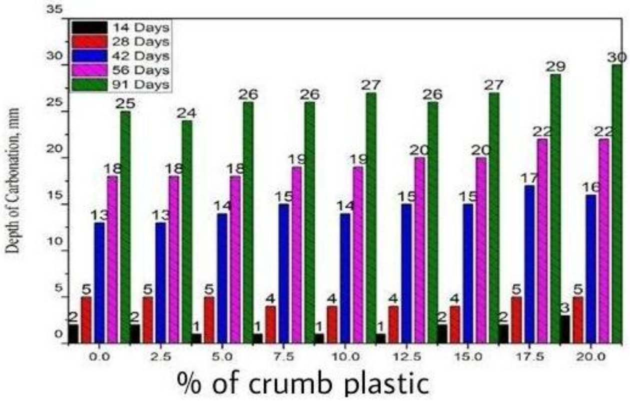
From the water penetration test of concrete, gradual increase in the depth of penetration was noticed, as the amount of crumb plastic was increased from 0% to 20%. The enplastic concrete mixes with w/c 0.4, 0.45 and 0.5 exhibited low to medium permeability, while all the mixes with w/c 0.3 exhibited low permeability From the results of water absorption test, it was clear that the control mix specimens absorbed more water than the plasticized concrete up to 7.5% substitution with crumb plastic for the series with w/c 0.3, 0.4 and 0.45. Minimum water absorption was noticed for the mixes with 7.5% crumb plastic. Beyond 12.5% substitution, there was slightly higher amount of water absorption as compared to the control mix concrete specimens. Similar results were obtained in the chloride ion penetration test




| | 0 | 2.5 | 5 | 7.5 | 10 | 12.5 | 15 | 17.5 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| W/C=0.3 | 4.0 | 4.0 | 5.0 | 7.0 | 7.0 | 8.0 | 10.0 | 10.0 | 13.0 |
| W/C=0.4 | 10.0 | 9.0 | 12.0 | 22.5 | 26.5 | 28.0 | 28.0 | 32.5 | 41.0 |
| W/C=0.45 | 12.0 | 10.0 | 12.0 | 15.0 | 34.0 | 35.5 | 37.0 | 41.0 | 45.0 |
| W/C=0.5 | 19.0 | 22.5 | 21.5 | 30.5 | 39.0 | 41.0 | 41.0 | 50.0 | 50.0 |

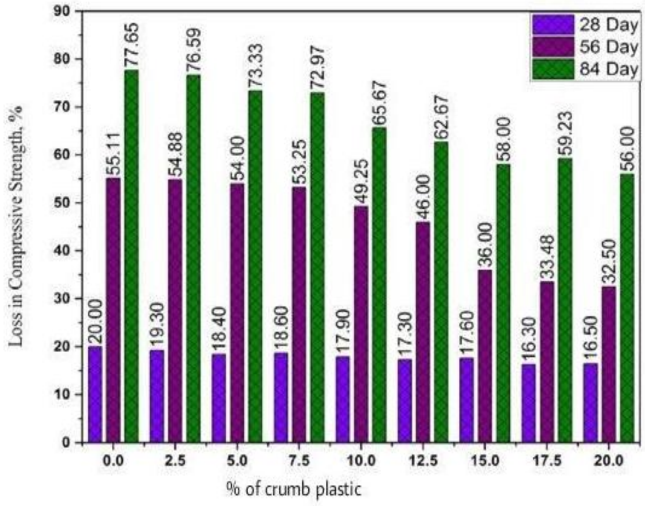
### D. Carbonation Test

From the results of carbonation test, we could notice that the depth of carbonation of the concrete mixes in which crumb plastic was substituted from 2.5% to 12.5% were lesser than or equal to that of control mix concrete in case of w/c 0.4 and 0.3. Minimum depth was observed in the specimens with 7.5% - 10% crumb plastic. But in the case of water-cement ratio of 0.45 and 0.5, there was gradual increase in the amount of carbonation as the amount of crumb plastic is increased.




### E. Acid Attack Test

From the acid attack test, it was noticed that the loss in compressive strength and weight of concrete specimens was higher in the control mix and was minimum for the mixes with 20% crumb plastic. The crumb plastic particles prevented the separation of constituent particles of concrete by tightly holding it. So the concrete with more crumb plastic were more resistant to the loss in compressive strength and loss in weight. The water absorption of acid attacked plasticized concrete was higher than that of the control mix at 28, 56 and 84 days




### F. Sulphate Attack Test

In sulphate attack test, more reduction in compressive strength was observed with the increase in the percentage of crumb plastic and with increase in water-cement ratio. Loss in weight up to 0.59% was observed for sulphate attacked specimens with more amount of crumb plastic, by the end of 182 days of immersion. From the results of corrosion test, as all the readings obtained in the macrocell corrosion test were less than 10 µA, we could conclude that there is no presence of sufficient corrosion in the specimens even at 182 days of ponding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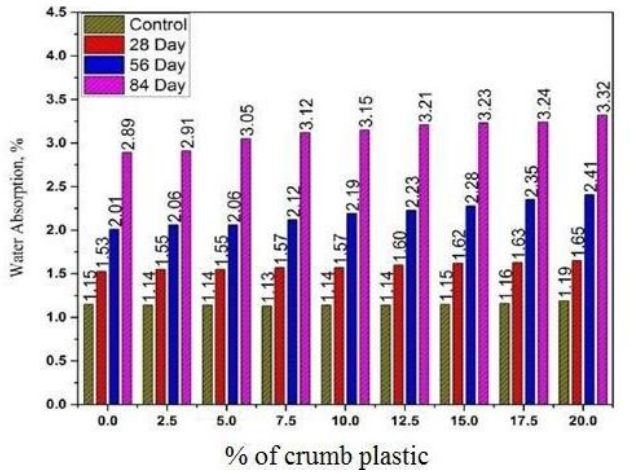
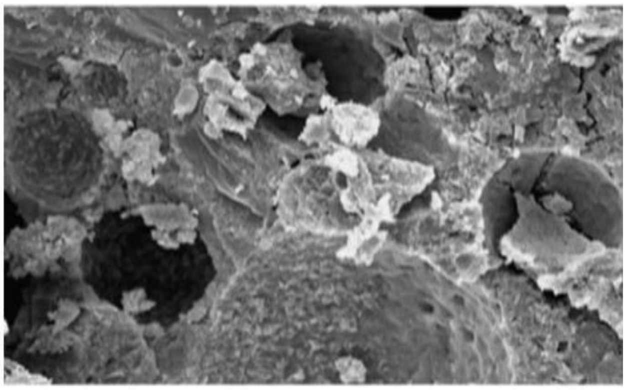



## G. Microstructure By SEM

Scanning Electron Microscopy tests were done on concrete specimens (taken as mentioned in the methodology) to study morphology and micro structural properties of the material. SEM images taken on the various constituent materials are given in a series on Figures: Image of cement in silica fume crumb plastic and course aggregate (river sand) passing through the 300 µm sieve were given in Figures respectively. The SEM image of concrete with and without crumb plastic are given in Figures When we observe the images of concrete specimens given in (images taken after 90 days of casting of concrete specimens), it appears that the cracks are running through cement stone (i.e. hydrated cement paste), not through aggregates. Crack formation through aggregate is generally observed with lightweight aggregate, where the strength of the aggregate is lower than that of hydrated cement. The clam shaped cavities suggest that crumb plastic delaminates from cement stone, so the bond between them is weak. Moreover, there are cracks and voids to note around plastic particles at the interface of the crumb plastic and cement paste, which reflects the weak bond between the crumb plastic and cement mortar leading to reduced compressive strength of concrete. The flexibility of plastic particles entails some degree of ductility to concrete, but ultimately weakens the matrix. From Figures 4.70 to 4.74, we can observe that there are more voids in the concrete as the amount of crumb plastic was increased. The images of concrete with 10% crumb plastic and that with 20% crumb plastic clearly shows that there was lack of internal packing in the concrete with 20% crumb plastic. It could be understood that the difference between the two w/c ratio samples (0.4 and 0.3) are seen as less dense structure with more cracks for the higher water/cement ratio sample. This is explained by the fact that the stoichiometric water demand of cement paste is satisfied by adding as little water as that represented by 0.3 w/c ratio, with any excess only generating voids and space in concrete, and this could be one parameter for the lower density and strength. The images of control mixes with 0.4 and 0.3 w/c ratios (Figures 4.70 and 4.74) demonstrate this difference in the achieved density very well.



## H. Modeling

It discusses of ABAQUS/Standard is a general purpose finite element program designed specifically for advanced structural and heat transfer analysis. It is designed for both nonlinear and linear stress analysis of both very small and extremely large structures. The element library provides a complete geometric modeling capability. Solids in one, two, and three dimensions as well as shells, beams, pipes and pipe bends with deforming sections, cables etc. can be modeled using first, second or third order interpolation. The multilevel sub structuring capability is another useful facility. The material library contains several different constitutive models, for example, linear and non-linear elasticity, rubber, plasticity, concrete, sand, soils, acoustic etc. ABAQUS has a built-in automatic and adaptive choice of time instrumentation. This approach provides uniform accuracy throughout the solution history and is in most cases significantly more efficient and practical than user controlled fixed time instrumentation

In this modeling vertical stress are calculated for five concrete mixes of M30 grade o concrete for different percentages of concrete and waste plastic. Abaqus has been used for modeling and analyzing the stress in this modeling we chose the two paths has been considered. In path one denotes the vertical path passing through centre of one of loading pressure in centre and edge loading pattern of two circular loading pressure centre of one of them. In second path denotes the vertical path passing the midpoint of two loading pressure in centre and edge loading while it is centre point in corner loading

In this software young modulus, Poisson ratio are used for calculate the stress model has been carried out for pavement construction for this IRC 37-2012 and IRC 58-2002 are used in which S11 denote the stress in Sxx direction. In S22 denote the stress in Syy direction. In S33 denote the stress in Szz direction for all different concrete mixes the stress are calculated for the vertical direction of the pavement and law of proposition has been compared for manually and systematically

Modeling has been done for slab size 3.5m x 3.5m there was three layers top layer was concrete slab bottom two layers was soil has been considered by applying the load mesh image has been created for every individuals vertical direction of pavement at the edge an centre XY Date different stress of vertical direction of the pavement has been recorded and by using visualization path has been created from this values stress has been calculated and compared and it has been analyses using abaqus software and graph has been drawn.

**DATA REQUIREMENTS FOR MODELLING IN ABAQUS**

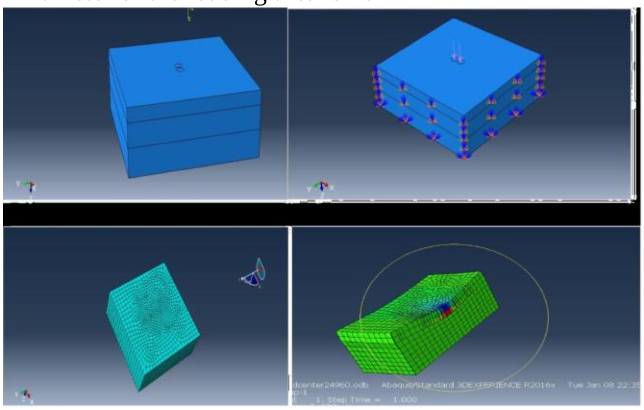
| M 30 Gread Concrete | Percentage of Concrete | Percentage of Plastic | Taken Modulus Value For Concrete | Modulus Taken For Soil Layers (1&2) |
|---|---|---|---|---|
| Mix 1 | 0.975 | 0.025 | 26780 | 61.15 |
| Mix 2 | 0.95 | 0.05 | 26175 | 61.15 |
| Mix 3 | 0.9 | 0.1 | 24960 | 61.15 |
| Mix 4 | 0.85 | 0.15 | 23750 | 61.15 |
| Mix 5 | 0.8 | 0.2 | 22530 | 61.15 |

POISSONS RATION
FOR CONCRETE = 0.2 IRC 58-2002 IS USED
FOR SOIL = 0.25 IRC 37-2012 IS USED
S11 denotes stress - Sxx DIRECTION
S22 denotes stress - Syy DIRECTION
S33 denotes stress - Szz DIRECTION

Path 1 denotes the vertical path passing through center of (one of) loading pressure [In center and edge loading pattern of two circular loading pressure-center of one of them] Path 2 denotes the vertical path passing through the midpoint of two loading pressures in center and edge loading case, while it is corner point in corner loading case.

Top layer
Middle layer
Bottom layer

Wheel loading pressure given in one circular area is 560 Kpa or 0.560 N/mm2 and tyre load is 20000N
Diameter of the loading area is 107 mm



## IV. CONCLUSION

- From the compacting factor test conducted on the concrete with and without crumb plastic, it was observed that all the values were in the range of 0.94 to 0.98. Addition of crumb plastic did not affect the workability of concrete. There was no need to increase or decrease the quantity of the super plasticizer as the crumb plastic was added to the concrete.
- In the compressive, flexural tensile and pull-off strength tests, gradual decrease in strength was noticed as the amount of crumb plastic was increased in concrete. The compressive and pull-off strength of the mix with 20% crumb plastic reduced by more than 50% compared to the control mix. The reduction in flexural strength for the same mix was only 25-27% when compared to the control mix.
- From the abrasion test, it was observed that the plastic concrete specimens showed better resistance to abrasion when compared to the control mix specimens. During the abrasion test, the crumb plastic particles present in the plastic concrete had projected beyond the smooth surface of the concrete and acted like a brush limiting the grinding/rubbing. This minimized the action of abrasive powder on the surface of concrete and hence the plastic concrete was more resistant to abrasion compared to the control mix.
- From the water penetration test of concrete, gradual increase in the depth of penetration was noticed, as the amount of crumb plastic was increased from 0% to 20%. All the concrete mixes with water-cement ratios of 0.4, 0.45 and 0.5 exhibited low to medium permeability, while those with a water-cement ratio of 0.3 exhibited low permeability.
- From the carbonation test, it was noticed that the depth of carbonation of the concrete mixes in which crumb plastic was substituted from 2.5% to 12.5% were lower than or equal to that of control mix concrete in the case of water-cement ratios of 0.4 and 0.3. Minimal depth of carbonation was observed in the specimens with 7.5% - 10% crumb plastic. But in the case of water-cement ratio of 0.45 and 0.5, there was gradual increase in the depth of carbonation as the amount of crumb plastic is increased.
- From the acid attack test, it was noticed that the loss in compressive strength and weight of concrete specimens were higher in the control mix and was minimum for the mixes with 20% crumb plastic. The crumb plastic particles prevented the separation of constituent particles of concrete by tightly holding it. So the concrete with more crumb plastic were more resistant to the loss in both compressive strength and weight. The water absorption of acid attacked plastic concretewas higher than that of the control mix at 28, 56 and 84 days.
- From the sulphate attack test, compressive strength was observed to be inversely proportional to the percentage of crumb plastic and water-cement ratio. Loss in weight up to 0.59% was observed for sulphate attacked specimens with higher amounts of crumb plastic after 182 days of immersion.
- From the results of corrosion test, as all the readings obtained in the macrocell corrosion test were less than 10 µA, we could conclude that there is no evidence of significant corrosion in the specimens even at 182 days of ponding.
- From the SEM analysis, a smooth, hard surface was observed on the river sand; while a rough,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irregular surface was noticed on the crumb plastic. In the analysis of concrete, it was observed that the bond between plastic particles and cement pastes was not as good as with traditional rigid aggregates. More voids were observed in the concrete as the amount of crumb plastic was increased

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