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AN EFFECTIVE ENVIRONMENTAL SOLUTION FOR DISPOSAL AND RECYCLING OF SINGLE USED FACE MASK

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ABSTRACT

The use of face mask in public became mandatory after the outbreak of Covid-19. This results in piling of face masks in the soil and water. It is important to find an effective solution for the disposal and recycling of single used face masks. In this paper a comprehensive analysis is carried out for possible primary and secondary recycling of used face masks and ear strings. Face mask and ear string are used as additives in cement blocks with different percentages as primary recycling. It is found that cement blocks with 1% of face mask and 1.5% of ear string shows an increase in compressive strength compared to conventional blocks. In secondary recycling, chemical decomposition of the face mask and ear string was tried in different reagents such as acid, alkali and alcohol of varying concentrations. It was found that alkali is more effective compared to other reagents.

Key words: Face mask, ear string, admixture, recycle, disintegration

Introduction

The recent pandemic has significantly affected health, economy and day-to-day life of people.To control the spread of the virus, face mask is used as primary personal protective equipment (PPE) which has led to accumulation of huge quantity of used face masks all over the world. Further, most of these masks contain plastics or other derivatives of plastics. Therefore, the extensive usage of face masks generates million tons of plastic wastes in the environment in a short span of time as quoted by Selvaranjan (2021). The material used in face mask is non-biodegradable and accumulates in landfills and makes its way in water.

Prata et al. (2020) reported that 3.4 billion of used face masks are discarded every day and it is observed that the used face masks were disposed in the city lanes, sewage systems, open spaces, shopping carts, parking places, domestic and public waste containers. This endangers public health and causes land and water pollution.

Ammendolia (2021) reported that the PPE debris consist of disposable gloves (44%), followed by face masks (31%), and disinfecting wipes (25%). Almost 97% of the face masks were designed for single use while only 3% were reusable. This results in piling of single used face mask in the environment.

Urgent attention is needed to address the threat of plastic PPE litter, to spread awareness on the proper disposable practices and to shift towards sustainable alternatives such as reusable face masks (Silva 2020, Vanapalli 2021).

Face Mask

Face masks are classified into different types as low barrier, moderate barrier and high barrier masks based on the filtration of bacteria, air permeability and breathing resistance (ASTM, 2007 and BS EN ISO 15223-1, 2016).

Single use face mask consists of three layers such as outer hydrophobic non-woven layer (translucent) such as polyester or polyester blend (Chellamani et al. 2013), middle melt-blown layer of non-woven material such as PPE (polyethylene, polystyrene, polypropylene, polyvinylchloride, polyethylene tetraphthalate) (generally in white colour) and an inner soft absorbent non-woven layer such as cotton (green, blue, or white colour). The polypropylene known as plastic is used as a major material to produce the face mask (Akber 2020).

The highly recommended mask to prevent the spread of virus is N95, which consists of four layers of materials: an outer layer of spun-bound polypropylene; a second layer of cellulose/polyester; a third layer of melt-blown polypropylene filter material; and an inner (fourth) layer of spun-bound polypropylene. The typical raw material used to produce N95 mask is polypropylene which is similar to surgical mask (Barycka 2020). The ear loops of face masks were made of natural and synthetic polyisoprene (i.e. latex-free) rubber (Santarsiero 2020).

Recycling of face masks

The two ways of recycling face masks are primary recycling and secondary/chemical recycling. Primary recycling is the reuse of the product in their original structure. In the secondary recycling the masks can be re-melted or disintegrated chemically (Lackner 2015). The literature related to primary and secondary recycling methods of face masks are discussed.

Primary Recycling

Douglas (2021) conducted experiments by adding fixed amount (30oz and 50oz) of shredded mask with concrete cylindrical specimen and found that the workability and compressive strength decreases compared to conventional concrete and suggested that the amount of quantity added with concrete need to be reduced. Koniorcyz (2022) added 1 mask per liter of concrete and found that the compressive strength is increased by 5% and tensile strength by 3% compared to conventional concrete. Also, it is mentioned that the addition of fibers into concrete did not affect the material property related to the durability of concrete as frost resistance, water permeability and fire performance band. Koniorcyz concludes that further research is required to find the quantity of the mask to be added with concrete. Li et al. (2022a) pretreated the face mask with graphene oxide and mixed in the cement paste. It is found that 0.1 % of face mask with respect to volume of the cement paste increased in the tensile strength by 47% but compressive strength decreased by 3% at 28 days compared to conventional cubes. Castellote et al. (2022) added 5% of the face mask with respect to weight of the cement in mortar cubes. It is found that the compressive and flexural strength of the cube is less than the conventional. From the literature, the quantity of the face mask to be added with the cement/concrete plays a significant role. There is no literature related to the effect of ear string in the cement. This paper aims to fill this gap to fix the percentage of face mask, ear strings and the effect of use of ear string in the cement mortar cubes.

Secondary Recycling

This part discusses the work done by researches on secondary recycling. Al-Salem et al. (2017) and Qin et al. (2018) disposed PPE by thermochemical process which increases air pollution. As per Zhao and Wang (2018) thermolysis of polymers such as polyvinyl chloride releases toxic chemicals such as dioxins. Jung et al. (2021) tried to dispose the face masks by pyrolysis using Ni/ SiO_2 as catalyst under certain temperature range in the atmosphere of N_2 or CO_2. Li et al. (2022b) reported that surgical masks can be converted into a burnable fuel having high heating value by pyrolysis process which can be used to generate electricity or in other applications.

Knicker (2022) reported that pp-based disposal face masks can undergo biodegradation by microorganisms at a low rate, which causes accumulation of degraded mask residues in the soil. It causes environmental pollution as does by microplastics from other resources. The earlier literature requires either use of energy or leave carbon foot print in the environment. An effective solution for disposal of face mask using common chemicals are studied in this paper.

Materials and Methods

In this study primary and secondary recycling methods are tried for the possible disposal and recycling of personnel protective (PP) face masks. In the primary recycling method, the face masks and ear strings are added with cement as construction materials. In the secondary recycling method, the face masks and the ear strings are subjected to different chemicals for possible decomposition.

Four different types of facemasks and their ear strings are selected for the chemical decomposition and possible reuse in the cement blocks. The three-ply blue face mask, 2ply black face mask, 3ply printed face mask with nose string and 3ply blue face mask without nose string are labelled as mask 1, 2, 3 and 4 respectively in this study (Fig.1).

Fig.1. Types of masks

For chemical decomposition, the masks are cut into small pieces without separating the layers. The average size of the mask pieces is 15mm x 15mm and the average length of ear string is15mm. The effect of chemicals on the face masks and ear strings are studied using10%, 20% and 40% concentrations of acid, alkali and alcohol. The chemicals selected in this research are sulfuric acid, sodium hydroxide and ethanol. The pieces of masks and ear strings are placed in beaker and immersed completely in the solutions and the effects are observed on 20th, 30th, 50th and 70th day.

Four different types of the face masks are cut into small pieces of 10 mm x 2.5 mm and the strings are cut into 2.5mmx 2.5 mm. The pieces of face masks of various types are mixed and added to cement as admixtures. Similarly, the pieces of ear strings are added separately with cement. The pieces of face masks and strings are added as 1%, 1.5% and 2% with respect to mass of cement. The size of cubes is 50mm x 50mm and the compressive strength of the cubes is measured after 7 days using standard compressive testing machine (ASTM C39/C39M, 2016) for conventional cubes and cubes with face masks and ear strings.

RESULTS AND DISCUSSION

Primary Recycling

The ratio of the compressive strength of the cubes with face mask or ear string with the compressive strength of the conventional mortar cube is calculated for 1%, 1.5% and 2% and it is given in fig.2.

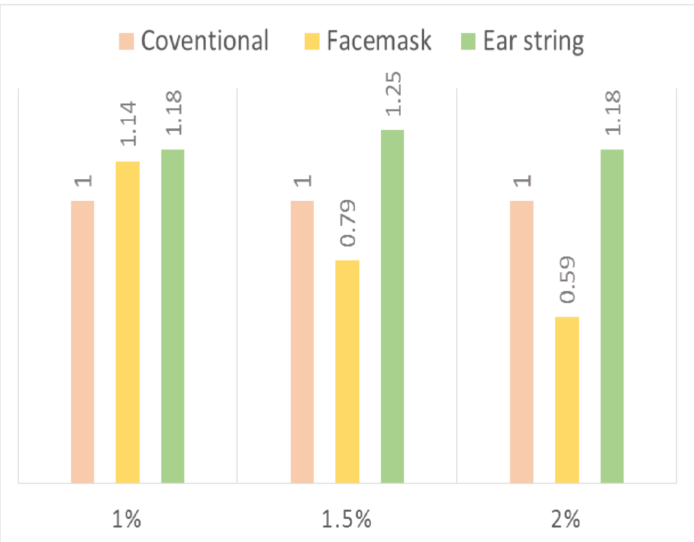


Fig. 2. Compressive strength ratio of face mask and ear string with conventional cubes

The cube with ear string shows more strength than conventional cube in all the percentages studied and the highest strength is achieved with 1.5% of ear strings. Compressive strength is increased in the cement cubes with 1% face mask and decreased with 1.5% and 2 % of face mask compared to conventional cement cube. The increase in ratio of face mask with respect to cement, shows a decrease in strength of the cube. The result obtained are different for face mask and ear string. The optimum percentage of face mask which improves the compressive is 1% and that of ear string is1.5 %.

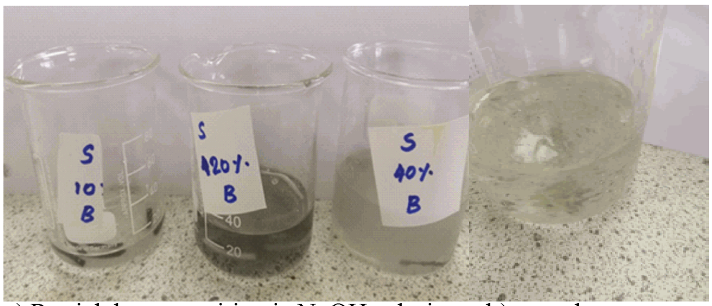
Secondary Recycling

Effect of acid, alkali and alcohol on the face masks and ear strings are observed at various time intervals and are reported below.

A. *Ear strings*

It is observed there is no change in the ear strings in all the concentrations of sulfuric acids and ethanol but it started to decompose in 40% solution of sodium hydroxide on 20th day.

On 30thday, small particles of the string can be seen clearly in 10% and 20% dilution of sulfuric acid and clear disintegration is seen in all the dilutions of sodium hydroxide. No changes are observed in all the dilutions of ethanol. On 50thday it is observed that the thread of the ear strings became weak in all the dilutions of sulfuric acid and small particles are observed in the mixture. The ear string disintegrated completely in 40 % and 20% dilution of sodium hydroxide and in 10% dilution the string is partially decomposed as shown in Fig.3a. The S stands for string and B stands for base (NaOH). On 70thday of observation there is no further change in the decomposition of ear string in sulfuric acid.The ear strings dissolved completely in all the dilutions of sodium hydroxide (Fig. 3 b). In ethanol the ear strings remain unaffected.



a) Partial decomposition in NaOH solution b) complete decom-position

Fig. 3. Effect of base on the ear string

B1. Mask 1

The layers of the mask 1 are separated in 20 and 40% dilution of sulfuric acid on 50th day. There is no change in the layers of the face masks in all the dilutions of sodium hydroxide till 30th day. The three layers of the mask 1 are separated in all the dilutions of sodium hydroxide on 50th day and remains same on 70th day. Ethanol has no effect on the mask.

B2. Mask 2

The layers of the mask remain intact in sulfuric acid on 20th day. Few black particles of the mask separate out in 40% sulfuric acid solution and separation of layers are seen in 20% sulfuric acid on 30th day and it remains same till 70th day. The fabric disintegrates into small particles in 40 % sodium hydroxide on 20th day and more disintegration are observed till 50thday. The fabric becomes brittle and started to break into pieces when kept in 40 % dilution of sodium hydroxide for further 20 days. Significant changes are not observed on mask 2 in 10% and 20 % dilution upto till fifty days. Later the fabric of the mask becomes soft and weak when kept for further twenty days.

B3. Mask 3

The mask remains unaffected in all dilutions of sulfuric acid and ethanol though only layers are separated in 40 % dilution after 30 days and there is no further change till 70th day. In sodium hydroxide the layers are separated in 10% and 20 % dilution on 20th day. In 40% dilution of sodium hydroxide the printed outer layer of the mask disintegrated into small particles when observed on 20th day whereas the middle layer and the inner layer remains unaffected. The disintegration further increased when kept for the next 30 days and the outer layer of mask decomposed completely in 40 % dilution of sodium hydroxide. In 20 % and 10 % dilutions of sodium hydroxide the decomposition started from 30th day and there is complete decomposition after 50 days in 20% dilution and it took 70 days to decompose completely in 10% dilution.

B4. Mask 4

The layers are separated in all dilutions of sodium hydroxide after 30th day and in acid it took 50days to show the same effect. There is no further disintegration of mask 4 in any of the three reagents even after 70 days. Table 1 and 2 shows the effect of acid and alkali on types of face masks and their strings after 20thday, 30th day, 40th day and 70th day.

Table 1. Effect of different percent dilution of acid on face masks and ear strings

	Chemical Reagent	Number of days	Mask 1	Mask 2	Mask 3	Mask 4	Strings
1.	**40% Acid**	20 Days	No	Very less	No	No	No
		30 days	No	Less	Less	No	No
		50 Days	Very less	Less	Less	Very less	Very less
		70 Days	Very less	Less	Less	Less	Less
2	**20% Acid**	20 Days	No	No	No	No	No
		30 days	No	Less	No	No	Very less
		50 Days	Less	Less	No	Less	Very less
		70 Days	Less	Less	No	Less	Less
3	**10% Acid**	20 Days	No	No	No	No	No
		30 days	No	No	Very less	No	Very less
		50 Days	Very less	No	Less	Less	Very less
		70 Days	Less	No	Less	Less	Less

Table 2. Effect of different percent dilution of alkali on face masks and ear strings

	Chemical Reagent	Number of days	Mask 1	Mask 2	Mask 3	Mask 4	Strings
1.	**40% Alkali**	20 Days	No	Very Less	Very Less	No	Less
		30 days	No	Less	Less	Very Less	Partial
		50 Days	Very Less	Partial	Partial	Less	Complete
		70 Days	Less	Partial	Partial	Less	Complete
2	**20% Alkali**	20 Days	No	No	Less	No	Very less
		30 days	No	No	Less	Less	Partial
		50 Days	Less	Less	Partial	Less	Complete
		70 Days	Less	Partial	Partial	Less	Complete
3	**10% Alkali**	20 Days	No	No	Less	No	Less
		30 days	No	No	Less	Less	Partial
		50 Days	Less	Less	Partial	Less	Partial
		70 Days	Less	Partial	Partial	Less	Complete

No indicates there is on effect ?
Very less indicates unclear solution
Less indicates reduction in size and separation of layers
Partial indicates breaking into pieces
Complete indicates the decomposition of entire mask and strings.

Conclusion

The reuse of different face masks and their ear strings as additive in the cement cubes has been tried with different percentage and the results are compared with conventional cement cubes. For non-load bearing structures, the face mask more than 1 % and for load bearing structure face mask less with1% can be used as additive. The percentage is calculated with respect to the weight of the cement. The ear strings show encouraging results in all the percentages used and the optimum value is found to be 1.5 %. The possible chemical decomposition of face mask and ear string with different concentrations of acid, alkali and alcohol is carried out. The most effective chemical is found to be alkali both for face mask and ear string. The results of chemical effect are same for different strings used in this analysis whereas the effect varies for the different types of single used mask chosen in this study. The polymers used in manufacturing the single use face masks are different as revealed from their responses to chemical decomposition. Further research is required to make material for face masks which can include the links such as ester or amide in the polymer chain. This undergoes easy hydrolysis and enhances the chemical decomposition

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