RECYCLABILITY OF PET WASTE IN SUSTAINABLE MORTAR PRODUCTION

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ABSTRACT. The study of this work is started with the aim of to find an alternative to solve solid waste disposal problem. Among all the solid waste plastic have become essential and unavoidable part in our lives. Polyethylene Terephthalate (PET) is one of the extensively utilized in plastic in the packaging industry because of light in weight, high-pressure sustainability, high stability, Nonreactivity with material and excellent quality of gas trapping which can conserve the gas in gaseous in the drink. Reusing PET waste to produce materials like concrete or mortar would be the best solutions for the disposal of waste. In this work, waste PET bottles were used to produce a PET resin by glycolysis in Diethylene glycol these resins were prepared for different proportion of PET particles and were added in percentage 5%, 10%, and 15% by mass of cement in the cement mortar. The effect of this resin on standard consistency, setting time, together with slump flow, and compressive strength of mortar is studied. It is observed that the addition of PET resin alters the standard consistency and Compressive Strength, increases the setting time, and slump flow. The findings of this study suggest that PET waste can be potentially utilized in the production of sustainable cement mortar

Keywords: Diethyelene glycol, PET Resin, Mortar, Compressive strength, Setting time, Sustainability

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INTRODUCTION

The production of plastic waste has been expanding considerably and is, for the most part, sent to dumping grounds. The enthusiasm for recycling it, both ecologic and economic, is not just because of its forcefulness towards the earth [1] yet in addition to its high volume in dumping grounds and high protection from atmospheric and biological agents, making this arrangement unsustainable.The primary procedure of waste dispersal was biologically common. This has brought about extensive amounts of garbage in the landfill [2] that is not decreased because of the disposal of junk contrasted with a high rate of waste disposal. Therefore the need to open another disposal expanded every once in a while. Polyethylene Terephthalate (PET) is a sort of plastic that is typically utilized for plastic bottles [3]. PET is utilized in carbonated drinks, mineral water and packaging industry in the whole world. PET has advantages such as high solidness high weight resistance, non-reactivity with substance, incredible nature of gas catching which can safeguard the gas in the beverages [4]. The construction industry uses cement on a large scale. About a few billion tons are being used every year. Utilizing PET resin in concrete as the polymer is an ideal route on account of depleting natural resources and sustainable development and having durable and strong concrete.[5]

In the last twenty years, the study has been carried out on the use of waste plastics as concrete and mortar constituent. The PET waste is utilized as replacement of constitutes of concrete such as fine aggregate and cement. [6] The PET fibre is used as reinforcement in concrete. The polyethylene terephthalate (PET) is one of the widely consumed plastic, in the total plastic waste generated. Nowadays, the literature has shown that many applications on mortar and concrete with utilizing plastic waste especially with the use of PET waste.[7]. The inclusion of PET fibres in the concrete is advantageous in order to control plastic shrinkage cracking. The plastic shrinkage cracks are widely explicated in mortar, which has large surface of exposure [8]. When surfaces are subjected to wetting and drying or freeze-thawing plastic shrinkage cracks are developed resulting into the rapid ruin of structure [9]. PET fibre has a low elastic modulus which is sufficient to give high performance to restrain cracks propagation in a mortar.[10]. Fibres in mortar act as uniformly distributing reinforcing material against the crack enlargement due to plastic shrinkage. Propagation of microcracks and macrocracks is sever issue in harden mortar can be arrested by providing uniform distribution of PET. PET fibres present in mix act as a bridge and stop the propagation of microcracks. Free shrinkage and restrained shrinkage tests have performed the evaluation of fibres capacity to reduce plastic shrinkage [11]. The diminish in free shrinkage does not necessarily indicate a reduction in overall cracking tendency. The cracking sensitivity of harden mix is primarily controlled by enhanced toughness owing to the incorporation of fibers and shrinkage deformation [12]. The toughness plays a very important role during the performance in static, dynamic and fatigue actions. The use of latexes or resins as polymer in to alter the properties of mortar and concrete. Polymer has shown advantages on properties to make material flexible or decreases the permeability. Polymer doses in concrete is between 10% to 20% of mass of cement. This resin could be utilized effectively at concentrating at paste and aggregate interface. [17]

PET waste can be handled by three ways reuse, recycle and reduce. Reuse of PET waste bottle is not feasible as it is used only ones and need to be crushed after use. Recycling of PET waste is may be carried out by two ways is one is by the mechanical way (crushing) or by changing its chemical structure converting as PET resin. PET waste can be reduced by consuming less, but at now there is no other material to substitute this.

MATERIALS

Cement

Ultra Tech 53 grades Ordinary Portland cement is used for this study the specific gravity of cement is 3.10

Fine Aggregate

River sand is used as fine aggregate

Table 1 Physical properties of Fine Aggregate

Sample	Specific gravity	Water absorption	Silt Content
Fine aggregate	2.62	1.10	5.83 Percent

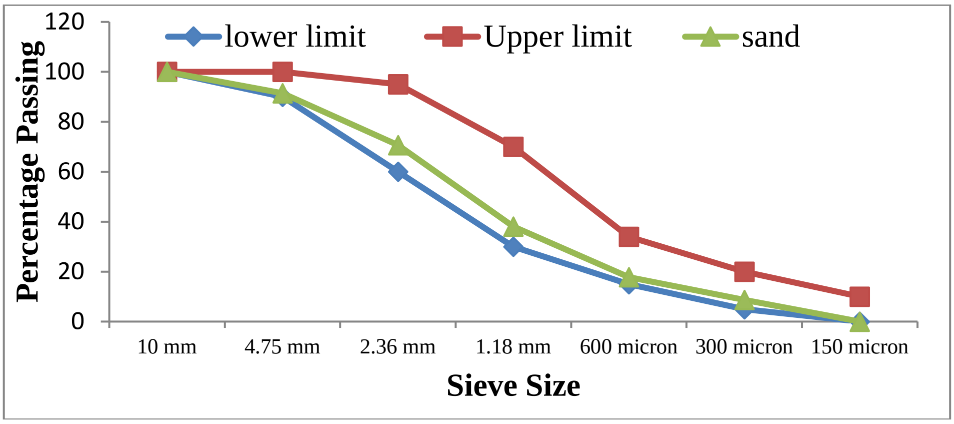

Figure 1 Fine aggregate confirming to Zone I

Water

Potable water is used during mixing and curing process.

PET Resin

PET Resin was obtained by glycolysis process with 10, 20, and 30 percentages of PET (Polyethylene terephthalate) partials in DEG (Diethyelene Glycol). Glycolysis of waste PET was done using DEG having 100 molecular weight [13] along with 0.5% zinc acetate as a catalyst. A three-necked glass flask with condenser and stirrer was used to conduct the reaction. The ingredients were heated at 180˚C for an hour; the temperature was further elevated till disappearance of all the solids at 210˚C [14].

TESTING PROGRAM

Standard consistency, Initial setting time and final setting time is determined as per IS 4031-1968 and IS 269-1976. Soundness is determined as per IS 4031-1968 and IS 269-1976. The mix ratio for normal cement mix is 1:3 (Cement: Sand) and water of quantity $(\frac{P}{4} + 3)$ percent of the combined weight of cement and sand mix chosen for determination of compressive and tensile strength. PET resin is added in normal cement mix with 5, 10, and 15% by weight of cement for all PET to glycol ratio. The flow table test is carried out according to IS 4031 part IV 2005. The compressive strength of cement mortar is determined as per IS 4031 part IV 2005. The tensile strength of mortar is determined as per IS 269 2013, ASTM C307 and IS 4031 part 8. Styrene monomer is added in PET resin with ratio 1:1 to reduce the viscosity and MF (Melamine Formaldehyde) was added in this mixture as a curing agent [15]. Oven dry and normal water curing was carried out on the mortar block.

RESULT AND DISCUSSION

Standard Consistency

The water required for standard consistency of the cement was slightly reduced with an increase in the addition of PET resin in the cement paste. The water requirement is reduced up to 0 to 4% for 5%, 10%, and 15%. PET resin content and same is shown in figure 2. There is no effect on consistency with an increase in PET to glycol content.

Soundness of Cement

It is essential that cement paste once set should not undergo a large change in volume if there is change in volume that will affect structure. Small change in the expansion of the cement was found due to the addition of PET resin with various 5%, 10% and 15% PET resin content as shown in figure 2. It is also notified that there is no effect on soundness for various PET to glycol ratios.

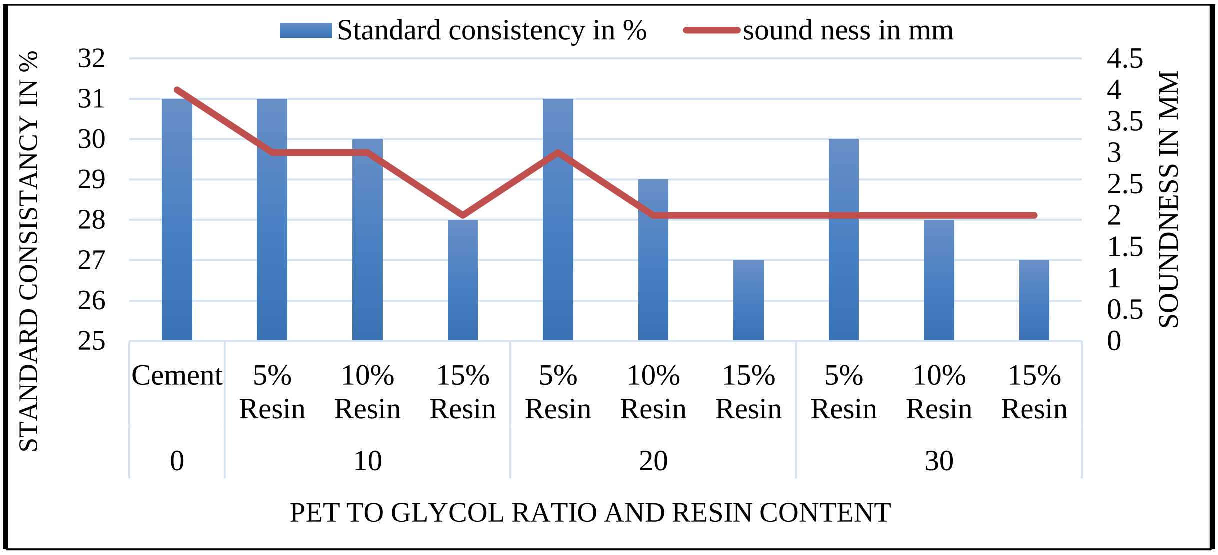

Figure 2 Standard consistency and Soundness

Flow Table Test on Mortar

It was observed that there is an increase in slump flow of mortar with the addition of various PET resin content as shown in figure 3. Maximum slump flow was observed for 15% PET resin content for all PET to glycol ratio. Slump flow increases 12.50 % to 37.50 %, 58.25% to

75% and 62.5% to 87.5 % for 5%, 10% and 15% PET resin content for 30% , 20% and 10% PET to glycol ratio respectively as compare to normal cement mortar. Slump flow gets affected by PET to glycol ratio as PET content goes on increasing slump flow goes on reducing.

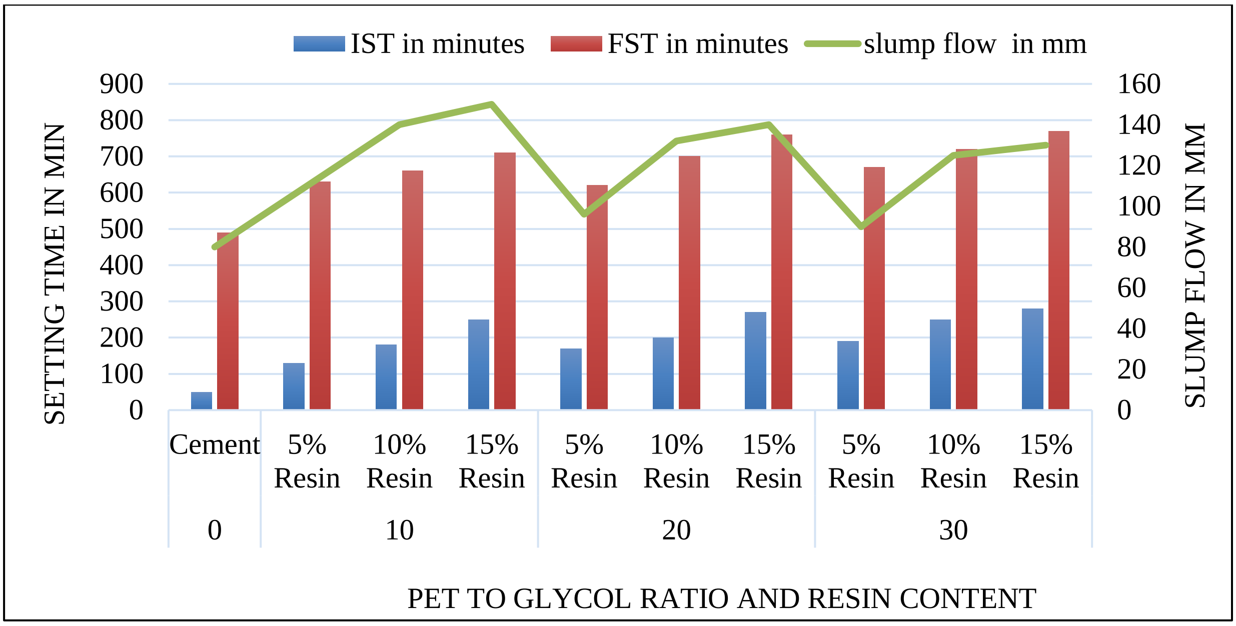

Figure 3 Effect of PET resin on Setting time and Slump flow.

Setting Time

Initial setting time is increased as the percentage of PET resin content increased. For 5%, 10% and 15% PET resin content initial setting time (IST) increases from 80 min to 230 min as compared to control cement paste for 5%, 10% and 15% PET to glycol ratio respectively same is shown in figure 3. This could be the advantage in ready-mix concretes. Final setting time (FST) is also increased from 140 minutes to 280 minutes for various PET resin content 5%, 10%,and 15% respectively for PET to glycol ratio of 5 %, 10% and 15%. Setting time is mainly caused by hydration of C_3A and C_3S and accompanied by temperature rises in the cement paste initial set correspondence rise of temperature final set correspondence to the peak temperature. Addition of PET resin with a different PET to glycol ratio it slows down the temperature rise at initial and peak level due to this there is increase in the initial and final setting time.

Compressive strength

1, 7, and 28 days compressive strength of the cement mortar was determined in oven dry and normal water curing. In 10% PET to glycol ratio, there is a reduction in compressive strength in comparison with normal cement mortar. After 1-day water curing mixes with 5%, 10%, and 15% PET resin respectively, along with curing agent gained 69.59%, 58.48%, and 53.22% less compressive strength [16]. While compressive strength at the age of 28 days was 52.80%, 50.70%, and 46.62% less in comparison with normal cement mix as shown in figure 5. However, in oven dry curing respectively, 121.64%, 134.50%, and 168.47% increase in compressive strength was observed for 1 day curing as this the advantage of polymer concrete. However, at 28 days curing the compressive strength reduces respectively by 47.79%,41.72 %, and 39.86 % with the addition of PET resin 5 %, 10%, and 15%

respectively same is shown in figure 4. This decrease in the strength could because of the separation of the interface between aggregate [17] and PET resin, and due to the addition of PET resin there might be absence of C3S and C2S most important compound which are responsible for hydration of cement paste.

Similar trend is observed with 20% and 30% PET to glycol ratio for 5%, 10%, and 15% PET resin content for normal water curing. In oven dry curing it is observed that cement gains early strength at 1 day curing as compare to normal cement mortar for all PET to glycol ratio and all resin contents, but at 28 days curing strength of normal cement mortar higher as compared to PET resin substitute for all PET to glycol ratio. It is observed that as PET to glycol ratio goes on increasing there is an improvement in compressive strength at all curing ages. Further increase in PET to glycol ratio may give desired results. Oven dry curing gives us good strength because of MF reacts with PET resin [18] and forms the ammonia curing agent. Among all the PET to glycol ratio, 30% PET to glycol ratio for mixture with 15% of resin content have shown good impact over substitute of cement.

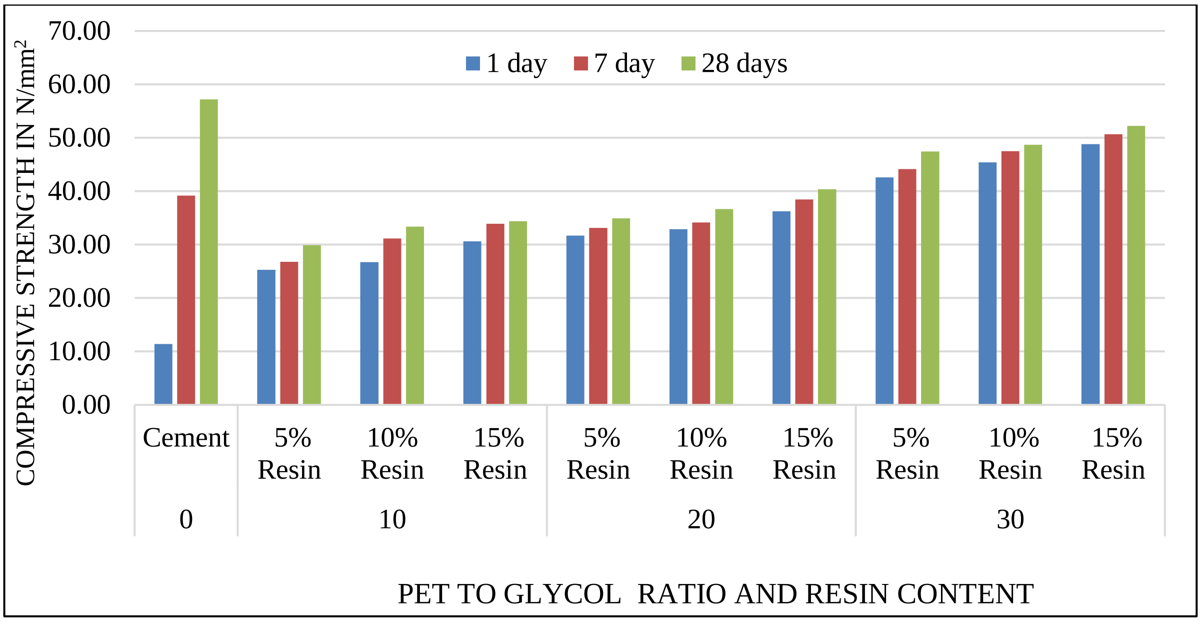

Figure 4 Compressive strength in oven dry curing at 1, 7, 28 days

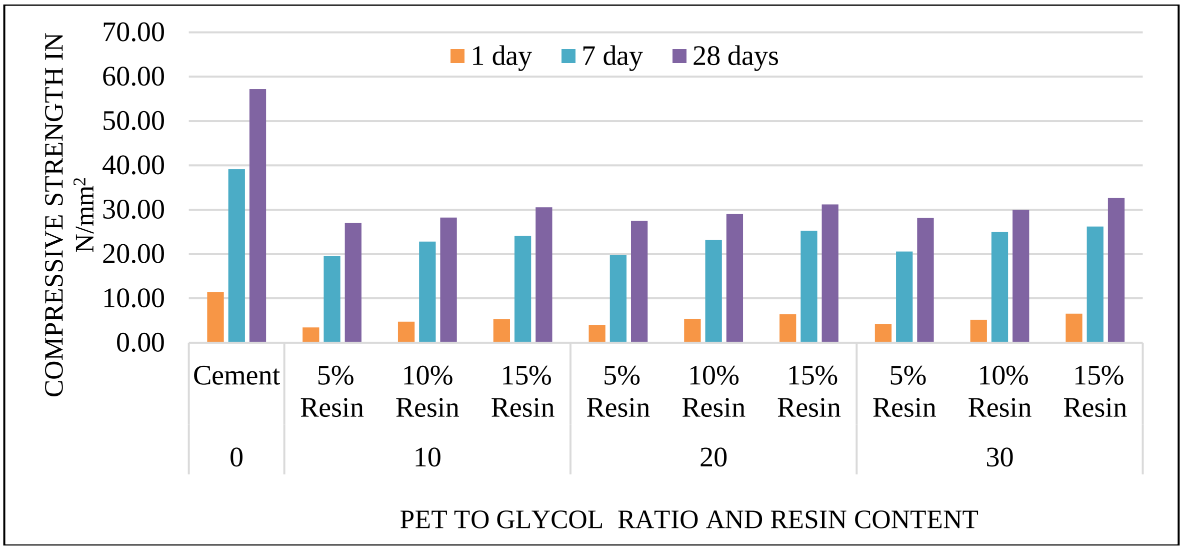

Figure 5 Compressive strength in normal curing at 1, 7, 28 days

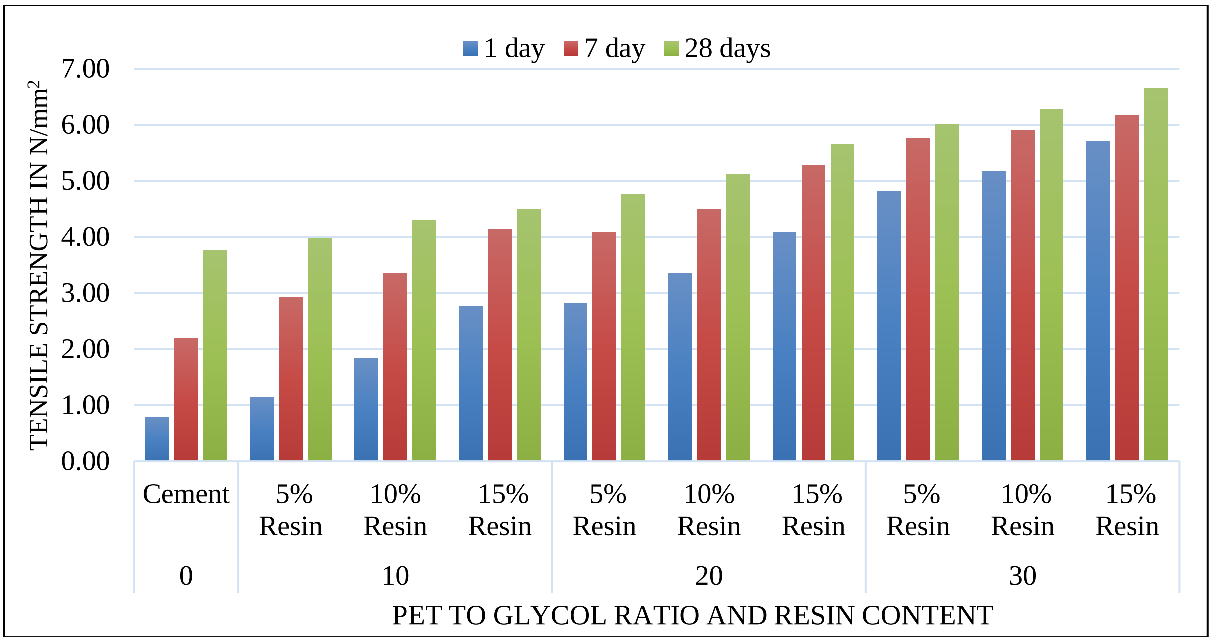

Figure 6 Tensile strength in oven dry curing at 1, 7, 28 days

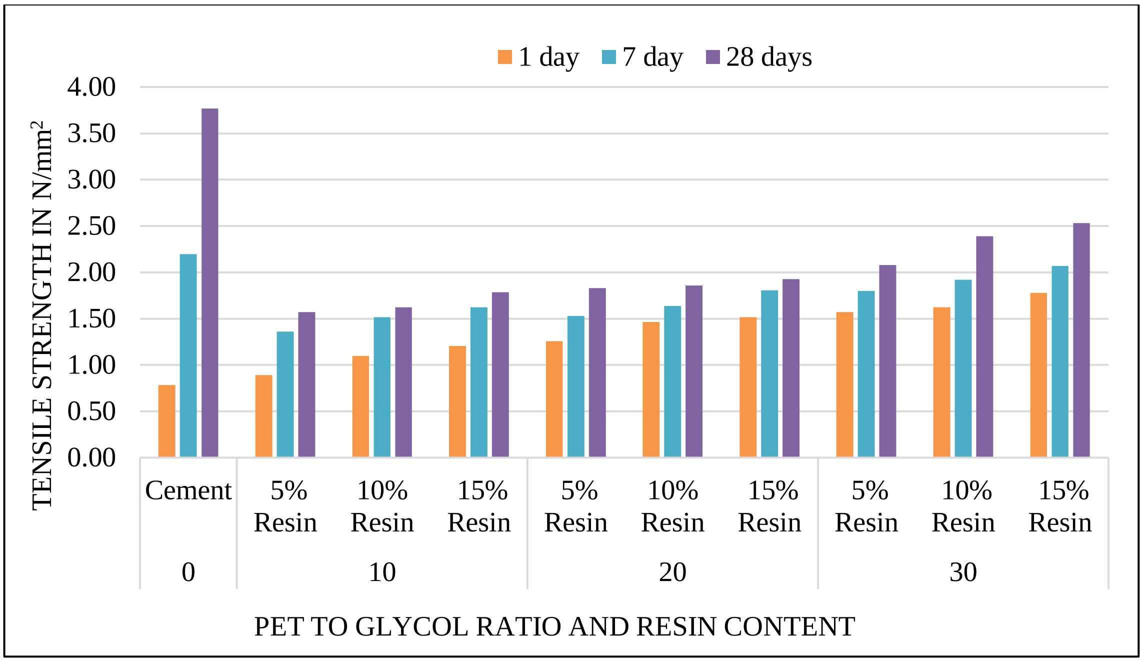

Figure 7 Tensile strength in normal curing at 1, 7, 28 days

Tensile Strength

The tensile strength of mortar is determined at 1, 7, 28 days of curing. Addition of PET resin in 5%, 10%, and 15% with a various PET to glycol ratio 10%, 20%, and 30% has shown excellent improvement in tensile strength of cement mortar under oven dry curing as compared to water curing as shown in fig.6.and figure 7. For 30% PET to glycol ratio 15% resin content gives the highest tensile strength at 28 days of curing is 6.64 N/mm^2. For 1 day oven dry curing 10% PET to glycol ratio there is gain in tensile strength 46.67%, 133.33%

and 253.33% respectively for 5%,10% and 15% resin content and for 28 days curing 5.56%, 13.89% and 19.44% gain is observed. There is minimum gain in tensile strength after 1 day curing for all PET to glycol ratio at all resin dosage. PET content goes on increasing it increase in tensile strength in oven dry curing. There is negative effect on tensile strength of mortar underwater curing because PET resin need curing agent to gain strength. It is observed that curing agent MF present in mix reacts only when specimen subjected to oven dry curing. There is a reduction in tensile strength in mortar at 28 days curing 58.33%, 56.94%, and 52.64% less as compared to normal cement mortar. This percentage reduces as PET to glycol ratio changes to 58.33% to 32.78% for 10% to 30% respectively for all resin content. Increase in tensile strength is because of the presence of PET act as bridging between particles when subjected to loading.

CONCLUDING REMARK

1) There is negligible reduction is noted for standard consistency with all PET to glycol ratio and PET resin content.
2) Soundness of cement does not get affected by the addition of PET resin in various percentages for PET to glycol ratio.
3) Initial setting time, final setting time and Slump flow increases as PET resin content increases in comparison with normal cement content specimen for all PET to glycol ratio.
4) PET resin and MF shows a reduction in compressive strength at all ages of curing in normal water curing.
5) At all PET resin content and PET to Glycol ratio, oven dry curing shows a positive impact on compressive strength at 1-day curing age in comparison with normal specimen. However, at 28 days curing age, the compressive strength is less in comparison with normal mix. This signifies that PET resin can be used in the applications where early strength is required.
6) PET resin increased the tensile strength of cement mortar under oven dry curing for all PET to glycol ratio and resin dosage, but underwater curing addition of PET resin have shown negative effect.

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