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Experimental Study On Reuse Of Single Use Surgical Mask In Concrete

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Abstract
The global surge in the use of single-use surgical masks during the COVID-19 pandemic has resulted in an unprecedented accumulation of plastic waste, primarily composed of non-biodegradable polypropylene. Improper disposal of these masks poses a serious environmental threat, contributing to microplastic pollution in terrestrial and aquatic ecosystems. This study presents an innovative approach to mitigate this crisis by repurposing shredded surgical masks as a partial additive in concrete. The research aims to assess the environmental viability of mask incorporation while analyzing its effect on the physical integrity of concrete, particularly in terms of strength development and long-term durability. By embedding polymeric fibers from discarded masks into cementitious matrices, this study aligns with sustainable waste management strategies and circular economy principles. The proposed method offers a dual benefit: reducing pandemic-induced plastic pollution and enhancing concrete's structural characteristics. The outcomes demonstrate the potential for transforming hazardous medical waste into a value-added component in construction materials, contributing to both environmental conservation and sustainable infrastructure development.

INTRODUCTION

The widespread use of single-use surgical masks during the COVID-19 pandemic has resulted in an alarming increase in plastic-based medical waste, with significant implications for environmental sustainability. These masks, primarily composed of polypropylene, are not biodegradable and often end up in landfills, public spaces, and aquatic ecosystems due to improper disposal practices. Over time, they fragment into microplastics, contributing to long-term ecological degradation and posing serious threats to marine life and terrestrial biodiversity. Despite global guidelines for proper disposal, lack of awareness and inadequate infrastructure have led to the uncontrolled release of this waste into the environment, making it one of the most visible forms of pollution emerging from the pandemic.

Considering these concerns, there is a growing need to identify sustainable and scalable solutions for managing single-use mask waste. Rather than relying solely on conventional disposal methods such as incineration or landfilling both of which carry environmental and health risks recycling and repurposing this material offer a more environmentally responsible alternative. Repurposing non-biodegradable materials like polypropylene into other industrial applications aligns with circular economy principles and supports global sustainability goals. This study is driven by the vision of transforming a public health necessity into an opportunity for environmental innovation, demonstrating how pandemic-related waste can be redirected from pollution pathways toward productive reuse in critical sectors like construction.

Objectives

This research aims to explore a sustainable approach for managing single-use surgical mask waste by incorporating it into concrete. The following objectives are established to evaluate both the environmental benefits and the engineering performance of the modified concrete mix:

To evaluate the environmental viability of incorporating shredded single-use surgical masks into concrete as a sustainable method for mitigating pandemic-related plastic pollution.
To investigate the influence of polypropylene-based mask fibers on the mechanical properties of concrete, specifically focusing on compressive and tensile strength performance.
To assess the durability characteristics of the modified concrete through targeted laboratory tests, examining its resistance to degradation under environmental exposure.
To determine the practical applicability of the modified concrete mix for use in industrial, non-structural, and temporary construction applications, promoting circular economy principles within the construction sector.

Literature Review

The unprecedented surge in personal protective equipment (PPE) usage during the COVID-19 pandemic has prompted researchers to explore sustainable disposal and reuse methods for these plastic-based materials, particularly single-use surgical masks composed of polypropylene. Several studies have investigated the integration of such waste into concrete to assess its viability as a reinforcing or modifying agent.

Shannon Kilmartin-Lynch et al. (2021) conducted a preliminary evaluation on incorporating shredded surgical masks into M30 grade concrete at varying proportions (0%, 0.15%, 0.2%, and 0.25% by volume). Their results revealed that mechanical properties such as compressive and tensile strength showed improvement up to 0.2% addition, followed by a marginal reduction at 0.25%. Nevertheless, all modified mixes outperformed the control mix (0%), suggesting that surgical masks at lower percentages can enhance strength while reducing micro-cracking, thereby improving overall concrete integrity.

Harish T. Mohan et al. (2021) examined the potential reuse of shredded PPE waste in M20 grade concrete using both river sand and M-sand. The fibers were incorporated at 2%, 4%, and 6% volume replacements. Their findings indicated an increase in compressive strength with higher PPE content, especially in mixes with river sand. However, a gradual decline was observed in flexural and split tensile strength at higher fiber ratios, emphasizing the need to optimize dosage for balanced performance.

Ranjan Kumar Gupta (2021) further explored the reuse of medical PPE kits in M30 concrete, incorporating shredded fibers at 0.1%, 0.15%, 0.2%, and 0.3% by volume. Compressive, tensile, and flexural strengths were tested at 7, 14, and 28 days. The study reported peak strength at 0.15% addition, after which the values declined, reinforcing the hypothesis that low-percentage inclusions of PPE waste can positively influence mechanical performance without compromising structural integrity.

Marta Castellote et al. (2022) investigated the effect of mask waste on cementitious materials by replacing 0%, 1%, 2.5%, and 5% of cement weight with shredded mask fibers. The study found a progressive reduction in compressive strength with increased mask content, with a 44% drop at 5% replacement. However, flexural strength remained relatively unaffected, and mortar appearance remained acceptable. This suggests a trade-off between sustainability and performance, highlighting the importance of maintaining mask content within optimal limits.

Malek et al. studied the influence of recycled polypropylene (PP) fibers on concrete's mechanical behavior at 0.5%, 1%, and 1.5% by weight of cement. A significant reduction in compressive, flexural, and tensile strengths was observed with all fiber types, though certain fiber forms (PPg) performed better than others. These results underline the critical role of fiber morphology, dispersion, and dosage in achieving desirable concrete performance when integrating plastic waste.

Collectively, the reviewed studies indicate that while polypropylene-based PPE waste, including surgical masks, holds potential for reuse in concrete, its effectiveness is highly dependent on fiber size, percentage, and mix design. Low-volume additions generally enhance certain mechanical properties, but excessive incorporation may impair structural performance. These findings provide a foundation for further investigation into optimized methodologies for incorporating surgical mask waste into concrete for sustainable construction solutions.

Methodology

The experimental methodology involved a systematic approach to processing single-use surgical masks and incorporating them into concrete. Various stages, including sterilization, thermal treatment, mechanical processing, and concrete mix preparation, were carried out in accordance with relevant Indian Standards.

The following table summarizes the key steps and procedures involved in the reuse of surgical mask waste in concrete applications:

Table.1. Materials Processing and Concrete Mix Methodology

Section	Procedure	Key Details
Concrete Mix Details	M20 grade concrete (1:1.5:3) used as the base mix.	Target strength: 20 MPa at 28 days; designed as per IS 10262:2019.
Collection & Sterilization	Masks collected from hygienic sources and sterilized in a UV chamber.	Ensures safety and removal of biological contaminants.
Thermal Processing	Pyrolysis in a muffle furnace at 600°C for 10 minutes.	Conducted in oxygen-deficient conditions to produce carbonized residue.
Powdering	Residue crushed and pulverized to fine powder.	Particle size similar to fine aggregates.
Specific Gravity	Measured using the density bottle method (IS 2720).	Specific gravity ≈ 1.27; indicates lightweight nature.
Shredding	Masks shredded into 2 cm × 1 cm fibers after removing non-polymer parts.	Maintains aspect ratio for proper bonding in concrete.
Mix Proportions, Casting, and Curing	Processed masks added to concrete in various proportions (0.1–0.3% powder; 1–2% fibers).	Specimens cast into cubes, cylinders, and beams; cured for 28 days before testing per IS codes.

Test on Concrete

Concrete samples incorporating shredded and powdered surgical masks were tested for mechanical and durability performance. Compressive, split tensile, and flexural strength tests showed improved results with 0.2% shredded mask content due to effective fiber reinforcement. Powdered masks, however, led to strength reduction due to poor bonding. The carbonation test confirmed no carbonation, indicating good durability. Overall, shredded mask fibers enhanced structural properties and sustainability of concrete.

Compressive Strength Test

The compressive strength test evaluates the load-bearing capacity of concrete, which is critical for structural applications. In this study, concrete cubes (100 mm × 100 mm × 100 mm) were cast with varying percentages of single-use surgical masks in shredded and powdered form. After 28 days of water curing, the cubes were tested using a Compression Testing Machine (CTM) in accordance with IS 516:1959. The compressive strength was calculated using:

$$\text{Compressive Strength } (\text{N/mm}^2) = \frac{\text{Load at Failure (N)}}{10000}$$

Table.2. Compressive Strength Results

Mask Form	% Mask	Avg. Load (kN)	Compressive Strength (N/mm²)
Shredded	0.0	210	21.00
Shredded	0.1	220	22.00
Shredded	0.2	240	24.00
Shredded	0.3	226	22.67
Powdered	1.0	206	20.66
Powdered	1.5	203	20.33
Powdered	2.0	187	18.67

Concrete with shredded surgical masks showed improved compressive strength, peaking at 24.00 N/mm² with 0.2% addition, compared to 21.00 N/mm² for the control mix. The increase is due to fiber reinforcement enhancing load transfer. Strength decreased slightly at 0.3% due to poor matrix bonding. In contrast, the powdered mask form resulted in reduced strength, dropping to 18.67 N/mm² at 2.0%, indicating poor bonding and increased porosity. Shredded masks are more effective for improving compressive strength in concrete.

Split Tensile Strength Test

To evaluate the tensile behaviour of concrete containing shredded and powdered forms of surgical mask waste, a split tensile strength test was conducted in accordance with ASTM C496 and IS 5816:1999. This test is critical for assessing the cracking resistance and structural performance of concrete, particularly in applications where tensile stresses are significant. Concrete cylinders with dimensions of 150 mm diameter and 300 mm height were cast and cured for 28 days. The specimens were then tested using a Compression Testing Machine (CTM) by applying load diametrically until failure. The tensile strength was calculated using the formula:

$$Split\,Tensile\,Strength\left(\frac{N}{mm^2}\right) = \frac{2P}{\pi DL}$$

Where
PPP = Load at failure in Newtons
DDD = Diameter of the cylinder (150 mm)
LLL = Length of the cylinder (300 mm)

Table.3. Split Tensile Strength Results

Mask Form	% Mask	Load at Failure (kN)	Split Tensile Strength (N/mm²)
Shredded	0.0	200	2.829
Shredded	0.1	223 (avg.)	3.159
Shredded	0.2	233 (avg.)	3.302
Shredded	0.3	203 (avg.)	2.876
Powdered	1.0	197 (avg.)	2.781
Powdered	1.5	193 (avg.)	2.734
Powdered	2.0	183 (avg.)	2.593

All samples were tested under a loading rate between 1.2 and 2.4 MPa/min using CTM with 10 kN/div least count. The results demonstrate that the inclusion of 0.1% to 0.2% shredded surgical masks enhanced the tensile strength of concrete, with peak performance observed at 0.2%. Beyond this level, strength declined slightly. In contrast, powdered mask additions showed a consistent reduction in tensile strength. This indicates that shredded mask fibers contribute more effectively to tensile behaviour by bridging microcracks, whereas powdered forms offer limited structural reinforcement.

Flexural Strength Test (Modulus of Rupture)

Flexural strength, or Modulus of Rupture (MR), is an indirect measure of the tensile strength of concrete, indicating its ability to resist bending. In this study, concrete beam specimens (500 mm × 100 mm × 100 mm) were tested after 28 days of curing using a Universal Testing Machine (UTM) to evaluate the effect of shredded and powdered single-use surgical masks. The test followed standard procedures, with load applied through a two-point loading setup. The flexural strength was calculated using the standard formula

$$Flexural\,Strength\,(MR) = \frac{PL}{bd^2}$$

Where,
P = Ultimate load (N)
L = Effective span length (mm)
b = Width of the specimen (mm)
d = Depth of the specimen (mm)

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Table.4. Flexural Strength Test Results

Mask Form	Mask Content (%)	Crack Distance (mm)	Load (kN)	Flexural Strength (MPa)
Shredded	0.0	170	3.4	2.38
Shredded	0.1	180	3.5	2.44
Shredded	0.2	190	3.6	2.51
Shredded	0.3	200	3.3	2.31
Powdered	0.0	170	3.4	2.38
Powdered	1.0	165	2.9	2.17
Powdered	1.5	163	2.8	2.03
Powdered	2.0	161	2.7	1.96

Shredded surgical mask fibers enhanced the flexural strength of concrete, with optimal performance at 0.2% dosage due to effective crack-bridging. In contrast, powdered masks reduced performance, likely from poor bonding. This demonstrates that small amounts of shredded mask fibers can improve concrete's tensile behavior and support sustainable waste reuse.

Carbonation Test of Concrete

The carbonation test was conducted to evaluate the effect of incorporating shredded single-use surgical mask (SM) fibers on the durability of concrete. Carbonation occurs when atmospheric carbon dioxide reacts with calcium hydroxide in the cement matrix, reducing the pH and increasing the risk of reinforcement corrosion. The phenolphthalein indicator method was used by spraying a 0.2% phenolphthalein solution on freshly broken or drilled concrete surfaces. A pink color indicates uncarbonated (alkaline) zones, while colorless areas indicate carbonation. The depth of carbonation was measured at multiple points and averaged. The inclusion of SM fibers may influence concrete porosity and gas permeability, affecting carbonation resistance and overall durability.

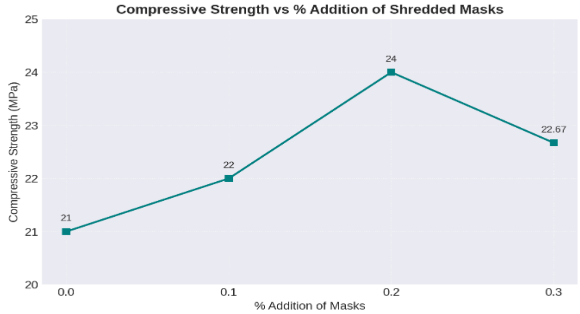
RESULTS AND INTERPRETATIONS

The research revealed that shredded surgical masks improve the mechanical performance of concrete, with optimal results at 0.2% addition. This enhancement is due to the fiber-like action that delays crack propagation and improves internal bonding. The powdered form showed reduced strength, indicating poor dispersion and bonding. Carbonation tests showed no change in alkalinity, confirming the durability of the mixes. These results support the potential use of shredded masks in structural concrete applications.

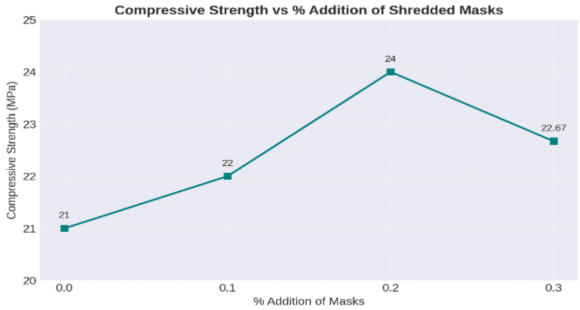
Compressive Strength Test

The compressive strength test revealed that shredded surgical masks enhance concrete strength, with the highest improvement of 20% observed at 0.2% addition. This is due to the fiber-like behaviour of the shredded masks, which delay crack formation and improve internal bonding.

However, at higher dosages, a decline in strength occurred, likely due to reduced bonding efficiency caused by increased mask content. In contrast, the powdered form consistently showed lower strength than the control mix due to poor bonding properties and non-uniform dispersion, making it suitable only for non-structural or temporary applications.



Shredded Mask Content



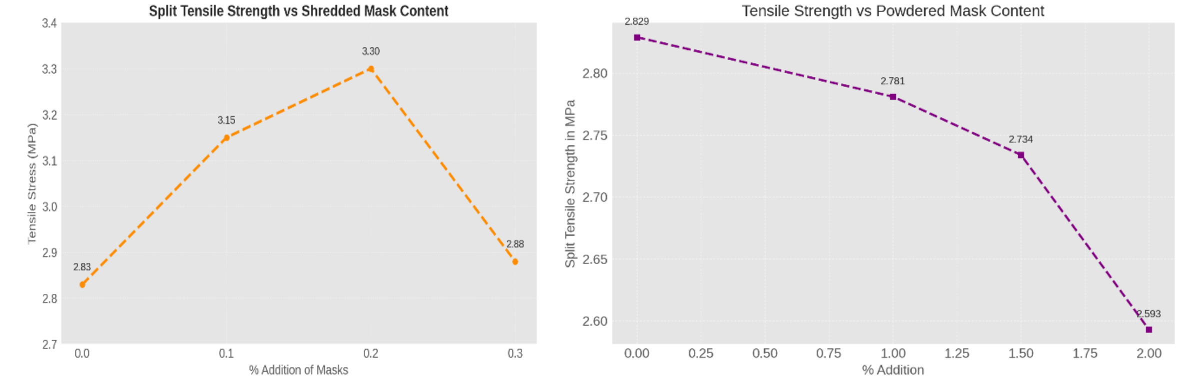
Powdered Mask Content

Fig.1. Compressive Strength vs Shredded Mask Content and Powdered Mask Content

Split Tensile Strength Test

Like compressive strength, the shredded mask form outperformed the powdered form in tensile strength. At 0.2% addition, a peak increase of 16.7% was recorded. The fibrous nature of the shredded masks contributed to crack resistance and improved stress distribution.

Higher percentages led to reduced strength due to fiber clustering. The powdered form showed inferior results, reinforcing its limited applicability in structural components.



Shredded Mask Content Powdered Mask Content

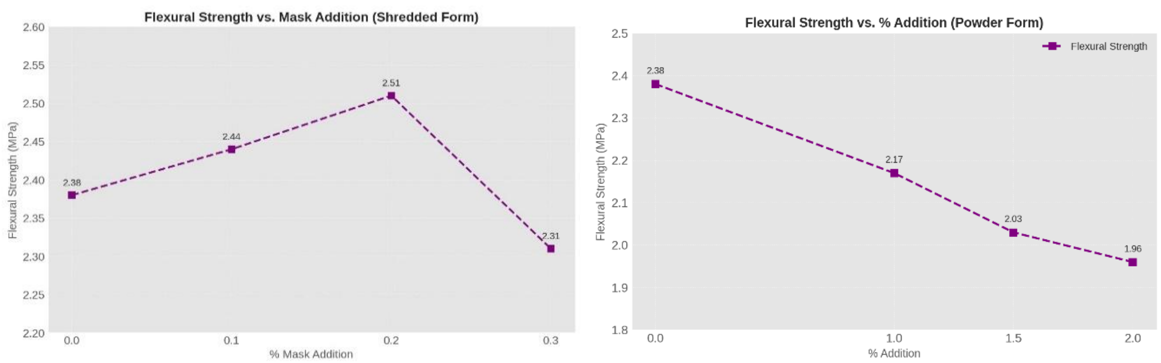
Fig.2. Tensile Strength vs Shredded Mask Content and Powdered Mask Content

Flexural Strength Test

Flexural testing, performed only on the shredded form, followed a similar trend. The strength increased up to 0.2% addition, then declined.

This confirms the reinforcing effect of shredded masks under bending loads. The flexural strength was calculated using:

$$Flexural\ Strength\ (MR) = \frac{PL}{bd^2}$$



Shredded Mask Content Powdered Mask Content

Fig.3.Flexural Strength vs. Shredded Mask Content and Powdered Mask Content

Carbonation Test

All specimens exhibited no signs of carbonation, indicated by a uniform pink coloration upon phenolphthalein application. This confirms that the inclusion of mask materials did not affect the alkalinity or durability of the concrete.

Fig.4.No Carbonation

CONCLUSION

In conclusion, the experimental investigation demonstrated that incorporating shredded single-use surgical masks into concrete significantly improved mechanical performance, particularly in terms of compressive, tensile, and flexural strength, with the 0.2% shredded mask mix yielding the most notable enhancements. The delayed onset of cracking observed in shredded-mask samples confirms their role as micro-reinforcing fibers, enhancing ductility. In contrast, the powdered mask form exhibited inferior performance compared to the control mix, suggesting its limited use in non-structural or temporary applications. Carbonation tests confirmed the durability of all specimens, indicating sound internal quality. The successful integration of sterilized masks into concrete presents a viable solution for sustainable waste management, leveraging the inherent polypropylene content to enhance concrete performance while simultaneously addressing environmental concerns related to plastic pollution. These findings affirm that properly processed surgical masks can be repurposed into concrete to improve structural performance and promote eco-friendly construction practices.

REFERENCES

1. American Society for Testing and Materials ASTM C293 – Standard Test Method for Flexural Strength of Concrete.
2. American Society for Testing and Materials C496-96 Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.
3. British adoption of a European (EN) standard Carbonation Test BS EN 14630:2006.
4. Bureau of Indian standards, Code of practice for a plain and reinforced concrete IS: 456-2000.
5. Bureau of Indian standards, Method of Tests for Strength of Concrete IS 516 (1959).
6. Desi Corbett (2021), 'PPE waste in concrete proves promising', Editor of Concrete in Australia, https://concreteinstitute.com.au/ppe-waste-in-concrete-proves-promising.
7. Harish T.Mohan , Karingamanna Jaya Narayanan, K.M.Mini (2021), 'A sustainable approach for the utilization of PPE biomedical waste in the construction sector', https://www.sciencedirect.com/science/article/pii/S2215098621001816.
8. Marta Castellote , Eva Jiménez-Relinque , María Grande, Francisco J. Rubiano and Ángel Castillo (2022) 'Face Mask Wastes as Cementitious Materials: A Possible Solution to a Big Concern', Institute of Construction Science Eduardo Torroja (IETcc-CSIC), 28050 Madrid, Spain.
9. RANJAN KUMAR GUPTA (2021) Experimental study on reuse of Waste Medical PPE kit in concrete. IARJSET. (n.d.). Vol. 8, from https://iarjset.com/papers/experimental-study-on-reuse-of-waste-medical-ppe-kit-in-concrete.
10. Yakin Ouederni. (2021, April 21). Construction Team Makes Use of Discarded Masks, Gloves in Concrete. The American University in Cairo. Retrieved March 15, 2022, from https://www.aucegypt.edu/news/construction-team-makes-use-discarded-masks-gloves-concrete.