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Study on Flexural and Shear Behaviour of Metalized Plastic Waste Fibre Reinforced Green Concrete

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Abstract – *Metalized Plastic Waste (MPW) is a major kind of plastic waste produced mostly by the food packaging sector globally. MPW is unsuited for effective recycling, leads to pollution and garbage rise, and is hazardous to the environment. The use of cement in the construction of concrete structures has a substantial influence on environmental pollution due to the emission of carbon dioxide. Employing industrial by-products with pozzolanic reactivity as a cement substitute can minimise carbon dioxide emissions while also improving the hardened characteristics of concrete. In this investigation, MPW fibre is added to concrete at 0 %, 0.25 %, 0.5%, 0.75 %, and 1 % by total volume of concrete, with cement substituted with 10 % silica fume***.** *The optimum amount of MPW fibre in green concrete is determined by examining the fresh and hardened characteristics. Flexural and shear behaviours are investigated utilising the optimal dose of MPW fibres. In the case of flexural and shear behaviour studies, the optimal specimens achieve almost the same failure load as the control specimen. MPW fibre reinforcement improves fracture resistance and increases specimen ductility.*

Keywords: Metalized Plastic Waste (MPW) Fibres, Silica fume concrete, Sustainability, Mechanical properties, Flexural behaviour, Shear behaviour

1.INTRODUCTION

Metalized plastics are a non-bio degradable waste material mainly produced from the food packing industry. The constant demand for plastic in daily use by a growing population has led to an alarming rise in post-consumer plastic waste, posing a danger to the environment. The current scenario in food industry has led to large-scale production of metallised plastic wastes (MPW). MPW is relatively unsuitable for effective recycling because it is made by a polymer coated in a thin layer of aluminium film therefore the recycling is not cost effective and mainly contributes to littering and landfill expansion thus, posing an environmental hazard. Safe and sustainable disposal methods are needed for the safety of the environment, current and the future generation.

One of the industrial by-products obtained from the exhaust gases of ferrosilicon, silicon, and other metal alloy smelting furnaces is silica fume, sometimes referred to as micro silica. When added to Portland cement concrete. which primarily consists of amorphous (non-crystalline) silicon dioxide (SiO_2), enhances the material's properties, particularly its compressive strength, bond strength, and abrasion resistance. Silica fume, which is used in concrete due to its fine particles, large surface area, and high SiO_2 content, is a highly reactive pozzolan. The volume of big pores is significantly reduced in all ages when silica fume is included in concrete mixes made with regular Portland cement. Because of its fineness, it essentially serves as a filler. Compared to concrete without silica fume, it is more cohesive and less prone to segregation and bleeding.

In this study cement is replaced by 10 % silica fume. Silica fume is substituted with cement from 5 %-15 % further it decreases the mechanical properties [5]. The silica fume concrete provides an increased compressive strength compared to other cement replacing materials such as natural zeolite [1]. By analysing research works it is identified that the silica fume concrete can increase the mechanical strength than conventional concrete at 28 days curing [6] and 10 % replacement of cement with silica fume provides more mechanical strength [6]. Many studies are being undertaken to test the performance of MPW fibre in various types of concrete. There hasn't been a lot of research done on MPW fibres in silica fume-based concrete. There has been no research in to the behaviour of shear fractures in MPW fibre reinforced concrete.

The MPW fibres are added to the total volume of concrete at 0 %. 0.25 %. 0.5 %, 0.75 % and 1 %. The MPW fibres are. distributed uniformly throughout the concrete. A total of 5 mixes are prepared with different dosage of MPW Fibre. For compressive strength test cube specimens are casted with a size of 150 × 150 × 150 mm, cylinders are casted with a size of 150 mm diameter and 300 mm length for split tensile strength test, prisms are casted with a size of 100 × 100 × 500 mm for flexural test.

The optimum percentage value is used for conducting flexural and shear behaviour study of RC Beams. The flexural and shear behaviour was conducted in 1 m × 0.15 m × 0.15 m size beam specimen under three-point loading in Universal Testing Machine (UTM). The flexural and shear crack patterns were studied. The development of cracks with respect to the increase in load were observed and compared with the control specimen. The ability of MPW fibre to resist the development of crack is studied.

2.MATERIALS USED FOR THE STUDY

2.1Physical properties of the material used

1) Cement: For this experimental investigation OPC 53 grade cement is used. The details of the test results are provided in table.1.

Table-1: Properties of cement.

Properties	Results
Standard consistency	32 %
Fineness	8
Specific gravity	3.15
Initial setting time	40 minutes
Final setting time	330 minutes
Soundness	2mm

2) Silica fume: white silica fume powder is used here shown in figure 3. the test is conducted as per IS 15388: 2003. The details of the test results are provided in table.2.

Table-2: Properties of silica fume.

Properties	Results
Specific gravity	2.24
fineness	10
Surface area (m^3/kg)	20000

3) Coarse aggregate: the maximum size of aggregate used for this study is 20 mm and it is well graded. The details of physical properties are shown in table 3.

Table- 3: Properties of Coarse Aggregate.

Properties	Results
Specific gravity	2.7
Bulk density	1330 kg/ m^3
Void ratio	0.37
Porosity	0.268 %
Crushing value	18.3 %
Fineness modulus	3.035

4) Fine aggregate: M sand passing through 4.75 mm IS sieve is used as fine aggregate. The details of the test results are provided in table.4

Table- 4: Properties of Fine Aggregate.

Properties	Results
Specific gravity	2.7
Bulk density	1750 kg/m^3
Void ratio	0.35
Porosity	0.26 %
Bulking of sand	32.01 %
Fineness modulus	3.7

5) Metalized Plastic Waste Fibres: the waste metalized plastic waste covers are collected from the waste damped areas in public places shown in figure 1 and shredded into a size of 3 cm length and 0.5 cm width shown in figure 2. The properties of the MPW fibres are provided in the table 5

Table- 5: Properties of MPW fibre

Properties	Results
Size (W*L) cm	0.5x3
Density (kg/m^3)	925
Thickness	0.07 mm

6) Superplasticizer: Conplast SP 430 is used. Which provides increase in workability and increase in compressive strength and reduce the water cement ratio.
7) Water: Collected from local fresh water sources, pH should not be less than 6

Fig-1: Metalized Plastic Waste (MPW)covers collected

Fig- 2: Shredded MPW fibres

Fig- 3: Silica fume

2.2 Mix proportion

M 30 grade concrete mix is used for this study

- Cement=354.8 kg/m³
- Silica Fume=39.4 kg/m³
- Fine Aggregate=826.55 kg/m³
- Coarse Aggregate=1082.34 kg/m³
- Water=158 kg/m³
- Superplasticizer =3.9 kg/m³

3.RESULTS AND DISCUSSION

3.1 Workability

The addition of MPW fibres in concrete significantly changes the workability performance. The volume of MPW fibre in concrete increases the workability reduces. Best workability performance is observed at 0.25 % shown in fig 4. After that the workability of concrete is reduced according to the increase in fibre dosage.

Fig- 4: Slump obtained at 0.25 % MPW fibre dosage

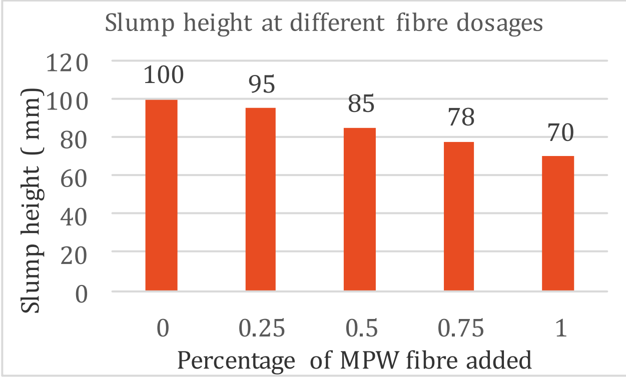

Chart-1: Relation between different MPW fibre dosage and slump height.

3.2 Compressive strength

The inclusion of MPW fibres in silica fume-based concrete reduces the compressive strength compared to the observed specimen as shown in chart-2

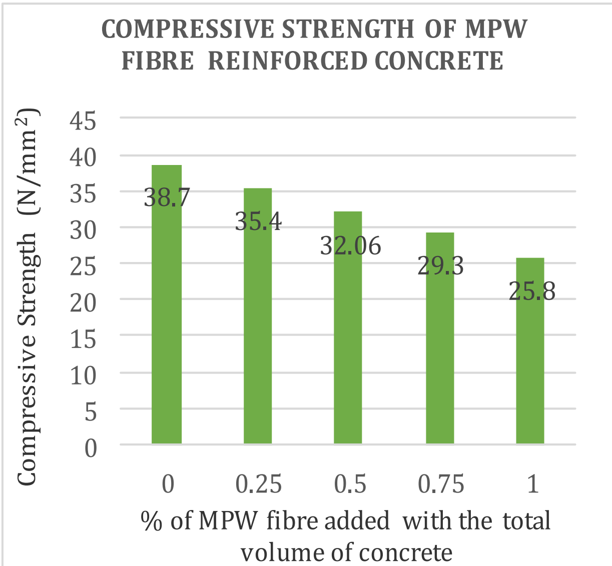

Chart-2: Compressive strength of cube specimens at different MPW Fibre dosages.

Fig -5: Fracture occurs in the cube at failure load

The slight reduction in the Compressive strength according to the increase in fibre dosage is mainly due to the low bonding and the physical characteristics of the MPW fibre in concrete. But the silica fume concrete is highly non segregative. It improves the bonding between the MPW fibre and the concrete. Therefore, the compressive strength obtained is much more than conventional concrete.

3.3 Split tensile strength

The split tensile strength of cylinder specimens shows an increase with the increase in the fibre dosage and there after it decrease with the addition of MPW Fibres shown in chart-3.

Fig-6: Fracture occurs in cylinder at failure load.

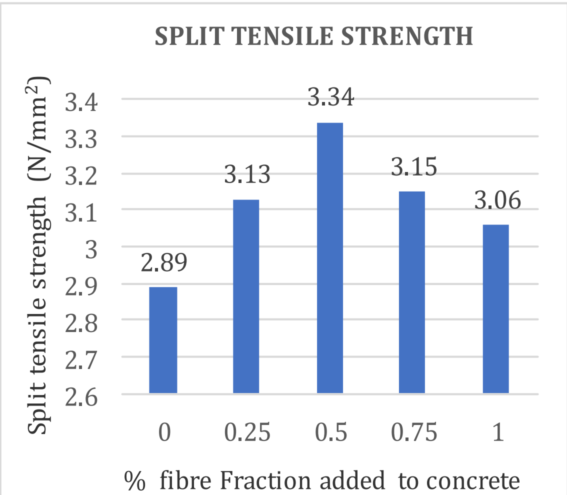

Chart-3: Split tensile strength with different MPW fibre dosages.

The split tensile strength increases up to 0.5 % this is happening because the fibres connected the split part of the specimen as splitting occurred across it and continued. As a result, this progressively maintained the tensile tension and prevented the concrete specimen from failing. The specimen's capacity to withstand strain is enhanced by their resistance to tension, which leads to increased splitting tensile strength.

3.4 Flexural Strength Test

A reduction is also observed in flexural strength compared to the observed specimen when the fibre dosage increases as shown in chart-4

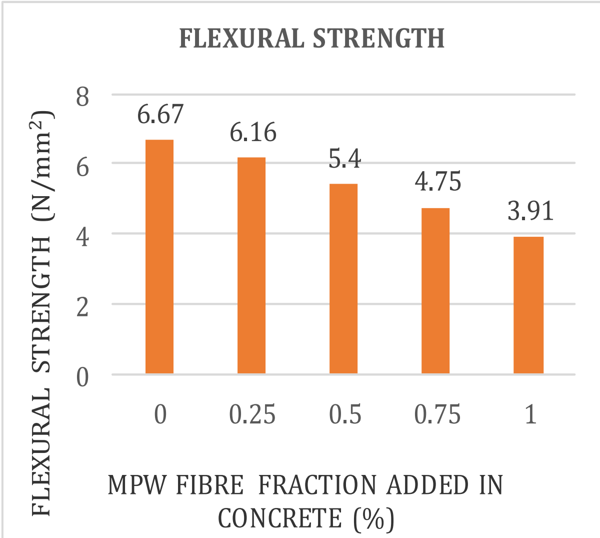

Chart-4: Flexural strength with different MPW fibre dosages

Along with compressive strength, flexural strength decreases as fibre dose increases. This is as a result of the MPW fibres in the concrete not adhering as well. In comparison to regular cement concrete, silica fume-based concrete achieves a higher flexural strength. The silica fume's high pozzolanic reactivity allows for significant pore modification, such as the reduction of larger pores, which strengthens the link between the concrete matrix and fibres.

3.5 Optimization study

The observed results demonstrate that as MPW fibre dose is raised, workability decreases. According to IS 456-2000, the 95 mm slump produced by this 0.25 % MPW fibre dose is appropriate for the construction of structural elements such beams, walls, and columns. The test findings showed that as the dose of MPW fibre is increased, the compressive and flexural strength falls. Up to a dose increase of 0.50 %, the split tensile strength of cylinder specimens increases; beyond that, it decreases with the addition of MPW fibres. According to the rising dose of fibre content, the addition of MPW fibres somewhat reduces the compressive strength and flexural strength. But the fresh and hardened properties are improved when silica fume is partially replaced with cement. It results in compressive and flexural strength for M30 grade concrete that is higher than desired strength. From the results it is clear that concrete can contain an ideal amount of MPW fibres. The necessary fresh and hardened qualities for M30 grade concrete are here provided by the addition of 0.25 % MPW fibre to the total volume of concrete.

3.6 Flexural behaviour

1000 mm x 150 mm x 150 mm R.C. beam specimen was cast to evaluate the flexural behaviour. Three beams are cast using 0 % MPW fibre reinforcement. It is preserved as a control specimen, and the remaining three beams are cast with 0.25 % MPW fibre reinforcement. The specimens are tested in a Universal Testing Machine (UTM). The crack patterns and crack propagation from the tension side to the compression side is analysed. The load deflection curve for both control and optimum specimen are plotted and compared.

Fig-7: Flexural crack formed in the MPW fibre reinforced beam at failure load.

Fig-8: Flexural crack formed in the observed specimen at failure load.

Figures 8 and 9 show that the MPW fibre reinforced beam is considerably resistant to fractures. The propagation of cracks from tension to compression is likewise shown to be quite limited.

Table- 6: Test results of flexural beams

Specimen	First crack load (kN)	Failure load (kN)
control	48	174
Best	44	172

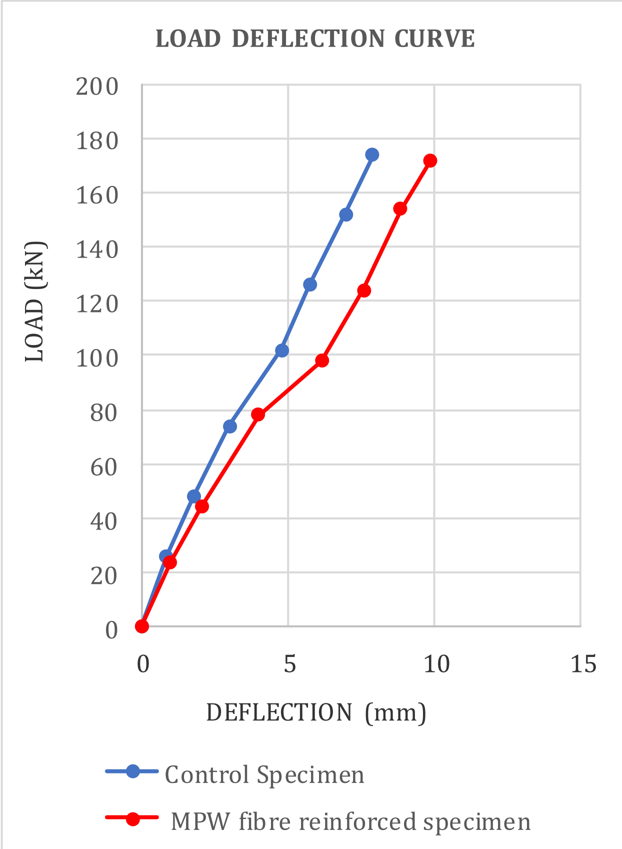

Chart-5: Load deflection diagram from flexural test

The failure loads of the control and optimal specimens are comparably quite similar. The MPW fibre reinforced beam exhibits a larger deflection than the control specimen, as seen by the load deflection curves. This reveals the ductile behaviour of the MPW reinforced concrete. The post load bearing capacity is improved by the increase in ductility, and the increased deflection also provides warnings before collapse.

3.7 Shear Behaviour

1000 mm x 150 mm x 150 mm R.C. beam specimen was cast to evaluate the shear behaviour. Three beams are cast using 0 % MPW fibre reinforcement. It is preserved as a control specimen, and the remaining three beams are cast with 0.25 % MPW fibre reinforcement. The specimens are tested in a Universal Testing Machine (UTM). The shear crack patterns are analysed. The load deflection curve for both control and optimum specimen are plotted and compared.

Fig-9: Shear crack formed in the control specimen.

Fig -10: Shear crack formed in the MPW fibre reinforced specimen

Figures 10 and 11 indicate that the MPW reinforcement provides significant shear crack resistance. Shear **cracks** emerge at a 45-degree angle to the support. The shear crack developed in the MPW fibre reinforced specimen limits crack propagation to the upper portion of the specimen.

Table-7: Test results of shear behaviour of beam specimens

Specimen	First crack load (kN)	Ultimate load (kN)	Ultimate shear capacity N/mm²
Control	58	196	4.35
Best	60	194.6	4.33

The ultimate shear load and ultimate shear capacity of the MPW fibre reinforced specimen are slightly lower than those of the control specimen, which are nearly identical. The load deflection curve of the shear behaviour investigation (chart-6) shows that the MPW fibre reinforced specimen exhibits greater deflection than the control specimen. It improves the post-load carrying capacity and lowers brittle failure.

MPW reinforced fibres in concrete will retain structural integrity because they hold the concrete together when a fracture forms and hence resist crack development. The bridging activity of the fibres in concrete also contributes to the increase in deflection of the MPW reinforced specimens.

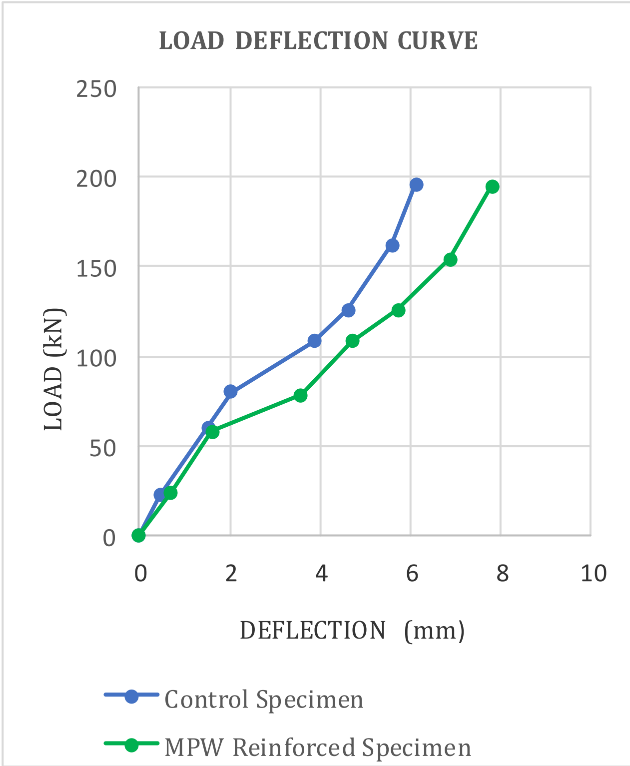

Chart-6: Load deflection diagram from shear test

4. CONCLUSIONS

The major conclusions obtained from the study is detailed below

- The inclusion of MPW fibres reduces compressive and flexural strength in proportion to the dose of fibre content. However, silica fume base concrete increases both fresh and hardened concrete characteristics. As a result, the compressive and flexural strengths are greater than in traditional concrete.

- The split tensile strength is seen to increase in the first two doses of MPW fibre, 0.25 % and 0.5 %, then to drop further at 0.5 %.

- Here, the necessary fresh and hardened characteristics of M30 grade concrete are provided by the addition of 0.25 % MPW fibre to the total volume of concrete.

- In the case of flexural behaviour, the optimal specimen's failure load is reduced by 1.14 % than control specimen, which is extremely slight and nearly identical.

- In the case of shear behaviour, the percentage difference in the failure load of the MPW reinforced beam is 0.71% lesser than that of the control specimen, which is extremely small and nearly identical.

- ❖ The addition of MPW fibres to concrete, on the other hand, can boost the fracture resistance of beam specimens. When comparing the MPW fibre reinforced beam specimen to the control specimen, the load to deflection rate increases. It prevents brittle failure and increases post-crack loading and ductility.

- ❖ The findings obtained demonstrate that silica fume and MPW fibre inclusion can be employed with acceptable technological properties. It may be applied to the construction of both structural and non-structural applications, such as buildings, roads, and pavements. Utilising this kind of concrete is a sustainable strategy that may also help to prevent environmental pollution.

5. FUTURE SCOPE

The current study investigates the effects of MPW fibres in silica fume-based concrete. Future research can be expanded. The efficiency of MPW fibre may be assessed using various cement-substituted concretes. Extended curing durations can be investigated to discover how concrete's hardened qualities have improved.

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