Influence of Waste Clinical Mask Fiber on Interfacial Strength Parameters

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Abstract

To investigate the influence of clinical mask fibers on the geotechnical properties of different interfaces. In the present study different geotechnical tests like Triaxial Shear Tests, California Bearing Ratio Tests, and split tensile strength tests were done to understand the behavior of different mix propositions containing clinical mask fiber. From the test result, it is clear that the addition of waste clinical mask fiber in different mix proportions increases the overall shear strength of the material. Also, the percentage increases in CBR value were recorded by about 40% with the addition of clinical mask fiber. In addition, from the split tensile tests results on different mix proportions, it is observed that the tensile strength value increases up to 45% to 50% with the addition of mask fiber to respective coarser and fine grain compositions. Thus, the study confirms that clinical mask fibers have the potential to improve the geotechnical properties and can be used as fill material in different construction like retaining structures and earthen embankments.

Introduction

The municipal and Industrial waste problem is a major issue nowadays worldwide. The emergence of the novel Covid-19 virus (SARS-CoV-2) raises the waste clinical mask in the environment since December 2019. Due to the Covid-19 pandemic disposal of clinical masks and medical waste is a massive problem for municipalities. The health agencies of the country like India have advised or make it mandatory for the general public to wear masks in public places. Also, no one seems aware of what to do with these masks (especially single times use ones) after using these masks (Satpal Singh, 2020; Aragaw and Mekonnen, 2021; Vaverková et al.2021; Sinha et al. 2020; Parkinson,(2020); Ragazzi et al.2020; UNEP,(2020); Yousefi et al.2021; Torkashvand et al. 2021; Sangkhm (2020)). To control the problem of disposal of the waste clinical mask, thereby required some preventive measures. Numerous industrial wastes like fly ash, pond ash, cement kiln dust, slag, plastic, paper, etc are generated globally in abundance every year. These wastes have different structural properties like adhesion, friction, tensile, filler, pozzolanic properties, etc (Kumar and Sharma, 2018, 2019). Both municipal and industrial waste has a significant ill effect on the environment in terms of air, water, and land pollutions. Various researchers utilized industrial waste for the construction of road sub-grade, structural fill, retaining fill, etc and reported tremendous results to the construction industry (Kumar and Gupta, 2015; Kumar and Sharma, 2018, 2019 Thanikella et al.2016). To increase the tensile strength of materials various researchers, investigate the reinforcing effect of different fibrous materials. Das and Viswanadham (2010) investigated the effect of geo-fibers, polypropylene, and polyester in soil. Kumar and Sharma, 2018 used polypropylene (PP) fiber with pond ash and Cement kiln dust to strengthen the structural fill. Different geotechnical tests like the Proctor test, California bearing ratio (CBR) test, direct shear test, and triaxial shear tests were conducted to investigate the geotechnical properties of mix containing polypropylene fiber. Nezhad et al. 2021 investigated the effect of natural and synthetic fibers on the tensile and bearing capacity of clay. The study reported that with the addition of basalt fiber to clay, the angle of friction enhances up to 100% while further with the addition of synthetic polyester (PET) fibers the cohesion value increased by 70%. In the present study, a small effort has been made to convert waste into resources by investigating the geotechnical properties of waste clinical mask fiber with different industrial wastes. To investigate the effect of waste clinical mask fiber on interfacial shear strength of different mix various consolidated drained triaxial shear tests were conducted. Also, a reference study has been conducted to investigate the California bearing ratio, and tensile strength testing using clinical mask fiber, industrial waste, and locally available soil (c-ϕ soil). The present study proposed the waste clinical mask fiber as construction material for structural fill, embankments construction, and backfill material in retaining material. In the present study, efforts have been made to replace conventional fiber with waste clinical mask fiber. Clinical mask fiber (CMF) has been used to impart tensile strength to a material. The addition of fiber accounts for a significant alteration and rectification in the engineering properties of materials. The efficiency of CMF in terms of strength parameters was checked along with the different industrial waste.

Experimental Methodology And Material
Based on reported literature different optimum mix percentages of soil, fiber, and industrial waste were selected. The fiber of the selected mix was then replaced with clinical mask fiber (CMF) and investigated the interfacial shear strength parameters, California bearing ratio, and tensile strength for different mix compositions. The detail of proposed mix in the present study is given in Table 1.

The scheme of proportions for laboratory testing is given in Table 2. The tests included California bearing ratio tests (as per IS 2720-16 (BIS 1973)), triaxial shear tests (as per IS 2720-12 (BIS 1991)). The split tensile strength is calculated according to ASTM C 496-96.

\[
T = \frac{2F_{\text{max}}}{\pi dl}
\]

(1)

\(T\) is split tensile strength;

\(F_{\text{max}}\) is applied maximum load;

\(L\) and \(d\) are length and diameter

**Material**

**Clinical mask fiber**

In the present study waste, clinical masks were collected from Medical College, Hamirpur. For the pre-treatment process, waste clinical masks were then kept for 48 hours in a separate container. Used masks are then washed in a washing machine using washing power before using these in the laboratory. The Clinical mask fibers are made up of polyester, polypropylene, and carbon fiber (Mask Fabrics 201, 2021). These fibers are used as reinforcing material in the construction industry. The waste clinical masks were finally divided into small sizes having lengths and diameters less than equal to 12mm and 0.02 mm respectively (Kumar and Sharma, 2018). Fig.1a&b showing waste clinical mask and mask fiber respectively used in the present study.

**Cement Kiln Dust**

Cement kiln dust (CKD) is a waste dust product of the cement industry, has pozzolanic properties. In the present study, Cement kiln dust (CKD) has been collected from Ultra-tech Cement Grinding & Blending Unit, Bagheri, Himachal Pradesh (India). The properties of Cement kiln dust (CKD) are listed in Table 3 which is given by the cement industry.

**Pond ash**

Pond ash is collected from Guru Gobind Singh Super Thermal Power Plant, Roopnagar (Punjab) India. The physical and chemical properties of pond ash are presented in Table 4.

**Clay and Expansive Clay**

In the present study, clay has been collected from Tihra, Himachal Pradesh, India. The Geotechnical properties of clay are listed in Table 5.

**Results And Discussion**

To understand the effect of clinical mask fiber of geotechnical properties of a different mix of industrial waste, clay, and expansive clay are presented in the following sections:

**Triaxial Shear Tests**
The Consolidated drained tests were conducted on the composition which contains pond ash, cement kiln dust, and clinical mask ber. The tests were conducted under different cell pressure i.e. 50, 100, and 150 kPa respectively. From the test result, the normal and shear stresses are plotted as shown in Fig.2. Evident from Table 6 that with the replacement of 25% of pond ash with cement kiln dust the cohesion and interface friction value increase from 0 to 16.66 kN/m² and 33.4° to 42° respectively. With the addition of 1% of clinical mask fiber the shear strength parameters i.e. c and φ increase to 30 kN/m² and 54.46° respectively. Evident that with the addition of waste clinical mask fiber the cohesion value increases 80% and friction value increases up to 30% respectively. Similarly, the Unconsolidated un-drained tests were conducted on the composition which clay and expansive clay along with clinical mask fiber. From the test result clear that with the addition of clinical mask fiber to clay and expansive clay the cohesion and angle of friction increase significantly as shown in Fig.3 and Table 6. Clear from the test result that waste clinical mask fiber has the potential to strengthen the retaining structure, soil subgrade, and earth embankment.

**California Bearing Ratio Tests**

To simulate the saturated soil conditions of a sub-grade the soaked California Bearing Ratio (CBR) tests were conducted on different mix proportions. Evident, from Fig.4 the CBR value of different mixes increases significantly with the addition of clinical mask fiber. The CBR value of 75% pond ash mixed with 25% of cement dust was recorded 20%, while with addition on of clinical mask up to 1% it increases up to 28%. Evident that with the addition of 1% of waste clinical masks fiber having aspect ratio up to 600, the percentage increases in CBR value was recorded about 40% respectively. With further increases in the percentage of masks fiber (i.e. up to 1.5%), the soaked CBR value starts decreasing compared to the CBR value at 1% fiber.

For clayey and expansive soil, the percentage increases in CBR% values were recorded at 25% and 37.5% with the addition of 0.5% and 1% masks fiber respectively (Fig.4). Based on the tests result that waste clinical mask ber helps in increasing the bearing capacity of subgrade or embankment as well.

**Split tensile strength (STS) test**

Evident from Fig. 5, the result of split tensile test on different mix proportions containing waste clinical mask fiber. It is observed that the tensile strength value increases up to 45% to 50 % with the addition of mask fiber to respective coarser and fine grain compositions. From the comparison of soil samples containing mask fiber and soil samples without mask fiber, it is observed that samples containing mask fiber show less deformation. Also, the sample containing mask fiber reflects lesser tension cracks under applied load. This reduction in deformation and tension cracks is due to increases in the total contact area between the different materials. Similar kinds of results were reported by the different researchers using fibrous material in different soil compositions (Kumar and Sharma, 2018; Kumar and Gupta, 2015). Moreover, it is observed that with increases in curing period the split tensile strength of different mixes increases, which further increases with the addition of clinical mask fiber. Also, evident (Fig.5) that beyond 20 days the increment in strength becomes constant with further increases in the curing period.

**Conclusions**

In the present study different geotechnical tests like Triaxial Shear Tests, California Bearing Ratio Tests, and split tensile strength tests were done to understand the behavior of different mix propositions containing clinical mask fiber. The based on key observations from the present study it can be concluded that clinical mask fiber has various construction benefits. From the test result with the addition of waste, clinical mask fiber in coarser mix proportion increases the cohesion value up to 80% and friction value increases up to 30% respectively. Similarly, from unconsolidated un-drained tests with the addition of clinical mask fiber to clay and expansive clay the cohesion and angle of friction increases significantly. Also, the percentage increases in CBR value were recorded by about 40% with the addition of clinical mask fiber. From the split tensile tests results on different mix proportions containing waste clinical mask fiber, it is observed that the tensile strength value
increases up to 45–50% with the addition of mask fiber to respective coarser and fine grain compositions. Thus, the study confirms that clinical mask fibers have the potential to improve the geotechnical properties.

Declarations

Funding

Not applicable.

Conflicts of interest/Competing interests

The authors declare that they have no conflict of interest.

Data Availability Statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

Code availability

Not applicable

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Tables

Table 1 The detail of a proposed mix in present study
| Author & Year | Material Used | Optimum mix | Proposed Mix for Present study |
|--------------|--------------|-------------|---------------------------------|
| Kumar and Sharma, 2018 | Pond ash (PA), Cement Kiln Dust (CKD), Polypropylene fiber (PPF) | 75% Pond ash +25% Cement Kiln Dust +1% Polypropylene fiber | 75% Pond ash +25% Cement Kiln Dust +1% Clinical mask fiber (CMF); 75% Pond ash +25% Cement Kiln Dust |
| Samer Rabab'ah et al. 2021 | Glass fiber (GF), expansive soil (ES) | 1%GF+99% ES | 1%CMF+99%ES; 100%ES |
| Nezhad et al. 2021 | Synthetic polyester (PET), Basalt fibers (BS), Bagasse (BG), Clay (CL) | 0.5%PET+99.5%Clay | 0.5%CMF+99.5%Clay; 100%Clay |

Table 2 Scheme of proportions for laboratory testing

| Laboratory testing | Mix proportions |
|--------------------|-----------------|
| **Triaxial shear test** | Consolidated drained test: 75% PA +25% CKD +1%CMF; 75% PA +25% CKD; 100%PA  
Unconsolidated un-drained test: 1%CMF+99%EC; 100%EC; 0.5%CMF+99.5%CL; 100%CL |
| California bearing ratio Test (soaked) | 75% PA +25% CKD +1%CMF; 75% PA +25% CKD; 100% PA; 1%CMF+99%EC; 100%EC; 0.5%CMF+99.5%CL; 100%CL |
| Split tensile strength test | 75% PA +25% CKD +1%CMF; 75% PA +25% CKD; 100% PA; 1%CMF+99%EC; 100%EC; 0.5%CMF+99.5%CL; 100%CL |

**Note:** CMF: Clinical mask fiber, CKD: Cement kiln dust, PA: Pond ash, CL: Clay, EC: Expansive clay

Table 3 Chemical Composition of Cement Kiln Dust
### Chemical composition

| Chemical composition | Values (%) |
|----------------------|------------|
| Cao                  | 56         |
| SiO$_2$              | 15         |
| Al$_2$O$_3$          | 10         |
| Fe$_2$O$_3$          | 6          |
| Mgo                  | 4          |
| Na$_2$O, K$_2$O, Loss on ignition | 9          |

**Table 4** Physical and Chemical properties of Pond Ash.

| Physical Parameters    | Values | Chemical composition             | Values (%) |
|------------------------|--------|----------------------------------|------------|
| Color                  | Grey   | Silica (SiO$_2$)                 | 58         |
| Specific gravity, Gs   | 1.73   | Alumina (Al$_2$O$_3$)            | 20         |
| Plasticity index       | Non-plastic | Iron oxide (Fe$_2$O$_3$) | 11         |
| Uniformity coefficient, Cu | 3     | Magnese (Mgo), Calcium oxide (Cao), Loss on ignition | 3          |
| Coefficient of curvature, Cc | 1.4   | Calcium oxide (Cao), Loss on ignition | 5.3        |

**Table 5** Average value of geotechnical properties of clay

| Properties                              | Clay Values | Expansive Clay Values |
|-----------------------------------------|-------------|-----------------------|
| Specific gravity, Gs                    | 2.63        | 2.74                  |
| Content% (sand: silt: clay)             | 0:11:89     | 0:9:91                |
| Liquid limit (%)                        | 44          | 53                    |
| Plastic limit (%)                       | 23          | 25                    |
| Plasticity Index (%)                    | 21          | 28                    |
| USCS Classification                      | Cl          | CH                    |

**Table 6** Shear strength parameter
| Sr. No. | Mix proportion          | Cohesion c (kN/m²) or adhesion | Angle of internal friction φ (degrees) |
|--------|-------------------------|--------------------------------|--------------------------------------|
| 1      | 100%PA                  | 0                              | 33.4                                 |
| 2      | 75%PA + 25%CKD          | 16.66                          | 42                                   |
| 3      | 75%PA + 25%CKD + 1%CMF  | 30                             | 54.46                                |
| 4      | 100%CL                  | 40                             | 0                                    |
| 5      | 0.5%CMF + 99.5%CL       | 42                             | 9.64                                 |
| 6      | 100%EC                  | 45                             | 0                                    |
| 7      | 1%CMF + 99%EC           | 47.33                          | 9.09                                 |

**Figures**

![Figure 1](image)

(a) Waste clinical mask (b) Finally divided mask fiber

*Figure 1*

(a) Waste clinical mask (b) Finally divided mask fiber
Figure 2

Shear stress against normal stress (Consolidated drained test)
Figure 3
Shear stress against normal stress (Unconsolidated un-drained test)

Figure 4
Mix proportions
Variation of CBR values of different mix proportions.

Figure 5

Variation of split tensile strength with time for different mix