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PRODUCT DEVELOPMENT USING POLY MASKS AND PLASTIC PELLETS AS ADDITIVE IN CONCRETE

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ABSTRACT
In Asia, on daily basis the total biomedical waste generation is summed to be around 16,659.48 tons/day. Disposal of biomedical plastics wastes like masks, plastic syringe and polyethylene bottles have been now a big matter of concern because of the various health hazards and pollution caused by them. Their use in concrete would lead to decrease the biomedical plastics waste. This paper presents a study on utilization of biomedical wastes granules (obtained through shredding process of plastic bottles, syringes etc.) This research work has been carried out by designing two different grades of concrete for structural and non-structural purpose, in five different percentage ratios such as 5%, 10%, 15%, 20% and 25%. Different characteristics like compressive strength, flexural-strength and indirect tensile strength of casted specimens such as cubes, beams and cylinders are tested and analysed with the existing conventional grades of concrete. It is observed that biomedical waste granules (Plastic pellets) and masks shows superior capability in compression and flexural test. Failure pattern of the tested concrete specimens showed the proper bonding between cement sand matrix and plastic pellets. This integrity of mixture not only enhanced the strength but also shock resistance as compared to conventional mix. This research work is expected to bring new perspective in sustainable utilization of biomedical waste in concrete and hence reduction in biomedical waste management problem. The products like pavers, blocks, chamber covers etc. would be produced cost-effectively and used for the beatification of footpaths, cycle tracks etc.in urban infrastructure.

Keywords:
Biomedical waste, masks, polyethylene bottles, plastic syringe, plastic pellets, mechanical properties

I. Introduction
Concrete is a uniform mixture made up of coarse aggregate (CA), fine aggregate (FA), water and cement and it gets harden over time. Concrete plays an extensive role in the construction and helps to improve our civil engineering field and infrastructural development. Its high strength, durability are the main properties that are useful in construction of roads, bridges, airports, railway lines and tunnels, ports, harbour’s and many other projects. Flexural strength is the main defect in concrete material along with, low ductility and heavy mass as well as low energy absorption. Due to the defects there is a necessity to make usage of steel reinforcement to increase the flexural strength and ductility. Concrete technology is bringing huge revolutions day by day and hence usage of natural resources also increased. Utilization of these natural resources in big amount leads to create shortage of it. Along with toxic biomedical waste, natural resource shortage is also a big issue now a day.
The pandemic coronavirus disease has shown a rapid growth of infected patients all part of the world. For controlling this pandemic entire world adopting various medical practices, it is peak time to maintain health and hygiene. Due to these condition huge quantities of biomedical waste is generated. According to the report from Wuhan, it is observed that there is a drastic growth in biomedical plastic waste formation from 50 tons to around 247 tons per day during the pandemic. Hospital waste management is a major concern in India and worldwide also. Improper waste management may harmful to environment and health. The proper collection, treatment & disposal of biomedical waste will reduce the volume of hazardous wastes and will promote healthy environment. There are various categories of biomedical waste for example Anatomical human waste, infection waste, Incineration biomedical waste ash, pathological waste, pharmaceutical waste, biomedical plastic waste, waste containing huge amount of metals, etc. The Biomedical plastic waste (BPW) is solid biomedical waste

like polyethylene glucose bottles, syringes, masks etc. Plastics have become an inseparable part of our lives. The consumption of plastic is gradually growing day by day. Disposal of biomedical plastics wastes like plastic syringe, glucose bottles and masks have always been a big matter of concern because of the various health issues and environmental pollution caused by them. Statistics says that generation of bio medical waste in India is around 550.9 tons per day, and it is annually increasing by 8% [1]. Recycling of plastic has a limitation like awareness of sorting of plastic waste based on its use [2]. This paper addresses this limitation by proper sorting of plastic waste which could be used in concrete by shredding. There is a scope of utilization of biomedical waste ash in the production of concrete. Research revealed that use of Hospital waste in concrete not only lowers the cost of construction but also reduces environmental hazards [3]. Biomedical waste fibres produced by shredding operation can be used to produce fibre reinforced concrete, it was found that the use of 1% plastic fibres by the volume of cement enhances compressive as well as flexural strength. Further increase in the percentage reduces strength of resultant concrete [4]. Study conducted revealed that the optimum percentage of fibres used up to 0.9% by the volume of cement, enhances the compressive and split tensile strength by 1.5 time more than a control concrete without fibres [5]. Product development can be done by using composite mortar. Composite mortar is produced by using hot mixed shredded personal protective equipment waste combined with filler material like natural or artificial sand. Highly durable and superior product may be developed than the conventional mud blocks [6]. Bio medical waste ash left after incineration process need to ground to very fine even finer than cement to get a better result, from investigation it was found that optimum percentage of replacement of cement is 3 % by the volume of cement. At this replacement level the strength found to be increased [7]. Chemical composition of incinerated biomedical waste as indicated that it contains oxides of calcium and silica. Hence it was used partially to replace fine aggregate and result obtained showed that it has good performance over conventional concrete [8]. After reviewing all the literature, it was found that fibres and ash of biomedical waste was used to check its performance. It was found that Concrete containing plastic aggregates can stop or divert the propagation of micro cracks and improve concrete toughness, which is of great practical significance [9].In this paper instead of ash the fine granules of plastic waste was tried in place of fine aggregate. Natural river sand is getting scarce now due to its overexploitation. Exploring alternative resources is need of time hence in this paper attempt is made conserve a valuable natural resource (River sand) up to some extent.

The polyethylene bottles plastic or masks of biomedical waste can easily be obtained from hospital, and it require lesser cost for shredding and is to be used into concrete as additives to examine the effect on strength of concrete. This research work has been carried out in a perspective to minimize the disposal problem of medical plastic waste and for effective usage of medical plastics waste that are harmful to our environment. This work is an attempt to bring revolution in effective usage of biomedical plastic wastes in concrete as additives in perspective to reduce the biomedical plastic waste disposal problem, also to conserve the usage of natural resources.

II. Materials and Methods

a. Material Used

2.1.1 Cement: Cement is a construction material used in concrete to bind other constituent material together. Different types of cement are available. We are using Ordinary Portland Cement (53grade) cement confirming to IS 8112-1982 and tested as per the Indian Standards.

2.1.2 Fine Aggregate: Fine aggregate confirming to the grading curve zone III having specific gravity 2.63 and water absorption ratio 1.00% obtained as per IS 383-1970 specifications.

2.1.3 2.1.3 Coarse Aggregate: 20 mm nominal sized aggregates having specific gravity 2.64 and water absorption ratio 0.50% confirming to IS: 383-1970 specifications.

2.1.4 2.1.4 Biomedical waste: There are various categories of biomedical waste for example, Anatomical human waste, infection waste, Incineration biomedical waste ash, pathological waste, biomedical plastic waste, pharmaceutical waste, waste containing huge amount of metals, etc. The Biomedical plastic waste is solid biomedical waste like polyethylene glucose bottles, syringes, masks etc.

2.1.5 Biomedical Waste Procurement: The collection of biomedical wastes like use and throw masks, polyethylene bottles and saline pipes from nearby hospitals is done. Then separation of needles or any other sharp metallic objects from wastes if present is carried out. For utilization of biomedical waste in concrete it needs to be processed to form granule like structure.

2.1.6 Shredding: The collected biomedical plastic waste is dumped in a shredder. Then the waste is crushed in small pieces.

2.1.7 Disinfection: The standard processes of disinfection such as,

1. Ultraviolet light (UV): Ultraviolet light (UV) refers to the electromagnetic wave with length between 200 nm and 400 nm.
2. Chemical disinfection: The crushed medical wastes are mixed with chemical disinfectants such as sodium hypochlorite, calcium hypochlorite, chlorine dioxide, etc.
3. High temperature steam disinfection: This uses water vapor with temperature higher than 100 °C. The shredded material is placed in the disinfection tank and the waste shredded material is disinfected by chemical disinfection method. Disinfection using chlorine is more cost effective as it costs approx. $ 1.5 per liter. Quantity of Chlorine used is also very less, concentration 20 gm/liter. The contact time require for disinfection is only 10 min. For more safety it is suggested to soak biomedical waste for a 1 -2 Hrs.in chorine tank of desired concentration.

2.1.8 Cleansing: After disinfecting the shredded material is dumped in a tank filled with clean water and the cleaning process is completed.

2.1.9 Dryer: After cleaning the disinfected material, it is dumped in a dryer for completing the drying process.

Then after completion of all these processes, shredded waste is transformed in small granules forms. Granular form plastic pellets along with the other ingredients for dry mixing are shown in the Figure1. In this study fine aggregates are replaced by plastic pellets in varying percentages. The sieve analysis of the plastic pellets was conducted and results obtained are shown in Table 1

2.1.10 Mixing Water: Potable water was used for the complete experimental work.

Fig.1 Preparation of dry concrete mix

Table 1 Sieve analysis of plastic pellets (granules)

Sieve Size (mm)	Cumulative percentage passing
10.0	100.00
4.75	100.00

2.36	100.00
1.18	99.46
0.6	0.00
0.3	0.00
0.15	0.00

III. Experimental methods

3.1.1 Preparation of Specimen

For the preparation of test samples by using IS10262 concrete mixture proportion for M15 & M25 grade concrete was found out. The constituent materials are weighed and mixed properly by manual concrete mixing method by taking precautions to ensure uniformity of mix. Then the plastic pellets are mixed in the concrete by replacing fine aggregates by five different percentages namely 5%, 10%, 15%, 20% & 25% for comparing with control mix. For each design mix concrete of M15 & M25 grade, 6 nos. of specimens of cube size 150 mm x 150 mm x 150 mm were cast for each 7 & 28 days curing. The beam moulds of size 100 mm x 100 mm x 500 mm were cast by compacting with tamping rod for flexural strength test. While casting these beams, 2 layers of masks are placed by giving sufficient cover from all four sides in between 3 concrete layers of same thickness. These mask layers are made by stitching together forming long strip of around 480 mm length and 80mm width. Cylinders of size diam. 100 mm and length 200 mm were also cast to evaluate indirect tensile strength. The Figure 2 shows the casting of cubes and beam.

Fig.2 Beam and cube specimen casting

3.1.2 Mix Design

Mixture proportion obtained by using IS-10262-2019 for M15 and M25 grade concrete is shown in the Table 2. The proportion of control mix M25 is 1:1.44:3.13 and the proportion of control mix M15 is 1:1.89:3.78. Plastic waste granules are used in varying percentages namely 5%, 10%, 15%, 20% and 25% by the weight of fine aggregate during casting. The mix proportions obtained by design of experiment are as follows-

Table 2 Concrete mixture proportion

Concrete mixes	Cement (kg/m^3)	Water (kg/m^3)	Natural aggregate (kg/m^3)		Plastic aggregate(Kg/M^3)
			Coarse	Fine	
Control mix (M15)	319.3	191.6	1206.09	605.28	0.00
PA05	319.3	194.5	1206.09		30.26
PA10	319.3	201.4	1206.09		60.52
PA15	319.3	205.6	1206.09		90.79
PA20	319.3	210.2	1206.09		121.05
PA25	319.3	214.6	1206.09		151.32
Control mix (M25)	383.2	176.22	1201.18	554.47	0.00

PA05	383.2	180.24	1201.18	27.72
PA10	383.2	184.52	1201.18	55.44
PA15	383.2	188.65	1201.18	83.17
PA20	383.2	204.52	1201.18	110.89
PA25	383.2	210.65	1201.18	138.61

In the normal mixing approach, fine aggregates are added to coarse aggregates followed by cement and water. For the present research, a two-stage mixing process was adopted. In the two-stage mixing process, the required water was proportionally split into two. First, FA & CA were mixed for 60 seconds. Addition of 50 % water was done to the dry mix of FA & CA and was mixed for another 60 seconds. Further, cement was addedto the mixture and was mixed for another 30 seconds. Lastly, the remaining 50 %water was added and mixed for another 120 seconds. During the 1st stage, cement slurry layer formed on the surface of CA which goes in to the cement mortar and fills up the cracks and voids. At the 2nd stage of mixing, the remaining 50% water was added to complete the mix process.

IV. Test results and analysis

4.1 Wet Concrete Density

The wet concrete density test is carried out immediately after casting the moulds with fresh concrete. For calculating the wet density of concrete blended with different percentages of biomedical waste, the weight of empty mould and moulds with concrete blended with different percentages of biomedical waste. As increase in percentage of biomedical plastic waste (BPW) as fine aggregate replacement the density of wet concrete gradually decreases and as higher the waste contents lower is the density. This is due to the relation between density and specific gravity. Since specific gravity of the fine aggregate is more as compared to biomedical plastic waste, therefore, the density of the Control mix is highest. As shown in Figure 3.

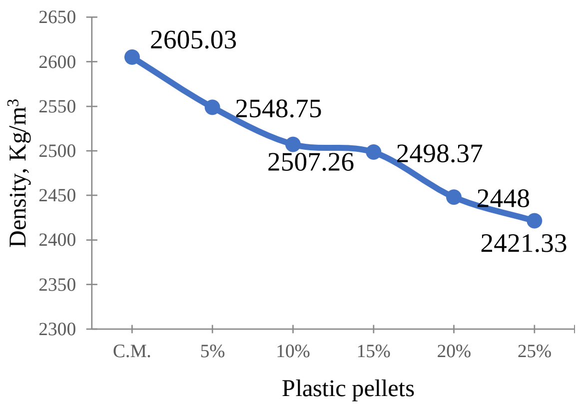

Fig.3 Wet Concrete Density test values of different mixes

4.2 Segregation

Segregation is derived as the separation of the materials mixed in the concrete. During these mixes, up to 20% replacement there was no segregation found. Thus these mixes satisfied the requirement of homogeneity. But during 25% replacement of biomedical plastic waste the segregation of waste material was started. And due to low density of waste material it was travelling to the top of mould while compacting with tamping rod.

4.3 Slump Cone test

As per IS Code: 6461, Concrete Workability is known as, the characteristic of wet concrete which helps to determine the uniformity with which it can be prepared, placed, compacted and finished. In this test also we come to know that as we increase the biomedical waste percentages in concrete mix, the slump value also increases gradually. The control mix showed the least slump value. And in the case of 25% replacement the slump value was the highest and this mix fails as it showed shear slump pattern where as other mixes showed true slump. As shown in Figure 4

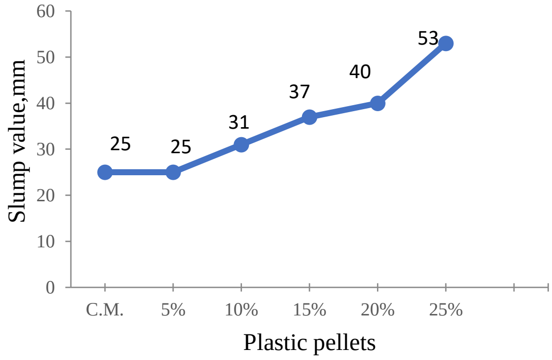

Fig.4 Slump Cone Test values in mm

4.4 Compressive Strength Test

Compression strength of biomedical waste blended concrete mixes was tested with the help of compression testing machine (CTM) of 100T capacity confirming to IS: 516-1959 guidelines. Fresh concrete was placed in the cast iron molds and then compacted with the tamping rod for higher compaction and finish ability in concrete. Concrete cube moulds having size of 150 mm × 150 mm × 150 mm were casted & left for curing in curing pond and then compression test is done after 7 days & 28 days of curing.

In the case of M25 grade concrete, Compression strength upto 10% replacement of biomedical waste showed nearly similar results as of control mix. And further it gradually decreases. As shown in Figure 5. The compressive strength is estomated by using curve fitting techniques. The equation $y = -0.0072x^2 - 0.2397x + 31.853$ is best fit to obtain compressive strength aftrer 28 days with degree of confidence 97%. Simmilarly equation $y = -0.0131x^2 + 0.0343x + 20.651$ is best fit for obtaining compressive strength at the end of 7 days with degre of confidence 95%.

Where as in the case of M15 grade concrete, up to 15% replacement of waste compression strength was similar to conventional concrete mix & further adding waste it started decreasing. As shown in Figure 6. The equation $y = -0.0231x^2 + 0.2588x + 20.09$ is best fit to obtain compressive strength aftrer 28 days with degree of confidence 96%. Simmilarly equation $y = -0.0151x^2 + 0.1603x + 12.355$ is best fit for obtaining compressive strength at the end of 7 days with degre of confidence 97%.

By using TK solver method percentage error was found out .Solver method used to find out residual error in model and experimnetal results are presented in Table 3. The results obtained experimentally and by solver are nearly equal with percetage error of 2%. Simmillarly reslts obtained experimentally were verified using curve fitting techniques and it was found that the results are nearly equal with percentage error of 3%.

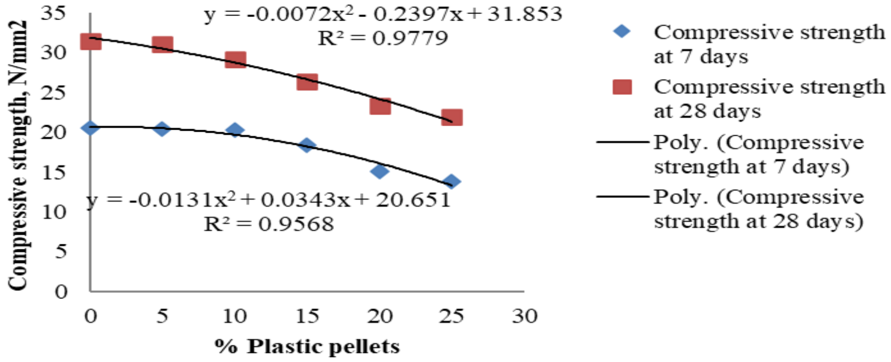

Fig.5 Compression Strength of M25 grade concrete after 7 & 28 days

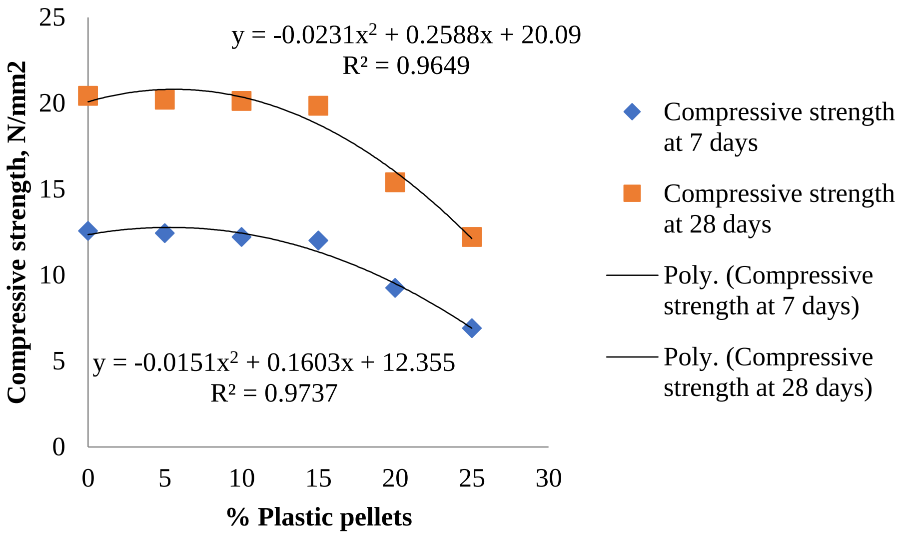

Fig.6 Compression Strength of M15 grade concrete after 7 & 28 days

Table3 Error calculation

X	Yi	Y model	Error	Error^2
0	20.5	20.79054	-0.291	0.0844138
5	20.41	20.4943	-0.084	0.0071064
10	20.31	19.60558	0.7044	0.4962112
15	18.36	18.12437	0.2356	0.0555199
20	15.02	16.05069	-1.031	1.0623177
25	13.85	13.38452	0.4655	0.2166708
	18.075			1.922239

4.5 Flexural and Indirect tensile Strength Test:

Flexural strength test calculates the strength of concrete in tension indirectly. This test calculates the capacity of concrete beam or slab without reinforcement to resist failure in bending. The flexural test results of concrete specimen are denoted as a modulus of rupture and it is given in N/mm^2 or MPa. Beam specimens of size 100mm x 100mm x 500mm were prepared using cast iron molds as per required conditions. And after demolding, the beams were immersed in curing pond for curing. In this work the flexural strength test is taken by two-point load method after completing 28 days of curing. This test is carried out on the specimens instantly after taking out the specimens from the curing pond to prevent decline in flexural strength of test samples. Indirect tensile strength was conducted on the cylinders under Compression testing machine.

Figure 7 shows results obtained by conducting the flexural and indirect tensile strength depict that enhancement in strength at 10 percent replacement and later on declination in strength. Figure 8 shows the failure pattern of flexural strength test, indicates failure at weak matrix and plastic pellets were seen opened but in un- bond condition. Failure pattern of indirect tensile strength is shown in Figure 9 indicates that plastic pellets are properly bonded with matrix in the two specimen tested and de bonded from matrix in one tested specimen. However, the decrease in bond strength between Plastic aggregates and cement paste due to the hydrophobic nature of plastic are the reasons indicated in several studies for the poor mechanical properties [10].

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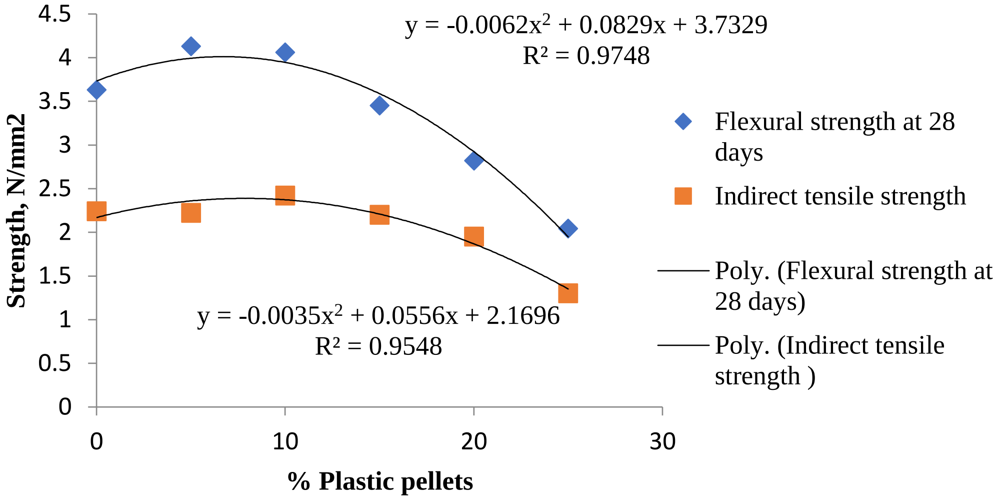

Fig.7 Flexural and inditect tensile Strength of M25 grade concrete after 28 days

Fig.8 Plastic pellets coated with matrix found in bonded form in flexural test

Fig.9 Failure pattern of cylinder specimen in indirect tensile test

V. Conclusion

According to the research work test results, following conclusions can be drawn

1. As the compressive strength of M25 grade concrete mixes blended with **5%** & **10%** Plastic pellets nearly showed similar compression strength as of conventional concrete mix, thus the optimum percentage of medical waste that can be added in M25 grade concrete is 10%. And in the case of M15 grade concrete, mixes blended with 5%, 10% & 15% medical waste showed similar compression strength as of conventional concrete mix. Therefore, the optimum percentage of medical waste is 15% in M15 Grade concrete.
2. Flexural strength of 5% & 10% medical waste blended concrete increases by 13.77% as compared to conventional concrete mix because of the mask layers added in between them. Hence it is concluded that Masks used in layers in concrete, enhances the flexural and fatigue strength of concrete.
3. Concrete blended with biomedical plastic waste (masks and pellets) can be used for the construction of internal roads in villages as well as cities. The flexural strength found to be improved which will provide better serviceability than the road constructed using conventional concrete.
4. The low cost and environmental friendly product development would be possible like paver

blocks or bricks and light weight concrete, chamber covers would be used in beatification of footpaths.

5. The utilization of biomedical plastic waste will definitely produce the sustainable concrete to achieve sustainable development subjected to blended Concrete prepared with proper selected plastic waste material & with optimized concrete mix design.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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