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A Safe Collection Process of Covid-19 Disposable Face Masks for the Applications in Asphalt Pavements

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During the Covid-19 pandemic, plastic pollution became exacerbated by the disposal of face masks. The practical collection, processing, and application of the face mask have become a major challenge. Several studies have examined the added benefits of using face masks on asphalt pavements; however, these studies were limited to the application and have not addressed the appropriate collection process. This research aims to develop a theoretical collection process of disposable face masks originating from locations other than hospitals. The process aims to collect face masks safely and practically from residential, commercial, and educational zones. The masks would be collected twice a month and disinfected and sterilized before being transported to a shredding company for processing before being transported to an asphalt plant for use in asphalt mixtures. The developed collection method will minimize the risk of being affected by the Covid-19 virus and provide a practical procedure that can be used by waste management facilities. Additionally, the developed collection method could aid the construction industry in adopting a more environmentally friendly, sustainable, and cost- effective method of construction.

Key Words: Plastic Waste, Construction, Construction Material, Recycling, Safety, Sustainability, Environment, Covid-19, Face mask, Waste Collection

Introduction

The whole world is facing the problem of the Covid-19 pandemic. There are millions of people who have lost their lives due to getting unconscious while wearing Personal Protection Equipment (PPE) (e.g., masks, shields, or gloves) (De, 2020; Saberian et. al., 2021). The use of face masks as part of the health campaign against the coronavirus has been so successful that it has become a necessity to prevent the spread of the virus (Zhou et al., 2022; Iboi et al., 2021; Hornik et al., 2020; Royo-Bordonada et al., 2020). Though the use of face masks is incredibly needed, disposing of them is threatening the environment. Daily, a large amount of waste is generated from the disposable of millions of masks. In 2020, the total estimated used face masks were more than 129 billion globally. A sharp 20% growth is expected between 2020 and 2025 (Akarsu et al., 2021; Fernández-Arribas et al., 2021; Prata et. al., 2020). The collection of face masks is a very challenging task because they can be easily littered in many places (Prata et. al., 2020; Saberian et. al., 2021) without breaking down in the environment (Pandit et al., 2021; Morganti, 2020; Dhawan et al., 2019; Henneberry, 2020), which results in major waste management and environmental issues (Aragaw, 2020). According to Bai & Sutanto (2002), recycling is the mostwidely accepted sustainable method of plastic waste management. Nevertheless, recycling plastic wastes is a multifaceted process that involves collection, processing, storage, transportation, treatment, and application. Waste collection and transportation account for about 70% of the recycling process cost (Greco et al., 2015; Tavares et al., 2009). Therefore, a proper collection method is essential to determine the most cost-effective recycling process (Huang et al., 2011; Jacobsen et al., 2013). While the use of plastic waste and other waste by-product (i.e., steel slag) as a modifier in asphalt pavement has greatly enhanced the road's adhesion, lowered the thermal susceptibility of pavements, improved asphalt performance, and reduced construction costs (Rahat et al., 2022a; Rahat et al., 2022b; Wang et al., 2022), more work is still needed on developing as safe and practical collection process. This paper aims to develop a theoretical collection process of disposable face masks that is originated from locations other than hospitals. Residential, commercial, and educational zones are used as focused collection areas. Since medical plastic wastes are incinerated and present potential bio-medical hazards (Tejaswini et al., 2022; Chowdhury et al., 2022), they are not considered in this study. The masks would be collected twice a month with the application of disinfectants and sterilization procedures and transported to a shredding company for processing before transporting them to the asphalt plant for application in asphalt mixtures. The developed process will minimize the risk of being affected by Covid-19 virus and aid the construction industry in adopting a more environmentally friendly, sustainable, and cost-effective method of construction.

Literature Review

Applications of Covid-19 Plastic Wastes in Construction Application

During the pandemic of the Covid-19 personal protective equipment (PPE) (i.e., face mask, face shield, gloves) has become popular among the people. For this reason, the amount of used PPE, especially face masks have been increased drastically, and for the unawareness of people face masks are found here and there. Since PPE can save people from Covid-19, it will have a bad long-term impact on the environment as most of the PPEs are made with non-biodegradable material. The disposable face mask is the most used and is made of polypropylene (Henneberry, 2020). As per the best knowledge of the author, there are several studies has been conducted with used Covid-19 PPE (i.e., face masks, face shield, gloves) for construction application (e.g., pavement base/subbase, hot mix asphalt (HMA), concrete). The authors found the improvement of mechanical performance of the structures by using this PPE in construction. Table 1 provides a review of the most relevant studies on Covid-19 PPE used in construction applications.

Table 1

Studies on the application of used Covid-19 PPE in construction

Author	PPE	Application	Tests conducted	Results
Saberian et al., (2021)	Face mask	Pavement base/subbase	Modified compaction test Unconfined compressive strength Resilient modulus (Mr)	Improved compressive strength Improved resilient modulus

Kilmartin-Lynch et al., (2021)	Face mask	Concrete	Compressive strength Indirect tensile strength Elasticity modulus Ultrasonic pulse velocity	Improved overall concrete quality
Wang et al., (2022)	Face mask	HMA	Superpave mix design Asphalt pavement analyzer test (APA)	Improved rutting depth
Goli & Sadeghi, (2022)	Face mask	HMA	Marshall test Resilient modulus Indirect tensile Moisture damage Rutting and Fatigue test	Improved the overall properties of HMA
Kilmartin-Lynch et al., (2022a)	Nitrile gloves	Concrete	Compressive strength Modulus of elasticity Ultrasonic pulse velocity Scanning Electron Microscope (SEM)	Improved compressive strength Improved bond strength in microscale
Kilmartin-Lynch et al., (2022b)	Isolation gown	Concrete	Ultrasonic pulse velocity (UPV) Compressive strength Flexural strength test Scanning Electron Microscope (SEM)	Improved mechanical properties of concrete
Massarra et al., (2022)	Face mask	HMA	Cost estimation Life cycle cost analysis (LCCA)	Improved LCCA

Using shredded face mask blends at different percentages for highway base and subbase applications, Saberian et al., (2021) tested modified compaction and resilient modulus. Recycling concrete aggregate base and three different concentrations of shredded face mask (1%, 2%, and 3%) were combined for stiffness and strength. Fibrous recycled concrete aggregate mixes strengthened, and pliability increased with the addition of shredded face mask fibers. Strength remained at 216 kPa with 1% SFM and RCA added, but modulus increased (314.35 MP).

Based on this trend, Kilmartin-Lynch et al., (2021) tested concrete with a face mask. For pressure strength and indirect tensile strength, elasticity modulus, and ultrasonic pulse velocity, the masks were inserted with volumes of 0% (control), 0.10%, 0.15%, 0.20%, and 0.25%. Concrete settings improved in strength and quality as a result of the addition of single-use masks.

In 2022, Wang et al. evaluated the rutting resistance of hot mix asphalt (HMA) pavement using the Covid-19 face mask for the first time. By adding 1.5% of shredded face mask (SFM) by weight to the mix, the rutting depth was reduced to 0.93 mm, nearly nil.

Goli & Sadeghi, (2022) followed up on this study by incorporating two different sizes of SFMs into a mix of HMA, one which was 8 mm length and one which was 12 mm in length. In order to evaluate the overall properties of the HMA, the researchers conducted the Marshall test, resilient modulus, indirect tensile, moisture damage, rutting, and fatigue test for both scenarios. It has been found that in both scenarios, there has been an improvement in the overall quality of the HMA, although the improvement in the 12 mm fiber mixture has shown better performance than the 8 mm fiber mixture.

In line with the trend toward face masks, Kilmartin-Lynch et al. (2022a) used shredded nitrile gloves when performing structural concrete work. In order to determine the effect of shredded nitrile gloves on concrete's mechanical properties, quality, and bond performance with cement matrix, compression strength, modulus of elasticity, ultrasonic pulse velocity, and SEM-EDS analysis were conducted. Blended concrete composites with 0.2% shredded nitrile gloves show a 22% increase in compressive strength after 28 days. The compressive strength of nitrile gloves is improved by 20% after 28 days when they are shredded by 0.3%. The interfacial transition zone (ITZ) of the nitrile rubber and cement matrix shows no gaps after 28 days when they are shredded by 0.3%.Furthermore, Kilmartin-Lynch et al., (2022b) used plastic-based isolation gowns for structural concrete. As part of the concrete mix, the shredded isolation gowns were added at 0.01%, 0.02%, and 0.03%. A series of experiments was conducted alongside an SEM-EDS analysis to study the effects of various concentrations of shredded isolation gowns on the concrete's mechanical properties. Based on the results, the bridging effect was enhanced between the cement matrix and shredded isolation gowns, resulting in increased compressive strength, flexural strength, and modulus of elasticity.

Finally, Massarra et al., (2022) estimated the cost of construction of Covid-19 mask-modified asphalt pavement and conducted a life cycle cost analysis (LCCA) of mask-modified asphalt pavement and conventional asphalt pavement. Even though mask modified asphalt pavements have higher up-front costs, LCCA showed a 29% reduction in maintenance costs over its full 40- year lifespan.

Although previous studies have shown that using face masks improves asphalt performance, and is environmentally beneficial and cost-effective, the major challenge is collecting, separating, and processing the masks. There are no available safety procedures for collecting face masks from sources other than hospitals and then transferring the collected masks to the casting field so they can be used in asphalt mixtures.

Methodology

Developing a Collection Process of Disposable Face Masks

In this section, a theoretical process for collecting face masks from sources other than hospitals is developed. It should be noted that no practical application has been conducted. Usually, the medical masks from hospitals are collected in separate bags and then incinerated (Gidarakos et al., 2009). For this reason, the potential sources of disposable masks will be residential buildings, and commercial and educational districts. Figure 1 illustrates the steps of the collection process. Residential, commercial, and educational zones will be a focused area for collection. The collection sites will be designated by the solid waste management facility. Ciaccia, 2020 found that the presence of the Covid-19 virus in masks would not exceed seven (7) days. Therefore, to prevent the spread of the Covid-19 virus during collection, disposable face masks will be collected twice a month and a total cycle of 6 weeks from setting up to retrieving. All the containers will be setup at the starting of the procedure by the solid waste management facility and labeled with week and days where the week of setting up will be considered as Week 1.
Containers of Weeks 1 and 2 will be collected in Week 4 and containers of Weeks 3 and 4 will be collected in Week 2 of the following month and the cycle continued.

After collection from the sites, the masks will be transported to the recycling center for sterilization and separation. Disinfectants and sterilization procedures must be used for disinfecting the face masks. Some common practices suggested by Kampf et al., (2020) are 62– 71% ethanol, 0.5% hydrogen peroxide, or 0.1% sodium hypochlorite within 1 min of subjection to the masks. Other

applied dry heat technology on the masks at 70°C for one hour (Xiang et al., 2020). Because of its easy application and low cost, 0.5% hydrogen peroxide concertation for a minimum exposure time of 1 minute will be used.
The shredding company will be contacted earlier, so the sanitized masks are picked up either on the same day or the next day of sanitization. The masks will then be transported to a shredding company for removal of ear loops and nose strips and shredding. Finally, the shredded disposable face masks will be transported to the casting yard to prepare modified hot mix asphalt (HMA) samples to perform laboratory tests to evaluate the mechanical performance of disposable face masks modified HMA samples.

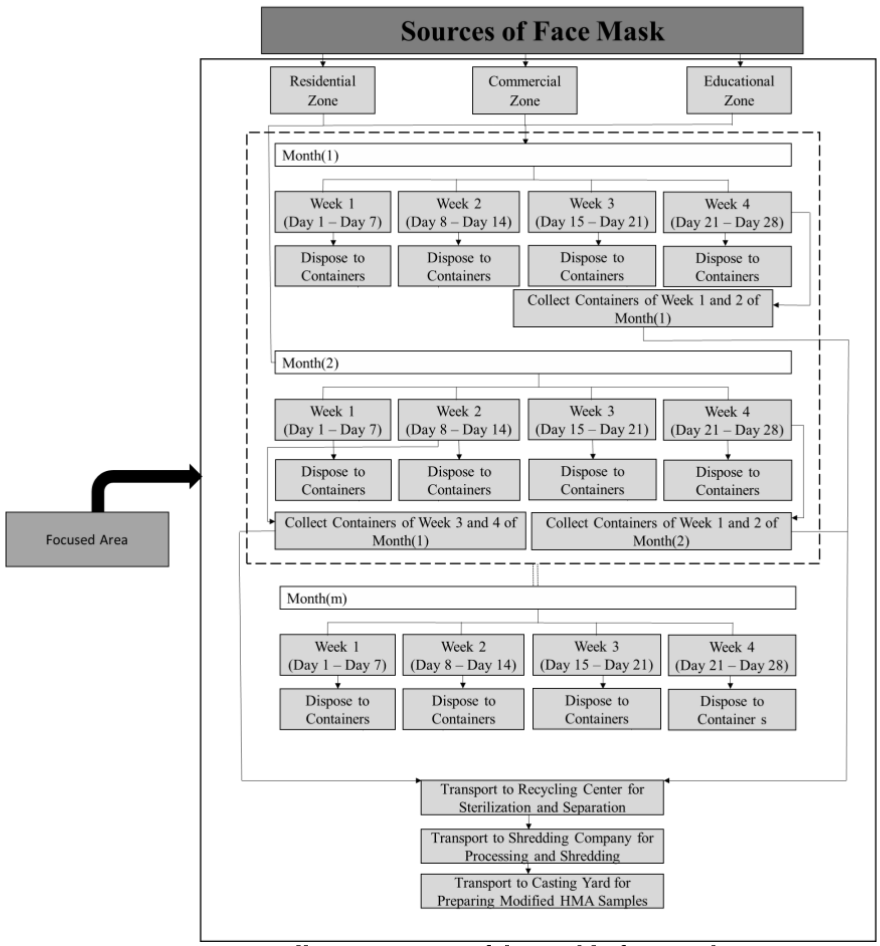

Figure 1. Collection process of disposable face masks

To carry out the collection, sterilization, and separation of face masks several numbers of laborers will be required. The number of labor depends on the number of collection points, containers, and volume of face masks.

Discussion

Example of Collection Process of Disposable Face Mask

Due to lack of accessibly to collection points because of Covid-19, the actual collection was not carried out, instead example of an application was carried out. It should be mentioned that this example does not represent any actual work. For this example, three collection points, four large containers of 95 gal (Capacity of 0.40 Tons of masks) at each location (i.e.,12 containers in total), and an arbitrary date (February 1st) would be chosen. The 12 containers would be assumed to be set up on February 1st, in the three collection points designated by the solid waste management agency and labeled with the week and days as follows: (Feb 1- Feb- 7), (Feb 8- Feb 14), (Feb 15- Feb 21), (Feb 22- Feb 28). Containers of Weeks 1 and 2 labeled as (Feb 1- Feb- 7), (Feb 8- Feb 14), and Weeks 3 and 4 labeled as (Feb 15- Feb 21), (Feb 21- Feb 28), would be collected on February 28th, and March 14th, respectively at the three collection points and transported to the recycling center of the solid waste management agency for separation and sanitization. Figure 4.1 shows the steps that would be taken only for one collection point. The same steps should be followed for the other two collection points.

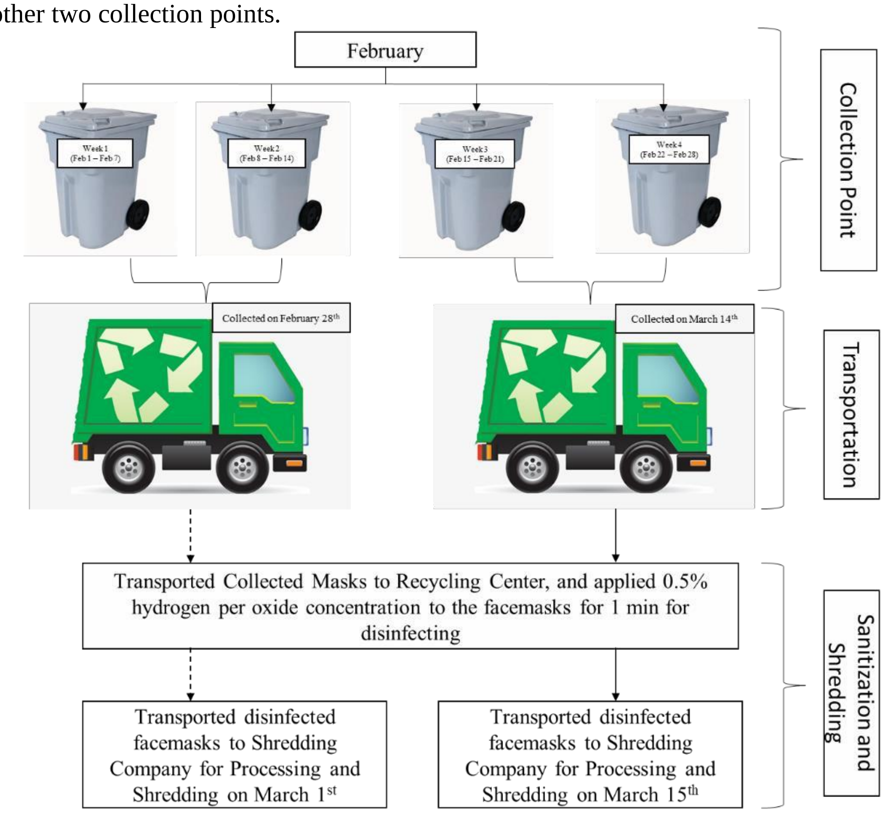

Figure 2. Flow chart of the example application at collection point

For sanitization, one bottle (32 oz) of hydrogen peroxide (H_2O_2) with 0.5% concentration applied for 1min would be needed for each container. Each container would take an average of 1 hour to set up, pick and sanitize. The shredding company would be contacted, and the pickup date would be scheduled on the second day of sanitization. The disinfected masks of containers of Weeks 1 and 2 labeled as (Feb 1- Feb- 7), (Feb 8- Feb 14), and Weeks 3 and 4 labeled as (Feb 15- Feb 21), (Feb 21- Feb 28), would be picked up on March 1st and March 15th, respectively. No labor would be needed for shredding since the shredding company offered a package that includes the pickup from the recycling center, removal of ear loops and nose strips, shredding of the face masks, and transportation to the casting yard. Based on the proposed methodology, Massarra et al. (2022) estimated the total cost associated with the application of face mask in HMA pavement as three- part costs: Cost of face mask collection, cost of face mask processing (i.e., shredding), and cost of HMA materials preparation with plastic. Table 2 shows the total pavement structure cost with and without face masks for different pavement sections adopted from (Massarra et al, 2022).

Table 2

Total pavement structure cost with and without face masks for different pavement sections for one lane asphalt pavement (Massarra et al, 2022)

Length(m)	Total cost of mask collection	Total cost of mask processing	Total cost of asphalt preparation	Total cost masks	Total cost without masks
1000	$1,311	$1779	$37,238	$37,754	$37,238
500	$655	$889	$18,576	$18,920	$18,576
250	$328	$445	$9,460	$10,074	$9,460
100	$131	$178	3,698	$3,784	3,698

There are three costs associated with the application of face masks to HMA pavement: the cost of collecting face masks, the cost of processing them (i.e., shredding), and the cost of preparing HMA materials with recycled plastic. There are several costs involved in collecting face masks, including the cost of setting up and picking up containers, sorting, and sanitizing masks, the cost of transportation to and from the waste facility, and the market price of the containers. Among the costs involved in processing face masks are those associated with transportation from the waste management facility to the plastic processing plant, the plastic processing plant to the asphalt mixing plant, as well as the cost of processing the recycled plastics. For HMA preparation with a mask, the cost will vary depending on the total weight of asphalt mixture and face mask modifier required for pavement sections, as well as the unit price for HMA, which will vary from location to location. Generally, agencies conducting the practical application on using face masks for asphalt pavement will be responsible for the collection, processing, and application costs. Despite the initial costs paid by these agencies it was found that there is a 29% maintenance cost reduction over the 40 years life cycle of the asphalt pavement when using facemasks (Massarra et al., 2022).

Conclusions and Recommendations

Globally, due to the wide spread of the Covid-19 pandemic, a large amount of plastic waste has been generated. Using Covid-19 plastic waste in various construction applications can improve environmental sustainability, reduce construction costs, improve performance, and provide construction materials at a consistent rate. The collection process of single-used Covid-19 face masks has been developed in this study. We have no intention to generalize the results and conclusions. Therefore, more in-depth work is needed on the application of the proposed methodology presented in this study. We want to mention that during the time of this study, Covid-19 was at its peak and there was high restriction of collecting Covid-19 generated wastes by any individuals or organizations except solid waste management agency. Although there was no practical application, the authors made sure to consult with the solid waste management agency to get their insight on the theory and found that the proposed methodology is in alignment with the process adopted by the solid waste management agency. The study concluded and recommended the following:

- Possibility to collect face masks without contracting Covid-19 following the collection process developed in this study.
- Same collection process can also be applied to other plastic wastes.
- Findings provide valuable insights into future efforts by industry and government agencies to develop sustainable approaches for the transportation, energy, and environmental industries.
- The research could provide a solution to reduce the plastic waste that is polluting the environment due to Covid-19 or another pandemic
- Research is required to develop a safe collection process for medical-generated plastic waste.
- A practical application is required to justify the feasibility of the process.

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