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The Viability of Incorporating Single-Use Surgical Masks into Concrete Blends Through Recycling and Reuse

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Recycling mask waste and reusing it in building materials can be a viable way to address environmental issues. This study aims to assess the viability of recycling and reusing single-use surgical masks in concrete mixtures, thereby improving the structure of concrete, leading to enhanced mechanical characteristics and durability. The method employed is a literature review of previous researchers' works. This article is based on primary reference sources from Research Gate, Science Direct, and Google Scholar. It was found that incorporating mask waste into concrete mixtures can increase compressive strength, tensile strength, flexural strength, exhibit no significant degradation at high temperatures, demonstrate better corrosion resistance, and enhance the overall quality of the concrete mix. Reducing medical waste that ends up in landfills or pollutes the environment by providing a solution to recycle surgical masks into construction materials and providing a foundation for further research to test the effectiveness and safety of using medical waste in various other construction applications. The novelty of this research lies in exploring innovative approaches to managing medical waste, specifically surgical masks which often become a source of environmental pollution. By attempting to reuse them in the construction industry, particularly in concrete mixtures, this research broadens the concept of sustainable waste management efforts.

Keywords: Recycling, Reusing, Improving, Mask waste, Concrete.

1. Introduction

The global impact of the coronavirus pandemic, which emerged in late 2019, swiftly halted various aspects of life, influencing economies, healthcare systems, and people's livelihoods worldwide (Boroujeni et al., 2021). During the period from 2019 to 2021, the COVID-19 pandemic led to the widespread use of disposable masks and other personal protective equipment (PPE) as effective means to mitigate the transmission of the virus (Selvaranjan et al., 2021). This has resulted in a significant increase in mask waste production. The surge in mask usage has the potential to pollute water, soil, and the environment, negatively impacting various living organisms (Mohammadhosseini et al., 2021). To reduce medical mask waste that can pollute the environment, the best step is to recycle it.

A potential solution to this problem involves recycling mask waste and incorporating it into building materials, which can reduce global waste generation and improve the performance of concrete (Meng et al., 2018). Given that such waste may contain infectious pathogens, the recycling process should include a thorough disinfection step. Storing such waste for nine days and using disinfectants can effectively deactivate the virus, thereby mitigating the potential for additional infection (Ilyas et al., 2020). Face masks typically consist of polypropylene (PP) fibers, which can be used as a reinforcing component in concrete (Wang et al., 2021). Polypropylene fibers help manage cracking caused by shrinkage and enhance rupture resistance in concrete. The recommended dosage of these fibers in concrete typically ranges from 0.1% to 2% based on the concrete volume for optimal outcomes (Idrees, 2020).

Kilmartin-Lynch et al. (2021) conducted research that presented a novel method for incorporating disposable face masks into the production of concrete. This method utilizes widely accessible cement and aggregates in Australia, incorporating varying levels of waste masks (0.10%, 0.15%, 0.20%, and 0.25%) to assess the impact on enhancing concrete's mechanical characteristics. The study involved cutting face masks into pieces and shreds before incorporating them into the concrete mix. The results showed an increase in concrete strength with the addition of mask waste up to 0.20%, with strength starting to decrease at 0.25%. Additionally, research conducted by Aal et al. (2022) incorporated mask waste at various levels (0%, 1%, 1.5%, 2.0%, and 2.5%) with tests targeting Split Tensile Strength (STS), Unconfined Compressive Strength (UCS), Flexural Strength (FS), and Permeability Value (PV). These tests aimed to gauge the consistency of the concrete and evaluate any enhancements in its mechanical properties. The findings indicated that the inclusion of mask waste improved the strength characteristics and overall effectiveness of the concrete samples, with the intensity of enhancement diminishing at the 2.5% level.

This research article review aims to determine the viability of recycling and reusing single-use surgical masks in concrete mixes as an effort to limit the volume of waste generated during the pandemic, which has emerged as a significant environmental concern. Additionally, it aims to assess the effect of adding disposable surgical masks on the performance of concrete mix as a construction material. This review paper draws from various references and existing literature.

2. Literature Review

2.1. Mask

Respiratory protection used to protect people from inhaling hazardous substances or airborne contaminants is known as a mask. Respiratory protection, such as masks, is not meant to substitute preventive measures that can eliminate diseases but rather aims to offer adequate protection to the wearer (Cohen & Birkner, 2012). In this study, a specific type of mask under consideration is the medical mask, typically crafted from a type of non-woven fabric known for its soft and thin surface, durability, effective absorption, strength, and a high melting point of 165ºC, allowing short-term use at temperatures up to 100ºC (Ririn et al., 2021). The mask is composed of three layers: melt-blown material makes up the central layer, and non-woven fabric that is waterproof makes up the outer and inner layers (Fadare & Okoffo, 2020). The primary roles of these layers, as illustrated in Fig. 1, include the inner layer collecting fluids released from the mouth, the middle layer acting as a filter, and the outer layer offering waterproofing (Sunda, 2020).

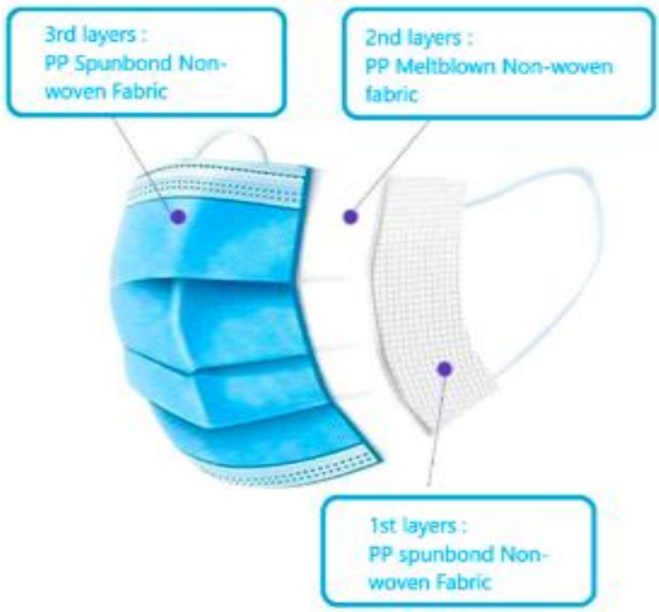

Figure 1. Three-layer Medical Mask

Source: Goli and Sadeghi (2022)

2.2. Physical properties of Disposable Surgical Mask

The Surgical Mask has dimensions measuring approximately 175 mm in length and 95 mm in width. Its composition includes non-woven polypropylene fiber material for both the outer and inner layers, while the middle layer is constructed from melt-blown fabric (Dowd et al., 2020). To maintain uniformity in the fiber material, two ear straps and the metal nose wire were removed.

Table 1. Physical Properties of Disposable Surgical Mask

Physical Properties	Surgical Mask
Specific gravity	0.91
Softening point (°C)	160
24-hour water absorption (%)	8.9
Tensile strength (MPa)	4.25
Tensile strength at break (MPa)	3.97
Extension break (%)	118.9
Breaking strength (N)	19.46
Aspect ratio	24

Source: Saberian et Al. (2021)

The density value of 0.91 indicates that this mask is lighter than water (density of water = 1). This means the mask is quite light, suitable for long-term use without adding excessive weight on the wearer. A softening point of 160°C shows that the mask material is fairly heat-resistant and will not easily melt or deform at temperatures below 160°C.The 8.9% water absorption value indicates that the mask material can absorb up to 8.9% of its weight in water over 24 hours. This provides insight into the absorbency and potential moisture the mask can handle during use. A tensile strength of 4.25 MPa indicates the material's ability to withstand tensile forces before experiencing permanent deformation or breaking. The tensile strength at break of 3.97 MPa represents the maximum strength the material can achieve before it fails or breaks. The 118.9% elongation at break shows that the mask is quite elastic and can stretch to more than twice its original length before breaking. The breaking strength of 19.46 N indicates the amount of force the mask can withstand before breaking. An aspect ratio of 24 means that the material's length is 24 times greater than its width, giving an idea of the shape and proportions of the mask.

Overall, these physical properties indicate that the surgical mask has good strength, high elasticity, moderate water absorption capacity, and is heat-resistant. The mask is designed to provide effective protection while remaining comfortable to wear.

Tabel 2. Composition of Mask Materials

Element	Weight (%)
Ca	25.85
Si	59.11
Mg	2.94
Al	9.99
K	2.11

Source: Ali et al. (2022)

Calcium is typically used in the form of calcium carbonate ($Ca\ CO_3$) as a filler or additive in various materials. Calcium can enhance the stiffness and strength of the material, as well as reduce production costs. Silicon, in the form of silica ($Si\ O_2$), is a major component. Silica provides good mechanical strength, high-temperature resistance, and chemical stability. The high silica content indicates that this material likely has excellent mechanical and thermal properties. Magnesium can be used to increase the strength and hardness of the material. Additionally, magnesium contributes to the material's ability to withstand tensile loads. Aluminums is usually added to improve strength, corrosion resistance, and thermal stability. Aluminums is also lightweight, which helps keep the mask's weight low. Potassium is typically found in compounds such as potassium carbonate (K_2CO_3). Even in small amounts, potassium can influence the chemical and physical properties of the material, such as enhancing solubility and reactivity.

This composition shows that the surgical mask material is designed to have good mechanical strength, high-temperature resistance, and chemical stability. Elements like silicon, aluminums, and calcium significantly contribute to these properties. Although present in smaller amounts, magnesium and potassium still play important roles in enhancing the overall characteristics of the material.

2.3. Concrete

According to (Herdiansyah & Pangaribuan, 2013), Concrete is a construction material made of sand and stone (gravel) combined with cement adhesive. Concrete can also be defined as the mixing of coarse aggregate and fine aggregate materials such as sand, gravel, stone, or other types of materials with cement adhesives and water to aid the freezing process or chemical process. Concrete is usually used for construction such as houses, buildings, bridges, etc., with a content weight between 2200 and 2500 Kg/cm and is made from natural aggregates broken or unbroken with additives.

2.4. Compressive and Tensile Strength Test

During the compressive strength test, a concrete specimen is subjected to pressure using a concrete crushing device. The device's top and lower jaws apply the load evenly to the specimen. It is crucial to avoid abrupt and continuous changes in the applied load. The concrete crusher should be equipped with a recording device capable of capturing the rupture force post-loading, with the results displayed on a screen monitor. To ensure precision, the piston's vertical axis must align with the device's vertical axis, and the piston must be positioned correctly along this axis during loading. This configuration ensures that the force is applied evenly through the center of the sample. At the point where the lower surface of the upper jaw collides with the vertical axis of the device, the machine's lower cylindrical surface should be perpendicular to its axis and maintain this alignment during loading, with a tolerance of ±1 mm (Ali et al., 2022).

In the tensile strength test (based on ASTM C496) Toghroli was conducted (Toghroli et al., 2018). The test specimen is positioned horizontally between concrete breaking plates, and the load is steadily increased, leading to a two-part collapse of the plate that shows the test specimen's vertical diameter. Up until the test specimen breaks, the load is applied consistently, evenly, and without abrupt variations at a rate of roughly 400 to 700 kPa.

2.5. Flexural Strength Test

Flexural strength testing was conducted using a universal testing machine on prismatic concrete beams with dimensions of 100 mm in width, 100 mm in height, and 400 mm in length. The testing procedures adhered to the ASTM C78 standard. According to Pane et al. (2015), flexural strength is defined as the ability of a concrete beam supported at both ends to resist the force applied perpendicular to its axis until the beam breaks. The flexural strength of concrete is measured in Megapascals (MPa), representing force per unit area.

2.6. Thermal Properties Measurement

Thermal properties were assessed using a thermogravimetric analyzer (Shimadzu, TGA-50). For measurement, 7 to 10 mg of each sample were put in an aluminum pan. The test was conducted at a pace of 10°C per minute over a temperature range of 25°C to 600°C. The concrete sample-containing aluminum pan was placed inside the TGA furnace. The mass loss in milligrams was recorded as the temperature rose while the sample was heated at the designated pace. The Shimadzu thermal analyzer software was then used to examine the TGA results (Idrees et al., 2022).

2.7. Durability Test

One accurate way to measure permeability is with the Rapid Chloride Permeability Test (RCPT), with increased permeability correlating to heightened durability issues, as highlighted (Idrees et al. (2021) dan Farooq et al. (2020)). Elevated RCPT levels are associated with more frequent corrosion processes in concrete. In accordance with ASTM C 1202, RCPT equipment is employed to assess the permeability of different mixtures. Idrees et al. (2021) observe a decrease in concrete durability in harsh environments. Idrees et al. (2021) observe a decrease in concrete durability in harsh environments. To address the impact of waste mask fibers on freeze-thaw resistance, cylindrical concrete samples underwent a testing regimen. These samples were subjected to freezing temperatures for 6 hours, followed by 6 hours at ambient temperatures (30 to 40°C) each day over a period of 10 days. Their ability to withstand freeze-thaw was then assessed using the RCPT test. The expectation is that more damaged samples would exhibit fractures and higher permeability, indicating compromised freeze-thaw resistance. This approach allows for an exploration of the potential effects of waste mask fibers on the concrete's overall durability in challenging conditions.

2.8. Ultrasonic Pulse Velocity (UPV) Test

To assess the uniformity and integrity of the concrete, an Ultrasonic Pulse Velocity (UPV) test was conducted according to ASTM C597 guidelines. The test utilized a 100-mm concrete cube sample and ultrasonic waves generated by CNS Electronic Ltd. Density and UPV are key parameters for evaluating the consistency and quality of the concrete mix. The UPV test operates by measuring the travel time of ultrasonic waves within concrete structures. In this process, the transmitter transducer, which is mounted on the concrete surface, emits ultrasonic waves, which pass through the concrete to reach the reception transducer. The Read-Out unit calculates the waves' travel time. PUNDIT Transportable Device In milliseconds, a non-destructive indicator tester. The two transducers can be placed directly, semi-directly, or indirectly. As the distance between the two transducers is known, the speed of the ultrasonic waves in the concrete material can be calculated by dividing the thickness of the concrete by the travel time. This calculation yields valuable information about the structural soundness and quality of the concrete. Since the speed of wave propagation depends on material density, the speed of ultrasonic wave propagation can be correlated with concrete density. This density can then be related to concrete quality using an empirical graph that shows the relationship between wave propagation speed and concrete quality (Khoeri, n.d.).

2.9. The Impact of Adding Mask Fibers on Concrete Mix Performance

Based on observations, incorporating mask fibers into concrete mixtures can enhance compressive strength, flexural strength, and modulus of elasticity (Kilmartin-Lynch et al., 2022). This addition does not affect material properties related to concrete durability, such as freeze resistance, water permeability, and fire performance (2022). This addition does not significantly impact durability properties of the concrete, such as freeze resistance, water permeability, or fire performance. Although the water absorption rate increases gradually with the addition of mask fibers, it remains within acceptable limits for construction materials. Microstructural investigations reveal high-quality concrete with improved interfacial transition zones (ITZs) and good compatibility. (Ahmed & Lim, 2022). Thus, mask waste, which poses an environmental problem worldwide, can be sustainably utilized to help construct eco-friendly buildings. Mask waste can be repurposed to produce better concrete with enhanced strength and durability, contributing to a circular economy, sustainability, and efficient waste management (Idrees et al., 2022).

Further research is needed to determine the optimal proportion of mask fibers that provide the best balance between strength enhancement and durability while minimizing negative effects. Long-term studies are necessary to monitor the performance of mask fiber-enhanced concrete under various environmental conditions, including extreme climates. Additionally, further evaluation of the environmental impact of producing concrete with mask fibers and the development of safe handling and usage procedures are essential. The creation of standard guidelines for using mask fibers in concrete, including technical specifications, testing methods, and best practices, is also required. With continuous research and development, this approach has significant potential to support sustainable construction and efficient waste management, offering innovative solutions in the construction industry.

3. Methods

This article uses the literature review method. The theme was chosen because the coronavirus pandemic has led to an increase in mask waste. Given the escalating volume of mask waste contributing to environmental pollution, an innovative and impactful approach to address this issue involves recycling masks and incorporating them as additives in concrete production. This sustainable strategy aims to not only mitigate the environmental impact of mask waste but also contribute to the development of more eco-friendly construction materials. Google Scholar, Research Gate, and Science Direct are the main sources of reference for this article.

4. Results and Discussion

4.1. Compressive Strength and Tensile Strength Test

The research by Idrees et al. (2022) shows the compressive strength of the mixture at 28 days, as illustrated in Fig. 1. Adding 0.5% mask fibers increases the compressive strength by 8.3%. As the fiber content increases, the compressive strength also increases, reaching a peak of 17.9% at 1% fiber content, then it starts to decrease. However, even with 1.5% fiber content, the compressive strength is still higher than the control, but it slightly decreases at 2% fiber content. The drop in compressive strength with higher fiber content is due to poor mixing and bonding of the fibers, which causes unevenness in the concrete mixture (Xie et al., 2021). Generally, as fiber content goes up, compressive strength tends to go down, often because air gets trapped during the mixing process.

Concrete with mask fibers also shows increased tensile strength, peaking at 2% fiber content. Fig. 2 shows that tensile strength rises with fiber content, reaching 23.3% at 1% fiber content before it starts to decrease. Overall, concrete with mask fibers has better tensile strength and crack resistance compared to regular concrete.

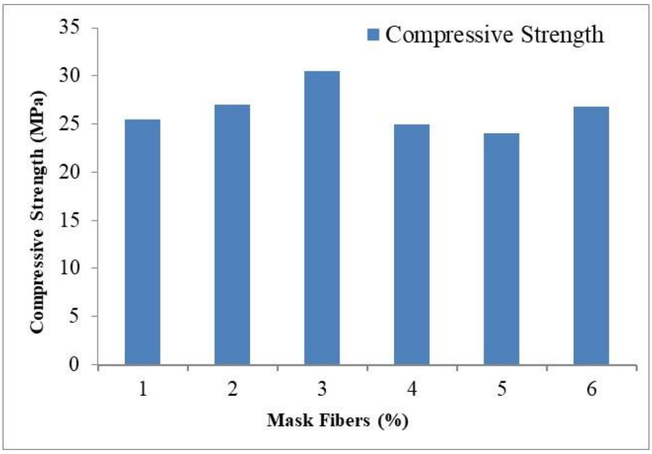

Figure 2. Compressive strength of concrete with mask waste at 28 days age Source: (Idrees et al., 2022)

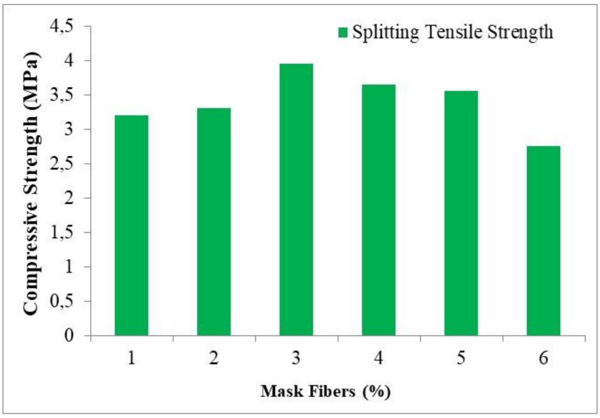

Figure 3. Tensile strength of concrete with mask waste at 28 days age Source: (Idrees et al., 2022)

4.2. Flexural Strength Test

The research by Aal et al. (2022) shows that the flexural strength of concrete increases with the addition of Personal Protective Equipment (PPE) fibers. For example, adding 0.5%, 1%, 1.5%, 2%, and 2.5% PPE fibers increases the flexural strength by 17.8%, 24%, 27.5%, 33.4%, and 1.6%, respectively. PPE fibers are especially effective in enhancing flexural strength with longer curing times, as seen with the 33.4% increase in strength at 2% fiber content. The main impact of PPE fibers is to improve strength. However, increasing the fiber content to 2.5% results in a decrease in flexural strength. This reduction may be due to the challenges associated with higher fiber content.

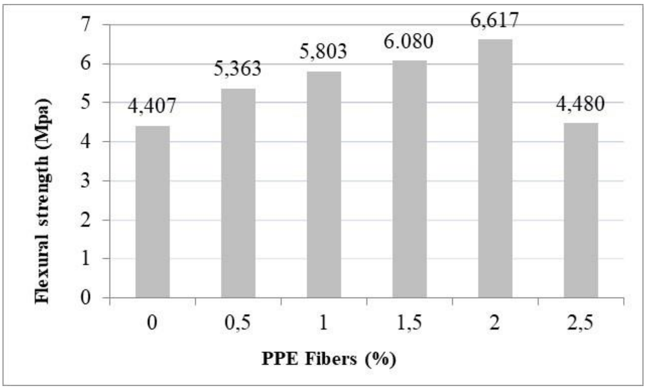

Figure 4. Flexural strength of concrete with mask waste at 28 days age

Source: (Aal et al., 2022)

4.3. Measurement of Thermal Properties

Research conducted by Ali et al. (2022) indicates that polypropylene fibers in concrete do not undergo significant degradation. This is because polypropylene is used sparingly in concrete and starts to degrade at 400°C, which is above the typical temperature threshold of 300°C. Concrete experiences weight loss due to the drying of residual capillary pore water below 70°C and the dehydration of calcium hydroxide above 450°C. After drying out the capillary pore water, concrete with mask fiber waste experienced a mass loss of 1.0%. Prolonging the drying period allows the concrete to retain more water during curing, enhancing its strength and durability. Concrete remains stable at high temperatures as it does not produce gas, and polypropylene fibers do not degrade significantly under these conditions. According to Fig. 4, as the percentage of fibers in the 28-day concrete sample increases, the mass loss also increases. However, samples with shredded mask fibers show a lower percentage of weight loss compared to those with other fibers. This trend can be explained by the different degradation characteristics of these materials.

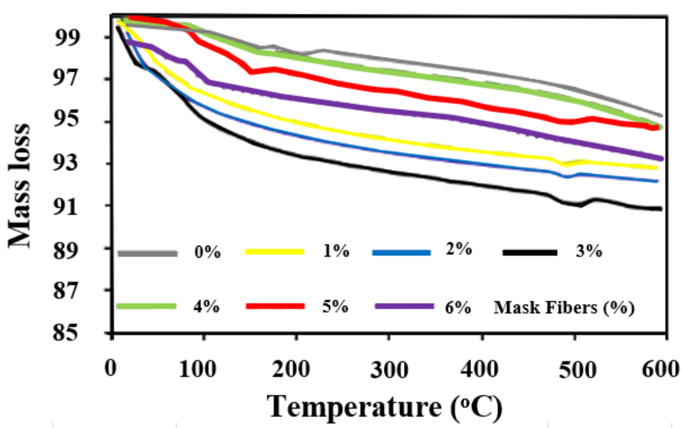

Figure 5. Thermogravimetric analysis at 28 days age

Source: (Ali et al., 2022)

4.4. Rapid Chloride Permeability Test (RCPT)

The research conducted by Idrees et al. (2022) indicates that lower chloride permeability corresponds to improved corrosion resistance. Fig. 5 shows that permeability decreases with the addition of mask waste fibers in concrete, reaching a minimum at a 1% addition rate. After 1% fiber content, permeability begins to increase. Thus, 1% fiber content is optimal, resulting in a 9.4% reduction in permeability. At lower levels, polypropylene fibers decrease permeability and enhance resistance to chloride infiltration by filling the pores (Liu et al., 2019). However, beyond the 1% threshold, fibers cause air entrapment, leading to increased permeability.

Increased volumes of polypropylene fibers lead to higher air content in the mixture (Akid et al., 2023). Improper fiber mixing and mixture inhomogeneity can also result in air pockets. At a 2% fiber concentration, permeability rises because the fibers trap more air within the mixture. This trend explains why compressive strength increases up to 1% due to reduced air entrapment. However, at 1.5% and 2%, the increased air volume trapped during mechanical mixing leads to a decrease in compressive strength (Idrees et al., 2022).

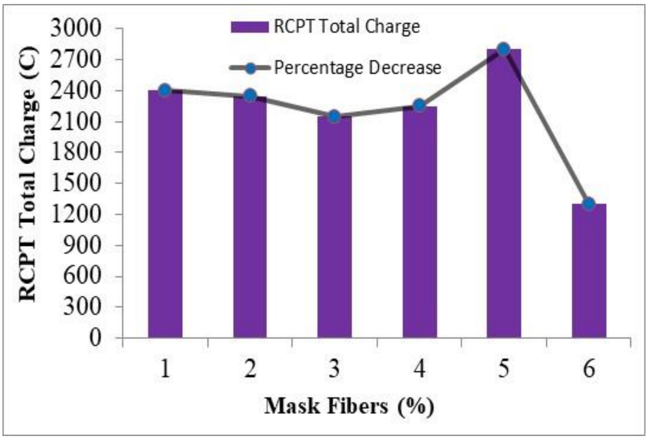

Figure 6. RCPT value of the concrete sample at 28 days age

Source: (Idrees et al., 2022)

4.5. Ultrasonic Pulse Velocity (UPV)

The research conducted by Kilmartin-Lynch et al. (2022) demonstrates the performance of the Ultrasonic Pulse Velocity (UPV) test conducted at both 7 days and 28 days after the concrete has been cast. Fig. 6 shows that all samples with 1% to 3% fiber content exhibited increases compared to the baseline control sample at both 7 and 28 days. UPV testing is commonly used to assess the general quality of concrete and to detect cracks or voids that may not be externally visible. Typically, UPV results with velocities exceeding 4500 m/s are considered indicative of very good quality (Kurup & Kumar, 2017). The study further suggests that increased fiber content enhances the quality of concrete samples, showing an upward trend in each case. This implies that integrating fiber waste improves the overall quality of composite concrete mixtures. This improvement likely stems from the polypropylene/polyethylene layers facilitating the formation of bonds between cement and aggregates, thereby reducing microcracks in the composite concrete mixtures (Kilmartin-Lynch et al., 2022).

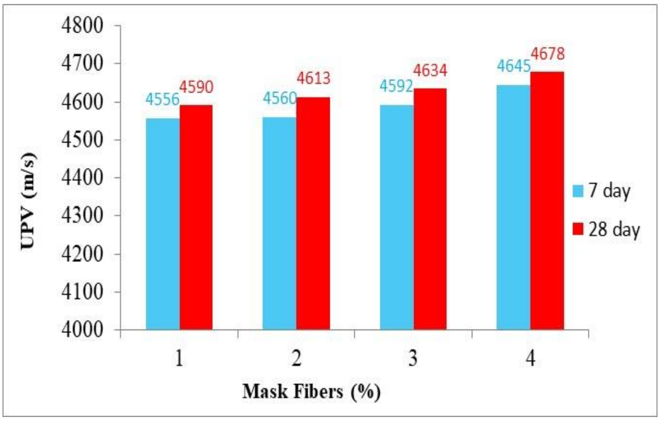

Figure 7. UPV testing for concrete samples at 7 days and 28 days age

Source: (Kilmartin-Lynch et al., 2022)

5. Conclusion

This study outlines the utilization of mask waste in the application of concrete mixtures through a literature review method. From the analysis results, it can be concluded that:

1. The utilization of mask waste can increase compressive and tensile strength in concrete mixtures, resulting in better crack resistance compared to regular concrete.

2. The utilization of PPE can enhance flexural strength of concrete mixtures typically improves; however, an increase in content by 2.5% results in a reduction in flexural strength.

3. The utilization of mask waste in concrete mixtures does not undergo significant degradation at high temperatures.

4. The utilization of mask waste in concrete mixtures exhibits better corrosion resistance.

5. The utilization of mask waste can significantly enhance the quality of concrete mixtures.

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