



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 5, May 2022

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.118

Evaluation of Reutilization of Single-Use Surgical Face Mask on Physical and Durability Properties of Concrete

Julius Maloba Watako^{1*}, Charles Karimi Kabubo², James Maina Kiambigi³

Graduate student, Department of Sustainable Materials Research & Technology Centre, Jomo Kenyatta University of Agriculture and Technology, P.O Box 62000-00200, Nairobi, Kenya¹.

Senior Lecturer, Department of Sustainable Materials Research & Technology Centre, Jomo Kenyatta University of Agriculture and Technology, P.O Box 62000-00200, Nairobi, Kenya².

Senior Lecturer, Department of Construction Management, Jomo Kenyatta University of Agriculture and Technology, P.O Box 62000-00200, Nairobi, Kenya³.

ABSTRACT: The outbreak of Covid-19 disease brought about increased demand and use of single-use surgical face masks (SUSFM) around the world. Since these are single-use protective equipment, there has been massive discharge of these wastes in the environment, ending up in our waste disposal facilities and water bodies posing a great challenge to environmental conservation. Because of the polypropylene material used in manufacture of these SUSFM, it takes as long as 25 years to degrade in the environment. These has necessitated this study to find out a low carbon strategy on how to mitigate these pandemic wastes. In the study, the nose strip, ear loop and binding of the SUSFM was cut off before shredding the mask in 5 mm width and 20 mm lengths materials. The shredded SUSFM materials were added to C30/37 grade concrete in various dosages by weight of cement in concrete as 0% being control mix, 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, and 3.0%. Physical characteristics were conducted on water absorption and density on concrete samples after 28 days of curing. Durability properties were conducted on abrasion and acid attack test on hardened concrete after 28 days of curing. From the study, it was concluded that the SUSFM materials can be used to improve the durability properties of concrete up to 1.5% SUSFM giving the best results of abrasion resistance. These gave a positive benefit of these SUSFM materials in manufacture of concrete at the same time providing a sustainable solution on the disposal of the pandemic wastes. However, it may not be suitable for enhancement of concrete water absorption and resistance of concrete to acid attack.

KEYWORDS: Covid-19, Single-use surgical face mask, low carbon, polypropylene.

I. INTRODUCTION

The outbreak of corona virus disease (Covid-19) in the world has resulted into increased production and use of single-use surgical face masks (SUSFM) around the world [1]. With the use of the model developed by Nzediegwu and Chang [2], it was estimated that 21 billion pieces of SUSFM are used monthly in Africa while in Asia it is estimated at 66 billion monthly. Polypropylene is material that mostly used to manufacture SUSFM whose density ranges from 20-25 kg/m³ [3]. Because of the presence of these polypropylene plastics in the SUSFM, it takes as long as 25 years for degradation [4]. The use of SUSFM reduces the rate at which the covid-19 spread among the population. However, the way they are disposed poses a big challenge to environmentalists. The disposal of these materials are ending up in waste facilities, landfills and in our water bodies [5]. It is reported that those that ends up in water bodies' fragments into micro plastics which affects marine life and eventually affecting human life [6]. These effects may be felt on human life way after the pandemic [7].

The Kenyan government made it mandatory to wear face masks in public in its efforts to contain the spread of the deadly covid-19 disease. To comply, many Kenyans used face masks in large numbers. After being used, the face masks were disposed in waste facilities. However, some SUSFM were thrown in the open fields, walkways which mostly were washed into water bodies. Some of the SUSFM were flushed in domestic toilets into sewer reticulation systems eventually blocking manholes causing overflows through manholes. These disposal systems poses a big challenge to the environment and overall health of the citizens during and post Covid-19 pandemic. To mitigate these

problems, a low carbon strategy was to be developed to utilize these wastes in meaningful materials such as concrete for use in infrastructure development. This has necessitated the need to investigate the feasibility of reutilizing the SUSFM to improve the physical and durability properties of concrete. The addition of fibres in the cementitious brittle material transforms it to a more ductile material [8]. Salunke [9], deduced that tensile strength, ductility and fatigue resistance is improved with addition of uniformly dispersed and closely spaced fibers. This was evidenced by Al-Hadithi and Hilal [10] who used shredded plastic fibers from beverage bottles in concrete. There was notable increase in compressive strength, ultrasonic pulse velocity and flexural strength by 43.4%, 44.4% and 82.2% respectively. Further, Malek et al. [11] while using white polypropylene fibers, the compressive strength improved by 39.4%, flexural strength by 162.4% and split tensile strength by 254.2% at 1.0% content of white polypropylene fibres in concrete. Workability of concrete decreased with increase in fiber content while compressive strength and flexural strength increased up to 1.5% fiber content in concrete as reported by Pandyaet and Purochit [12].

Saberian et al., [13] used shredded single-use surgical face masks together with recycled concrete aggregate to produce road base blend material with increased unconfined compressive strength and resilient modulus in comparison to the control material without the recycled surgical face masks material. Optimum contents reported was 1% of SUSFM material mixed with recycled concrete aggregate (RCA). Meddah and Bencheikh [8] while using industrial plastic waste in concrete, compressive and flexural strength improved at optimum dosage of 0.75% of 50 mm length fibres.

Research have been conducted to determine the impact of waste plastic materials in concrete properties. However, there are no conclusive studies on the reutilization SUSFM material to improve the physical and durability properties of concrete. To evaluate the feasibility of reuse of SUSFM material in concrete, density, water absorption, acid attack resistance and abrasion resistance tests on hardened concrete tests were performed.

II. METHODOLOGY

A. Materials

Cementitious materials used in the study was ordinary Portland cement of strength class CEM1/42.5N as Simba Power cement. Fine aggregate was river sand from river Malakisi, Malaba Kenya. The maximum size was 5 mm, Specific Gravity 2.7, Fineness Modulus 2.8, and particle size gradation obtained from sieve analysis lying within the grading limits. The coarse aggregate of minimum 10 mm and 20 mm maximum size with Flakiness Index of 16.5 and Water Absorption of 1.9% from Nzoia Quarry Ltd, Turbo Eldoret, Kenya was used in the study. Water used in the study was ordinary drinking water sourced from local water service provider, in Bungoma town, Kenya. Sika plastiment 40 KE from Sika Kenya Ltd with density of 1.05 kg/m³ was used as plasticizer in the ratio of 1 kg for every 100 kg of cement used in concrete. Hydrochloric acid of 2% concentration prepared in the University laboratory was used. SUSFM masks were sourced from local chemist in Bungoma town, Kenya as Promo-Kings 3 ply single-use surgical face masks. Nose strips, ear loops and masks binding were removed before shredding into 5mm width and 20 mm length fibres, shown in Figure 1. Properties of the SUSFM are as shown in Table I.

To avoid contamination and spread of Covid-19, used SUSFM was not allowed in the laboratory, hence the use of new unused SUSFM for this study. For commercial reutilization of SUSFM, there are several studies done to demonstrate how the used SUSFM can be cleaned before being reused as materials in concrete production. Xiang et al. [14] reported that heating SUSFM at 70°C for 60 minutes, the covid-19 virus can be destroyed. Further, Hamzavi et al. [15] proposed for use of ultra violet germicidal irradiation to inactivate Covid-19 virus from the used surgical face masks.

**Figure 1: Single-use surgical masks and shredded single-use surgical masks****Table I: Properties of Single-use Surgical Face Masks.**

Physical Properties	Description
Size of SUSFM masks	172.5 mm by 97.0 mm
Width of SUSFM fibers	5 mm
Length of SUSFM fibers	20 mm
Thickness	0.35 mm
Aspect Ratio	29
Density	0.166 kg/m ³
Weight	3.5 g
Shape	Rectangular

B. Mix Design

The mix design in the study adopted the DOE concrete design method. The proportions of materials in the concrete mix are shown in Table II.

Table II: Design Mix Proportion per M³ of Concrete

Batch ID.	Cement (kg)	Water (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	SUSFM (kg)
00	404	210	679	1107	0
05	404	210	679	1107	2.02
10	404	210	679	1107	4.04
15	404	210	679	1107	6.06
20	404	210	679	1107	8.08
25	404	210	679	1107	10.1
30	404	210	679	1107	12.12

C. Concrete Casting

The saturated surface dry (SSD) fine and coarse aggregates were weighed and mixed dry with weighed cement on a dry metallic pan till the mix was uniform. Water was weighed and half of the volume added to the dry mix and mixing continued till uniform. The remaining half volume of batching water was mixed with the Sika plastiment 40KE plasticizer before being added to the concrete mix. The mixing continued till a consistent mix was achieved. The shredded SUSFM material was added to the mix slowly to allow even distribution till the concrete mix was uniform. Shredded SUSFM materials were added to concrete in proportions of 0% as control mix, 0.5%, 1.0%, 1.5%, 2.0%,

2.5% and 3.0% by weight of cement in concrete. The range adopted was in agreement with Malek et al. [11]. Three samples for each of the seven mix regimes were cast for testing.

D. Methods

In the preparation of test samples, the 150 mm concrete cube molds were cleaned, dried and a thin coat of oil applied as lubricant to aid in the removal of samples. The prepared concrete was poured into molds in three layers with each layer being compacted by poker vibrator for 20 seconds. After compaction, the concrete in the mold was troweled level and kept undisturbed for 24 hours. The samples were demolded and cured by submerging them in water in the curing tank for 28 days. After 28 days, the samples were removed from the curing tank, air dried before testing. The process was repeated for all the tests conducted.

E. Testing Procedures

Densities of hardened concrete was determined to BS EN 12390-7 [16]. After 28 days of curing, the air dried test samples of hardened concrete were weighed on a weighing balance. The hardened concrete density, ρ , of cube sample was calculated using equation: Density, $\rho = M / V$ (kg/m^3) Where, M is the mass of the cube sample in kg and V is the cube sample volume calculated from its dimensions in m^3 .

Water absorption of hardened concrete samples were determined to BS EN 1881-122:2011+A1 [17]. After 28 days of curing, the air dried test samples of hardened concrete were weighed on weighing balance as W_1 . The surface dry test samples were kept in hot air oven, Biobase model BOV-V225F at 105°C for 24 hours period. Thereafter, the specimens were removed from the oven, air cooled and weighed as W_2 . Water absorption was calculated using equation: Water Absorption = $100 * (W_1 - W_2) / W_2$ (%). Where, W_1 is the weight of air dried concrete cube sample in kg and W_2 is the weight of dry concrete cube sample in kg.

The acid attack resistance was investigated in terms of percentage weight loss and compression strength loss of test samples. After 28 days of curing, the air dried test samples of hardened concrete were weighed as W_1 . The weighed samples were then immersed in the 2% hydrochloric acid in a plastic tank for 60 days. The tanks was tightly closed to ensure the concentration of the acid remains the same for the period of testing. After 60 days, concrete samples were tested for residual weight W_2 . A similar procedure was used by Rao et al., [18]. Acid attack was evaluated by determining the weight loss by using equation: Weight Loss (WL) = $100 * (W_1 - W_2) / W_1$ (%). Where, W_1 is the weight of sample before being immersed in the acid and W_2 is the weight of sample after acid attack.

For compressive strength loss, the air dried hardened concrete test samples were tested for compressive strength, FC_1 conducted using a Basic wizard type testing machine with digital readout unit model No. 00701/A. Another similar set of air dried samples were completely immersed in 2% hydrochloric acid solution in a plastic tank for 60 days. The samples in the tank with acid were covered throughout testing period to ensure the concentration of the acid remains the same. After 60 days, concrete samples were tested for residual compressive strength FC_2 . Acid attack was evaluated by determining the compressive strength loss by using equation: Compressive Strength Loss (CSL) = $100 * (FC_1 - FC_2) / FC_1$ (%). Where, FC_1 is the compressive strength of specimen before being immersed in the acid solution and FC_2 is the residual compressive strength of sample after acid attack.

Abrasion resistance test was determined in terms of weight loss on concrete samples. After 28 days of curing, the air dried test samples of hardened concrete were weighed, W_1 . Thereafter, the specimens were subjected to abrasion by use of wire brush as described by Arasa et al. [19]. The specimens were placed on the table and firmly held by a clamp before wire brushing to and fro on the upper surface of the sample 50 strokes. The to and fro brushing made one stroke. After wire brushing, the specimens were weighed as W_2 . Abrasion was evaluated by determining the weight loss by using equation: Weight loss (WL) = $100 * (W_1 - W_2) / W_1$ (%). Where, W_1 is the weight of sample before abrasion and W_2 is the weight of sample after abrasion.

III. EXPERIMENTAL RESULTS

A. Density Test on Hardened Concrete.

The results of density of hardened concrete incorporating SUSFM material are as shown in Figure 2 The results shows a general reduction in the density of concrete when the SUSFM material is added to concrete in comparison with the control specimen. The density was observed to have reduced from 1.5% to 7.7% at SUSFM material dosages of 0.5%

to 3.0% respectively. This is in agreement with Taherkhani [20] who reported similar trend with PET fibres on density of hardened concrete. This may be attributed to the addition of SUSFM material which are light in weight compared to other constituents of concrete and occupying a volume that could otherwise be occupied by the heavy concrete constituent materials [21].

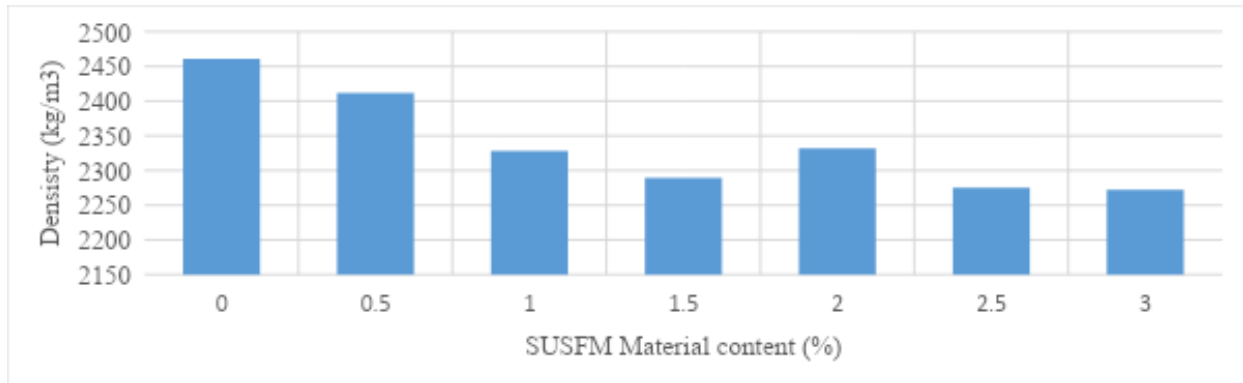


Figure 2: Density of hardened concrete with SUSFM Material

B. Water absorption test on hardened concrete

The water absorption of hardened concrete results are shown in Figure 3. From the results, water absorption of concrete with SUSFM material increased progressively compared to the control specimen. Water absorption of concrete increased by 16.9%, 40.3%, 53.6%, 60.7%, 64.4%, 70.8% when 0.5%, 1.0%, 2.0%, 2.5%, 2.5% and 3.0% of SUSFM material was added respectively. Generally, the water absorption of concrete increased with increase in the added SUSFM materials. Similar results were observed by Yuan and Jia [22]. This increase in water absorption may be attributed to increased amount of SUSFM material with the inner most layer made from absorbent materials with higher water absorption properties than other concrete constituents [23].

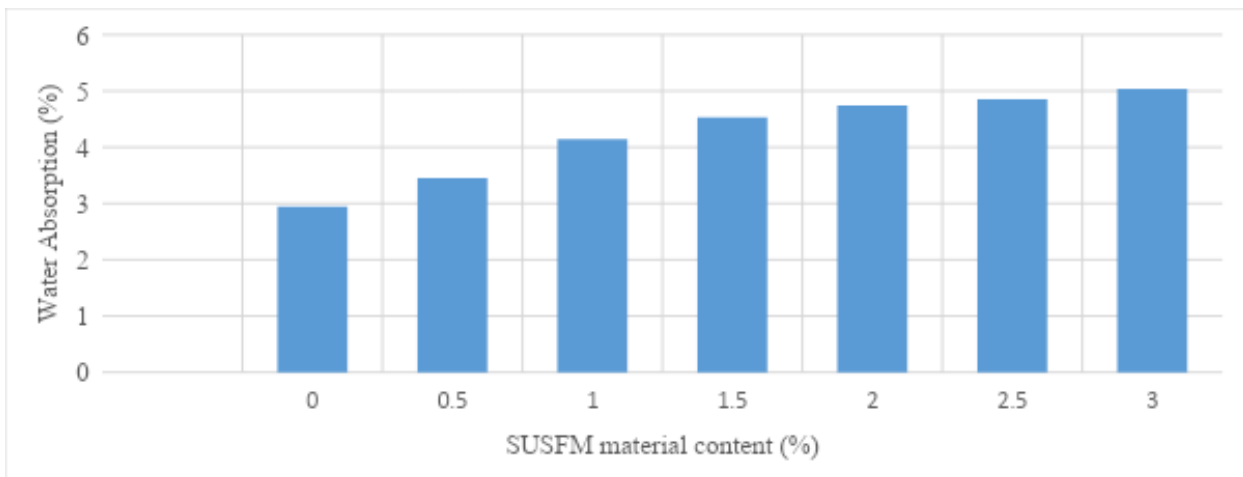


Figure 3: Water absorption of hardened concrete with SUSFM Material

C. Acid attack test on hardened concrete

The results of the compressive strength before and after exposure to the acid attack are presented in Figure 4. The Acid attack resistance was evaluated by determining compressive strength loss and weight loss as represented in Figure 5 and Figure 6 respectively. From the acid attack test results, when concrete with SUSFM material is subjected to acid attack, the residual compressive strength is lower than the original compressive strength. There was gradual increase in compressive strength loss compared to the control specimen. The control specimen compressive strength loss was 9.0% while the highest compressive strength loss of 38.3% was observed at 2.0% of added SUSFM material.

From the percentage weight loss results, there was a gradual increase in percentage weight loss from the control specimen. A 0.54% weight loss was observed for the control sample while the highest of 1.04% being registered at 2.0% SUSFM material content in the concrete. The increase in percentage loss of weight and compressive strength loss was attributed to degradation of concrete that was provoked by acid attack [18]. In addition, since concrete is an alkaline material, the attacking hydrochloric acid reacted with calcium compounds in concrete to form calcium salts that are soluble in water. The leaching of these salts reduces the volume of concrete and reduces cohesion of the paste [24].

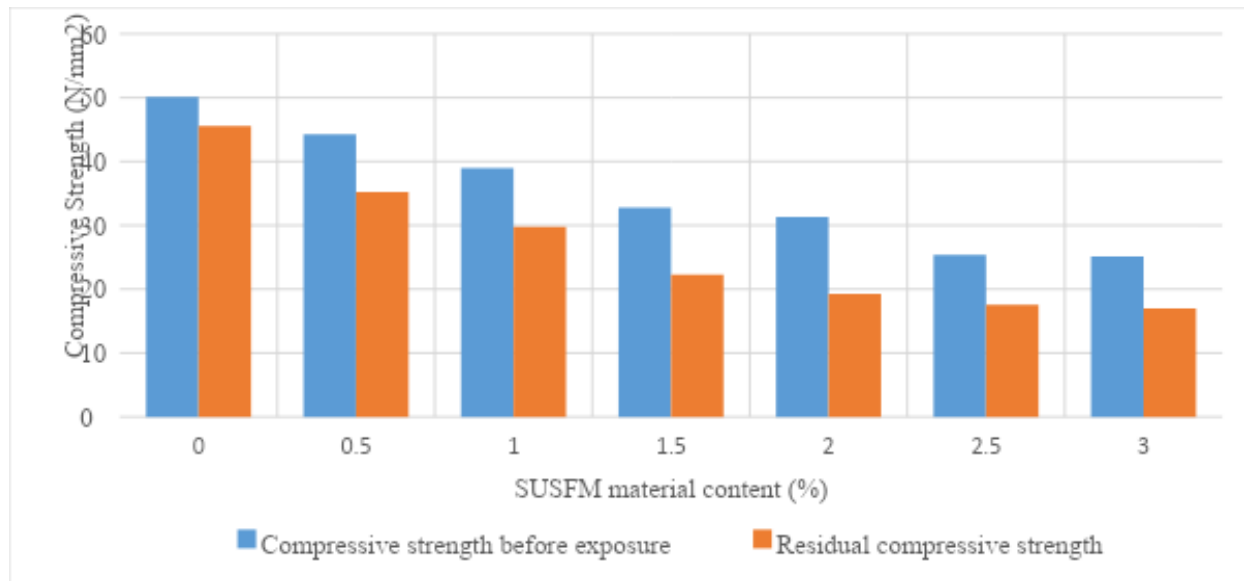


Figure 4: Compressive strength before exposure and residual compressive strength after the acid attack on hardened concrete.

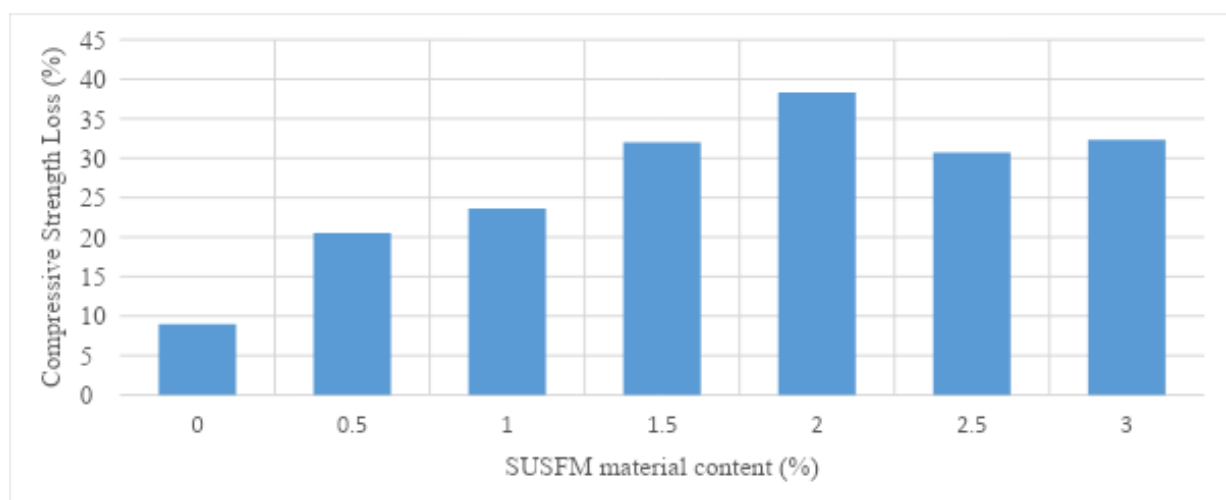


Figure 5: Compressive strength loss of hardened concrete after acid attack

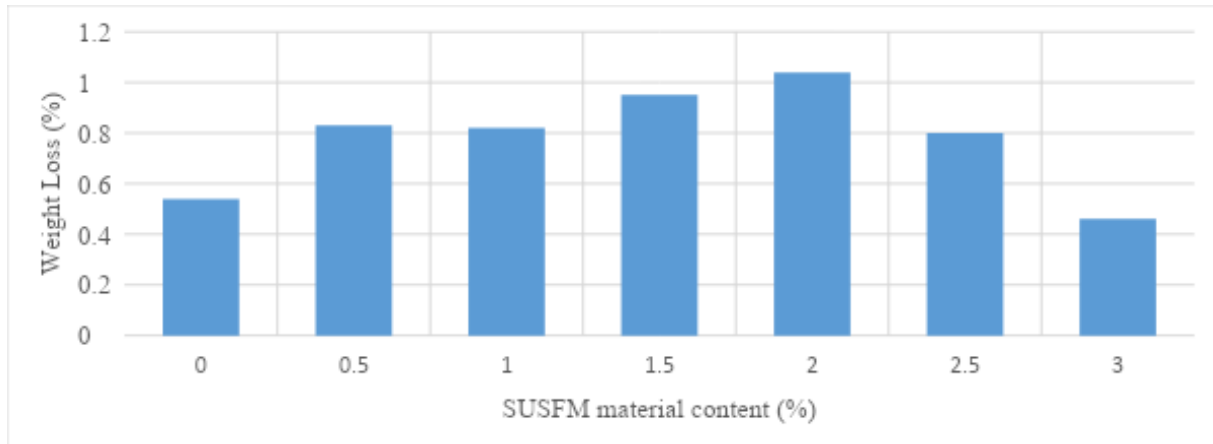


Figure 6: Weight loss of hardened concrete after acid attack

D. Abrasion resistance tests on Hardened concrete

The abrasion test results of concrete with SUSFM material subjected to abrasion were presented in Figure 7. From the results, the percentage abraded material for control specimen was 0.050%. The percentage abraded material reduced steadily from the control specimen at 0.05% to lowest 0.043% at 1.0% and 1.5% of additional SUSFM material content. A slight increase was reported at 2.0% and 2.5% of 0.044% and 0.045% at 3.0% SUSFM material content. This was in agreement with Alaskar et al. [25] who reported that 1.25% of polypropylene fibres mix had the highest abrasion resistance. Further, these results are similar to those reported by Abu-Saleem et al. [26]. The optimum content was recorded at 1.0% and 1.5% of SUSFM material in concrete which gave the least percentage of abraded material of 0.043%, hence the highest abrasion resistance. The reduction in abraded material can be attributed to SUSFM material's bridging action and strong bond between the SUSFM materials and concrete matrix hence higher energy absorption [27]. The reduction in abrasion resistance beyond the 2% SUSFM material content may be attributed to the development of weaker bonds between the material and concrete because of increased SUSFM material in the concrete mix [28].

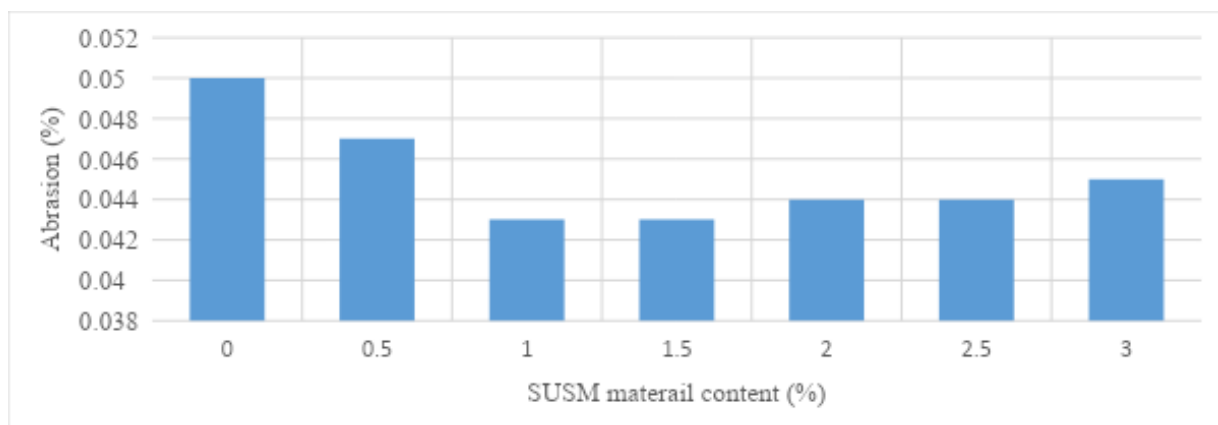


Figure 7: Abrasion of hardened concrete with SUSM material.

IV. CONCLUSION

A. Addition of SUSFM in concrete reduced the density of concrete which reduces the overall weight of building elements reduces hence reducing the overall loads on the foundations which translates into lower cost of construction. However, the water absorption of concrete increased with increased SUSFM materials hence may not be suitable for use in corrosive environments.

B. Incorporating SUSFM materials in concrete increases the compressive strength loss up to 38.3% at 2.0% while weight loss increased up to 2.0% of SUSFM material. This indicates negative effect on concrete exposed to acidic conditions.

C. Inclusion of SUSFM in concrete improved the abrasion resistance of concrete. The optimum SUSFM material content was recorded at 1.0% giving the least percentage of abraded material, hence the highest abrasion resistance. With this positive effect on concrete, the SUSFM materials can be used to improve abrasive resistance for concrete structures such pavements, industrial floors and slope stabilization.

REFERENCES

- [1] . J. J. Klemes, Y. V. Fan, R. R. Tar and P. Jiang, "Minimising the present and future plastic, energy and environmental footprints related to Covid-19", Renewable Sustainable Energy reviews, 127, 109883, 2020
- [2]. C. Nzediegwu and S. X. Chang, "Improper solid waste management increases potential for COVID-19 spread in developing countries", Resources, Conservation & Recycling, 161, 104947, 2020
- [3]. S. A. Abbasi, A. B. Khalil and M. Arslam, "Extensive use of face masks during Covid-19 pandemic: (Micro) plastic pollution and potential health concerns in Arabian Peninsula", Saudi journal of biological sciences, 27, 3181-3186, 2020
- [4] . J. C. Prata, A. L. P. Silva, T. R. Walker, A. C. Duarte, and T. Rocha Santos, "COVID-19 pandemic repercussions on the use and management of plastics", Environmental Science & Technology, 54 (13), 7760-7765, 2020
- [5] . A. L. P. Silva, J. C. Prata, T. R. walker, A. C. Duarle, W. Ouyang, D. Barcelo, and T. Rocha-Santos, "Increased plastic pollution due Covid-19 pandemic: Challenges and recommendations", Chemical Engineering Journal, 126683, 2020
- [6]. O. O. Fadare and E. D. Okoffo, "Covid-19 Face Masks: A Potential source of micro plastic fibers in the environment", Science of Total Environment, 737, 140279, 2020
- [7]. S. Kilmartin-Lynch, M. Saberian, J. Li and R. Roychan, "Preliminary evaluation of the feasibility of using polypropylene fibres from covid-19 single use face masks to improve mechanical properties of concrete", Journal of Cleaner Production, 296, 126460, 2021
- [8]. M. S. Meddah and M. Bencheikh, "Properties of concrete reinforced with different kinds of industrial waste fiber materials", Construction and Building Materials, 23, 3196-3205, 2009
- [9]. S. P. Salunke, "Comparative study of fibre reinforced concrete and nominal concrete", International Journal for Scientific Research and Development, 5, 2321-0613, 2017
- [10]. A. I. Al-Hadithi and N. N. Hilal, "The possibility of enhancing some properties of self- compacting concrete by adding waste plastic fibers", Journal of Building Engineering, 8, 20-28, 2016
- [11]. M. Malek, M. Jackowski, W. Lasica and M. Kadela, "Characteristics of recycled polypropylene fibres as an addition to concrete fabrication based on Portland cement", Materials MDPI, 13(8), 1827, 2020
- [12]. J. M. Pandyaet and B. M. Purochit, "Experimental study on the mechanical properties of concrete incorporating PET fibres", International Journal of Science Research and Development, 2 (09), 2321-0613, 2014
- [13]. M. Saberian, J. Li, S. Kilmartin and M. Boroujeni, "Repurposing of covid-19 single use face masks for pavement base/subbase", Science of Total Environment, 769, 145527, 2021
- [14]. Y. Xiang, Q. Song, Q and W. Gu, "Decontamination of surgical face masks and N95 respirators by dry heat pasteurization for one hour at 70°C", American Journal of Infection Control, 48 (8), 880-882, 2020
- [15]. I. H. Hamzavi, A. B. Lyons, I. Kohli, S. Narla, A. Parks-Miller, J. M. Gelfand, H. W. Lim and D. Ozog, "Ultraviolet germicidal irradiation: possible method for respirator disinfection to facilitate reuse during COVID-19 pandemic, Journal of American Academy of Dermatology, 82, 1511-1512, 2020
- [16]. British Standards Institution, Testing of hardened concrete. Density of hardened concrete, BS EN 12390-7, British Standards, 2019
- [17]. British Standards Institution, Testing concrete: Methods for determination of water absorption. London, BS EN 1881-122:2011+A1, British Standards, 2020
- [18]. H. S. Rao, H. M. Somasekharaiah and V. G. Ghorpade, "Residual compressive strength of fly ash based glass fibre reinforced high performance concrete subjected to acid attack", International journal of engineering, science and technology, 4 (1), 71-80, 2012
- [19]. F. O. Arasa, R. Onchiri, and Z. C. Abiero-Garly, "Experimental investigation on the compressive strength and durability performance of modified Dry-stack hollow sandcrete blocks", Open access library journal, 8, 1-13, 2021
- [20]. H. Taherkhani, "An investigation on the properties of the concrete containing waste PET fibres", International journal of Science and engineering investigations, 3, (27), 37-43, 2014



- [21]. N. Hidayat, R. N. Mutuku and J. N. Mwero, "Physical and mechanical experimental investigation of concrete incorporated with polyethylene terephthalate (PET) fibres", European international journal of science and technology, 6 (8), 2304-9693, 2018
- [22]. Z. Yuan and Y. Jia, "Mechanical properties and microstructure of glass fibre and polypropylene fibre reinforced concrete: An experimental study", Construction and building materials, 266, 121048, 2021
- [23]. L. Akshayaa, M. P. Brundha and D. Ezhilarasan, "Recent types and functions of face masks", European journal of molecular and clinical medicine, 07 (01), 2515-8260, 2020
- [24]. D. Maruthachalam, B. G. Vishnuram, M. Gurunathan, and I. Padmanaban, "Durability properties of fibrillated polypropylene fibre reinforced high performance concrete", Journal of structural engineering, 39, 1 – 9, 2011
- [25]. A. Alaskar, H. Alabduljabbar, A. M. Mohamed, F. Alrshoudif and R. Alyousef, "Abrasion and skid resistance of concrete containing waste polypropylene fibres and palm oil fuel ash as pavement material", Construction and building materials, 282,122681, 2021
- [26]. M. Abu-Saleem, Y. Zhuge, R. Hassanli, M. Ellis, M. Rahman and P. Levett, "Evaluation of concrete performance with different types of recycled plastic waste for kerbs application", Construction and Building materials, 293,123477, 2021
- [27]. C. D. Atis, O. Karahan, K. Ari, O. C. Sola and C. Bilim, "Relation between strength properties (Flexural and compressive) and abrasion resistance of fibre (steel and polypropylene) - Reinforced fly ash concrete", Journal of materials in civil engineering, 21,402-408, 2009
- [28]. R. Alyousef, "Sustainable use of waste polypropylene fibres to enhance the abrasion and skid resistance of two stage concrete", Sustainability MDPI, 13, 5200, 2021



INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 8.118



ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 **9940 572 462**  **6381 907 438**  **ijirset@gmail.com**



www.ijirset.com

Scan to save the contact details