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"EXPERIMENTAL ANALYSIS OF ADVANCED CONCRETE USING GLASS POWDER AND PLASTIC WASTE"

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ABSTRACT

Concrete is the most important material used for construction purposes all over the world. In the present situation, where technologies are improvising, waste production is also increasing at the same rate. But the land available to dispose of this waste material is getting reduced. Hence the new way of disposal is to recycle these waste materials into useful forms with other beneficial properties. Adopting this method also creates a sustainable environment by reducing the land filled with waste and using in construction area. Out of the waste material two are mostly generated, plastic waste and glass waste. The plastic waste is obtained from residential as well as industrial, and glass waste is produced mainly from industries. The present study comprises these two wastes, glass waste and plastic waste as replacement of cement and fine aggregates with evaluation of physical properties for use in different construction places. The cement is replaced by glass powder in percentage of 7%, 14% and 21% and fine aggregates (sand) are replaced by plastic waste in percentage of 5%, 10% and 15% by weight in mix design. The properties studied in the present study involve, compressive strength and flexural strength. After study it showed that the results in strength of concrete have been reduced due to lower adhesion between the glass powder mix and recycled aggregates. It is been observed that up to 10% their use is viable for construction works.

Keyword: *Structural concrete; Sand replacement; Recycled plastic; Glass powder; Mix design; Compressive strength.*

I. INTRODUCTION

Concrete is the widely used construction material composited by artificial mixing of different materials. It is used extensively in the development of infrastructure, bridges, dams, roads, etc. After China, India is the second country to use concrete in construction works. But as the usage rate of concrete is increasing, the waste production is also increasing. The manufacturing processes, municipal wastes and industrial wastes produce lots of waste plastic. These wastes are on higher rate and have an important impact environmentally too.

The environmental impact is assessed by how much quantity of waste is dumped at landfill sites as this waste is primarily consisted of plastic waste which is non-biodegradable. To make the environment sustainably developed, a new technique has to be adopted. One of the best solutions is reusing or recycling this plastic waste and glass waste to maximum possibility.

According to the Indian Central Pollution Board (CPB), about 20,000 tons of plastic and glass waste is dumped in India every day. This is a huge amount of waste which takes several years to degrade. The land used for dumping purpose losses its fertility too. These wastes create other problems too such as clogging of drainage pipes, damaging the resources, etc. Also the cement present in concrete mix produces CO_2 which makes concrete a less environmental friendly.

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When these wastes are used in concrete industry, they are effectively used and also help in lowering the quantity of concrete manufacturing, which makes the whole project more economical. Aggregates are replaced in concrete and these plastic chips act as fibre in concrete. They are also significantly lighter in weight than natural aggregates which help in producing lightweight concrete. These materials incorporate low densities in the resulting concrete. Also when cement is manufactured it produces large amount of green-house gases, which is the main cause of ozone layer depletion. Hence replacing cement by glass powder helps in building a sustainable environment. It improves the concrete durability, strength and maintains economy too.

Fig. 1: HDPE plastic with recycling label #2

II. LITERATUREREVIEW

Al- Manaseer and Dalal, who explored the effect of an increasing proportion of angular waste plastic particles on cylinder strength for three different water to binder ratios. It was found that compressive strength decreased with an increase in plastic aggregate content, with this loss in strength attributed to poor bonding between the plastic and cement paste. The plastic was able to pull out, rather than to split in tension, during compressive testing of the concrete.

Zoorob and Suparma, (2000) The various types of plastics in municipal wastes are Polyethylene terephthalate (PET), High density polyethylene (HDPE), Low density polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) etc. The major users of plastic are the packaging industries, consuming about 41%, 20% in building and construction, 15% in distribution and large industries, 9% in electrical and electronic, 7% in automotive, 2% in agriculture and 6% in other uses.

Aimin Xu and Ahmad shayam (2004), This paper shows that there is great potential for the utilization of waste glass in concrete in several forms, including fine aggregate, coarse aggregate and glass powder. It is considered that the latter form would provide much greater opportunities for value adding and cost recovery, as it could be used as a replacement for expensive materials such as silica fume, fly ash and cement. It undergoes beneficial Pozzolonic reactions in the concrete and could replace up to 30% of cement in some concrete mixes with satisfactory strength development. The drying shrinkage of the concrete containing GLP was acceptable.

Patel Dhirendra, Yadav R.K. and Chandak R. (2012) this paper deals with studies on the use of waste glass powder in concrete with moderate level of decrease in compressive strength at 28 days , is locally available, and its use as a cement replacement material presents an efficient waste management option, without compromising concrete performance. Research studies on the use of waste glass in concrete has been reported. Glass is amorphous with high silica content, thus making it potentially pozzolonic when the particle size is less than 75 micron. Studies have also shown that finely ground glass does not contribute to alkali-silica reaction. This paper concludes that the % decrease in 28 days strength of concrete by replacement of cement with 20% glass powder is only about 10%. It is clear that about 15% of cement replacement by fine glass powder provide the most optimal strength results because with this replacement the decrease in strength is less than 6%.

Saikia and de Brito(2013) tested concrete mixes containing three different sized and shaped particles: 1) large (10–20 mm length) particles; 2) shredded flaky fine particles (2–5 mm length); and 3) cylindrical pellet shaped particles (3 mm length). Each of these was tested over a series of replacement ratios, ranging from 0% to 15% of the sand. It was found that the higher the replacement ratio, the lower the concrete's compressive strength, attributed to the lack of interaction between the PET aggregate and cement paste.

R. N. Nibudey et al (2013) , studied the performance of concrete in presence of waste plastic fibres (WPF). The experimental works that adopted included tests of cube and cylinder specimens. The WPF that added to the concrete was ranged from (0 to 0.3 %).The specimens was cured at twenty eight days and after that tested to investigate compressive and tensile strength. The results indicated that at (1%) of WPF there was improved the mechanical properties of concrete as compared with control specimen.

Alani Mahmood Fawzi (2014) , studied the possible way to use waste plastic material as fine aggregate in structural elements by evaluate the mechanical properties of concrete. Various ratio of waste plastic was considered (2.5%,5% and 7.5%) by volume with ten percent of silica fume. Tests result indicated that the presence of waste plastic reduce concrete workability and decreased in compressive strength and modulus of elasticity compared with fresh concrete.

Subramani and Pugal (2015) reported that, the use of plastic waste as a replacement for conventional coarse aggregate improves the physical and mechanical properties of concrete mixes. It was reported that, the compressive strength, flexural strength and split tensile strength of concrete was increased by 8%, 5% and 3% as compared to that of control concrete at 15% replacement level. As the percentage of replacement increases beyond 15% all the properties of concrete showed downward trend. This fact was due to excess presence of water in the concrete mix because plastic waste has very low water absorption as compared to that of conventional coarse aggregate

Harini and Ramana (2015) studied the influence of replacement of plastic waste and silica fume as fine aggregate and cement respectively in concrete mixes. The plastic waste was replaced in the percentage 5%, 6%, 8%, 10%, 15%, 20% by volume and silica fume 5%, 10%, 15% by weight in concrete. They reported that, the degree of workability was high in all the replacement levels. It was also stated that, in all the replacement levels of plastic waste as fine aggregate showed marginal reduction approximately 10% in compressive strength as compared to that of control mix.

P. Ganesh et al (2015), investigated t h e increasing i n compressive strength of concrete by replace percentage of fine aggregate by waste plastic. Total of twenty seven specimens included cube and cylinder tests and compared with the reference specimen without replacements. The ratio used in the work was (0. 5, 1 and 1. 5 %) of waste plastic by volume. The results indicated that the ratio of waste plastic one percent give good result for compressive and tensile strength.

Vidya, B. and Tejaswi, et al (2015), this paper entitled that waste glass powders have been used as replacements to the concrete ingredient i.e. cement and the mechanical properties like compressive strength are measured. Also we were studied the size effect of glass powder on strength of concrete. For checking strength effect of replacement of cement by glass powder, the cement is replaced at 10%, 20% and 30%. For study of size effect of glass powder the powder is divided in to two grades one is glass powder having size less than 90 micron and another is glass powder having particle size ranges from 90 micron to 150 micron. It is found from study, Initial strength gain is very less due to addition of GLP on 7th day but it increases on the 28th day. It is found that 20% addition of GLP gives higher strength. And also GLP size less than 90 micron is very effective in enhancement of strength.

Sharma, N. and Kumar, R. (2015) studied the effect of 5%, 10% and 15% replacement of cement by glass powder on compressive strength and durability. The particle size effect was evaluated by using glass powder of size 600μm-100μm.The results shows that maximum increase in strength of concrete occurred when 10% replacement also the pozzolanic behaviour of waste glass appears, if they ground finer than 600μm. The early consumption of alkalis by glass particles helps in the reduction of alkali-silica reaction hence enhancing the durability of concrete.

J. M. Irwan and Mohd Haziman(2016), investigated the effects of r i n g shaped of waste plastic bottle on the flexural toughness. The width that looked out was (5mm and 10 mm) with applied loading at the third point of specimen. By tested results, there was increased in the toughness around (23%) in case of (5 mm) width and (40%) in case of (l0 mm) width.

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III. EXPERIMENTAL STUDY

3.1. Materials used for study

- **Cement:** - The cement used for the experimental program was ordinary portland cement (OPC) of grade 53, confirming to IS: 12269-1987. The specific gravity of cement is 3.15.
- **Coarse aggregates**: - The coarse aggregates used for the investigation was confirming to IS: 383-1970. The sizes used are 10mm and 20mm in the ratio 40%-60%.
- **Fine aggregates:** - The grading of fine aggregates should be uniform and should pass through 4.75mm sieve throughout the work process. The fine aggregates used was confirming to IS: 383-1970.
- **Glass Powder**: - Waste glass available in local shops has been collected and made into glass powder. Glass waste is very hard material. Before adding glass powder in the concrete it has to be powdered to desired size less than 150microns and 300microns. Glass powder is added to the cement separately before dry mixing with other material. The specific gravity of glass powder was found to be 2.69. This value is far less than 3.15 for Portland cement.

Table -1: Chemical properties of waste glass powder

Oxide composition	Content (%)
Silica (Sio2)	68.4
Alumina (Al2O3)	0.34
Iron Oxide (Fe2O3)	0.18
Calcium Oxide (Cao)	8.8
Magnesium Oxide (MgO)	3.1
Sodium Oxide (Na2O)	13.2
Potassium Oxide (K2O)	0.08
Sulphur trioxide (SO3)	-
Loss of ignition	0.29
Fineness % passing (sieve size)	82%

- **Plastic waste:** - HDPE was selected as the plastic for fine aggregate replacement in this study. The experiment began by finding the gradation of the fine aggregate owing to that the gradation of sand could provide a baseline for the desired incorporation of recycled HDPE plastic. The density of waste plastic is 0.94g/cm3 and specific gravity is 0.89. The mean size of the particles is 2mm-3mm which are black in colour.

3.2. Concrete Using Plastic Fibres and Glass Powder

- A number of researches have been done in past years with mixing plastic waste fibres and glass powder in concrete to make light weight concrete with equal strength characteristics. The use of plastic fibres and glass waste alters various properties in concrete.
- The combined effect of plastic waste and glass powder is as follows:
  1. Reduced weight of concrete mix – this makes the concrete use easy
  2. Reduced cost of construction
  3. It also reduces the accumulation of wastes on landfills.

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3.3. Objectives

- To develop modified concrete of M25 grade.
- To replace cement by glass powder with variable proportions.
- Replacement of fine aggregates by plastic waste in variable percentages.
- To investigate physical and mechanical properties of modified concrete.

IV. RESEARCH METHODOLOGY

4.1 General

A systematic approach is made to study the effect of waste plastic and glass powder on concrete with reference to the methods provided in the literature survey. The steps involved in the methodology of the proposed work are as follows:

1. The grade of mix concrete selected for the work viz. M25. Mix design is done as per IS10262-2009.
2. The waste plastic and glass powder is mixed by replacing by weight of cement in 7%, 14% & 21% and fine aggregate in percentages 5%, 10% and 15%.
3. The tests, compressive strength, slump and flexural strength, are then carried out on all the ingredients of mix and also on the final mix with different conditions of moisture.

4.2 Mix Design Proportion

The mix design of M25 was carried out as per IS 10262-2009. The proportions of cement, sand and aggregates are as obtained:

Table -2: Mix Proportion of M-25

Proportion	Water	Cement	Fine Aggregate	Coarse Aggregate
By weight	186 kg/m^3	422.73 kg/m^3	626.48 kg/m^3	1163.47 kg/m^3
In ratio	0.44	1	1.48	2.75

The quantity of plastic waste added in the concrete mix by replacing fine aggregates at 5%, 10% and 15% by weight and also replacing cement with glass powder in the same percentage ratio by weight.

Table -3: Quantity of HDPE plastic and glass powder after replacements

Model	Cement (kg/m3)	Glass powder (kg/m3)	Fine Aggregates (kg/m3)	Plastic waste (HDPE) (kg/m3)
M1	422.73	0	1163.47	0
M2	393.14	29.59	1105.3	58.17
M3	363.55	59.18	1047.09	116.38
M4	333.96	88.77	988.95	174.52

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4.3 Details of Specimens Prepared

- 150mm x 150mm x 150mm, cube specimens for compressive strength.
- 150 mm×150 mm×700 mm, beam specimens are used for flexural strength test.

V. RESULTS AND DISCUSSIONS

In order to achieve the objectives of this dissertation work, an experimental program was planned to investigate the effect of HDPE plastic and glass powder on compressive strength and flexural strength of concrete so that its feasibility can be assessed for the use of this concrete in near future. The experimental program consists of casting, curing and testing of concrete which lightweight by adding HDPE plastic and glass powder at different age of curing.

5.1 Analysis of Workability

Concrete mix with 5% HDPE plastic and glass powder gave the highest slump about 49 mm. Graph shows the decrease in slump measurement when glass powder and plastic waste was added. This result shows that concrete mix with higher content of a constant w/c ratio will give a lower workability as the stability of concrete mix with support of fibres.

Table -4: Workability Test results of cement and fine aggregates replaced with glass powder and HDPE plastic.

S. No.	Percentage (%)	HDPE plastic (% weight)	Glass powder (% weight)	Slump value (mm)
1	0%	0	0	56
2	5%	58.17	21.14	49
3	10%	116.38	42.27	45
4	15%	174.52	63.41	38

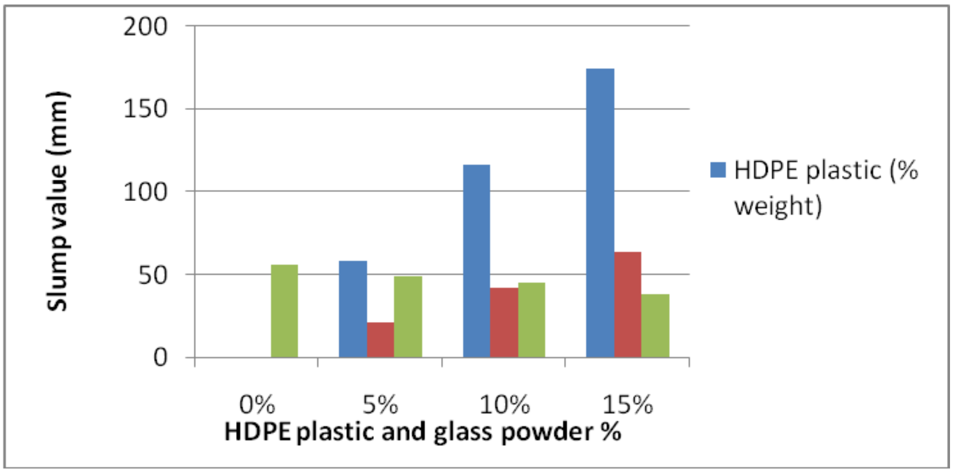

Fig - 2: Slump values after replacements in above quantities

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5.2 Analysis of Compressive strength

The modified concrete mixtures with varying percentages of glass powder for replacement of cement were prepared and casted into cubes.

Table - 5: Test results of compressive strength of different mix with different percentage of glass powder.

S. No.	Glass powder (%)	Average compressive strength (N/mm^2)		
		7 days	14 days	28 days
1	0%	18.21	24.85	31.42
2	7%	20.63	25.98	33.62
3	14%	22.31	28.32	35.92
4	21%	21.06	26.73	34.11

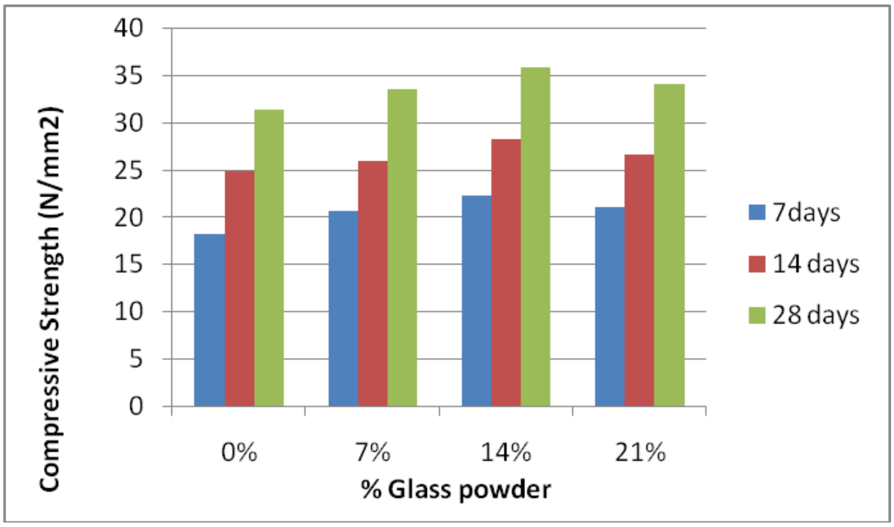

Fig - 3: Compressive strength values after replacement of cement with glass powder in above quantities

Table - 6: Test results of compressive strength of different mix with different percentages of HDPE plastic.

S. NO.	HDPE PLASTIC (%)	AVERAGE COMPRESSIVE STRENGTH (N/MM^2)		
		7 DAYS	14 DAYS	28 DAYS
1	0%	20.12	24.25	31.63
2	5%	21.56	26.58	34.27
3	10%	23.73	29.76	36.05
4	15%	22.37	27.42	33.88

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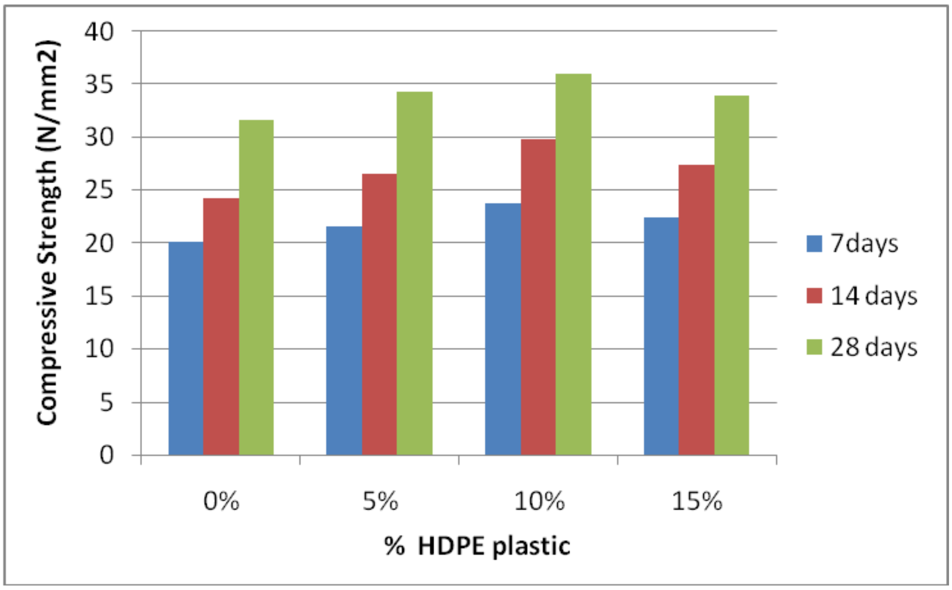

Fig – 4: Compressive strength values after replacement of fine aggregates with HDPE plastic in above quantity

It can be seen from above results that the maximum value of compressive strength is obtained when HDPE plastic and glass powder are mixed in concrete singly, are at 14% for glass powder and 10% for HDPE plastic. Hence mixing these optimum percentages obtained together and again testing the concrete cubes for compressive strength, we get the results as shown below.

Table - 7: Flexural strength test results of each mix with HDPE plastic and glass powder.

S. NO.	AVERAGE COMPRESSIVE STRENGTH FOR OPTIMUM PERCENTAGE OF HDPE PLASTIC (10%) + GLASS POWDER (14%) (N/MM2)		
	7 DAYS	14 DAYS	28 DAYS
1	23.74	29.42	36.84

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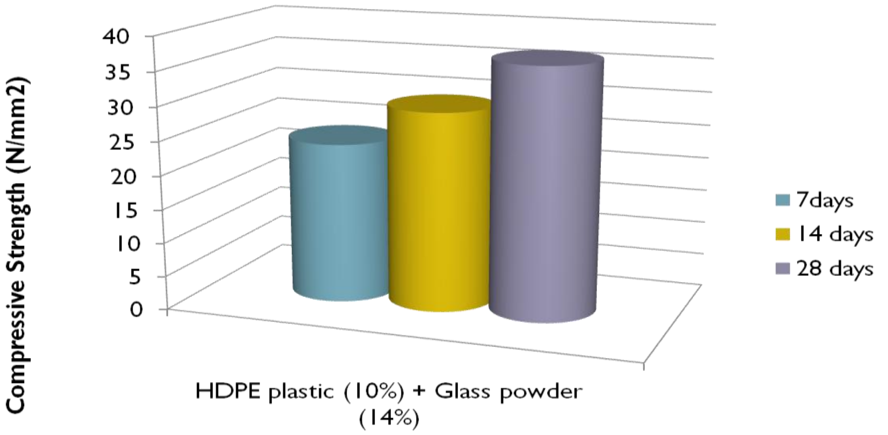

Fig – 5: Compressive strength values for optimum percentages of HDPE plastic and glass powder

5.3 Analysis of Flexural strength

When concrete is subjected to bending, then tensile and compressive stresses and in many cases direct shear stresses are developed. These stresses produce cracks in the concrete. The HDPE plastic and glass powder is hence added due to which ultimately flexural strength is increased. The optimum results of compressive strength are used here too for testing the beams. Hence 14% of glass powder as replacement of cement and 10% of HDPE plastic as replacement of fine aggregates is used.

Table - 8: Flexural strength test results of each mix with HDPE plastic and glass powder.

S. NO.	AVERAGE FLEXURAL STRENGTH FOR OPTIMUM PERCENTAGE OF HDPE PLASTIC (10%) + GLASS POWDER (14%) (N/MM2)		
	7 DAYS	14 DAYS	28 DAYS
1	4.58	5.82	6.76

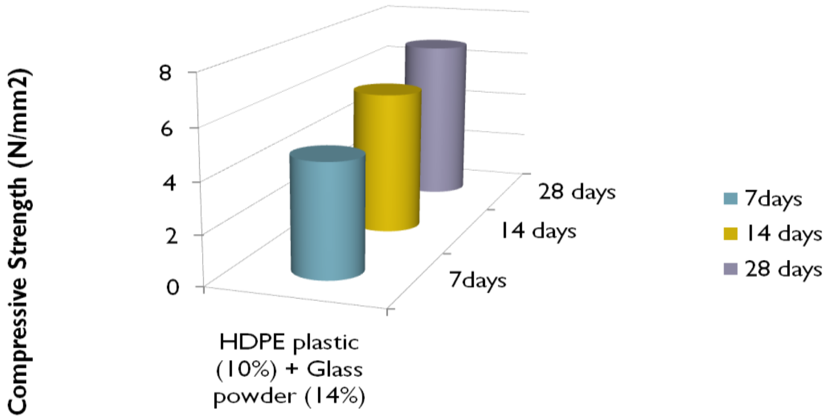

Fig - 6: Flexural strength values after replacements in above quantities

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V. CONCLUSION

The present dissertation work was carried out to investigate the compressive strength and other mechanical properties of concrete when waste materials, HDPE plastic and glass powder are added to it by replacing fine aggregates and cement. The HDPE plastic and glass powder are added by percentage weight of 5%, 10% and 15%.

6.1 Workability

1. From the experimental works conducted for workability, it is observed that when replacement amount is in increasing percentage, the slump is increasing with constant water-cement ratio. The best slump is found at 10% replacement as 45mm.
2. Adding plastic waste and glass powder has enabled concrete to be light weight and easy workable.

6.2 Strength Parameters

1. The HDPE plastic and glass powder is used in replacement of cement and fine aggregates in concrete of mix M25 (1:1.48:2.75).
2. On comparing the results it was found that the mixes with these two ingredients have better compressive strength than the conventional concrete. The effectiveness of plastic waste is affected by the type of plastic used and the shape & size of particles used in the concrete mix.
3. The optimum dosage of plastic waste in the form of HDPE in concrete is 10% when added in addition to glass powder of 14% by weight is found to be about 36.84 N/mm2 at the end of 28 days of curing. These two replaces fine aggregates and cement.
4. The glass powder also takes part in the hydration process which primarily is done by cement.
5. The plastic is easily available in market through shops. So is the glass waste which is then converted into powder form.
6. Large pieces of plastic waste are not recommended as they are not easily mixed in the concrete and create a irregular mass with large number of voids. Hence replacing fine aggregates with plastic waste is a good option which can be adopted.
7. The usage of these waste also reduced the amount of landfill which is previously used for dumping these plastics and glass without modifying them into new forms. But there has been a restriction to the usage. All types of plastics can be recycled unto new form for usage in different ways.
8. Only 30% of the total waste plastic produced can be recycled efficiently for other uses. It is hence required to stabilize a mode of disposal of these plastics for further recycle option.

6.3 Scope for Future Work

- From the results of the dissertation work that has been done, the recommendations for future can be conveyed for this work and subsequent works are. In making mix designs, the results of mixing could be done more carefully so that the mixture on the mortar can be more evenly spread.

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- The PET or plastic fibre material used should use plastic seeds from the manufacturer or work should be carried out with a special plastic crusher machine so that the aggregate size and weight of each aggregate can be reduced to facilitate workability.
- For the development of further research, it can use with a number of variations which are more or less same but without using broken stones as coarse aggregates.
- The waste plastic used can be varied to replace the cement also, but keeping the water factor enact so that the best plastic material can be seen.
- Also glass powder has good silica content which makes its powder easily and readily mixed in concrete and serves the same purpose as that of cement. But care should be taken while choosing the size of glass waste powder. It large sizes pieces are present they will disintegrate the concrete.

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