Microbial Induced Carbonate Precipitation As A Remedial Measure For Wind Erosion

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Abstract- *This project presents an experimental investigation on the application of microbial calcite to reduce the wind erosion potential using a common soil bacterium , Bacillus subtilis , mixed with medium containing urea and calcium chloride . In recent years, investigations in geomicrobiology have enabled significant advances in understanding the effect of microorganisms in the development of the soil behavior. In this project, a series of experimental study was conducted to investigate the applicability of biotechnologies in soil stabilization. Wind tunnel test and direct shear tests at different wind speeds ,bacterial concentration and cementation medium concentration were employed during the experimental works for an assessment of two soil parameters, namely; wind erosion potential and Shear strength. From the experimental results, it was observed that there is significant reduction in mass loss as compared to that of the untreated sand and the sand yielded varying degrees of wind erosion resistance. Wind erosion was severe for high velocities of wind and samples with low molar concentrations of cementation solution. The longer curing period as well as higher bacterial concentration results in high wind erosion resistance for MICP treated soil.*

Keywords- MICP,Wind erosion, Urea

I. INTRODUCTION

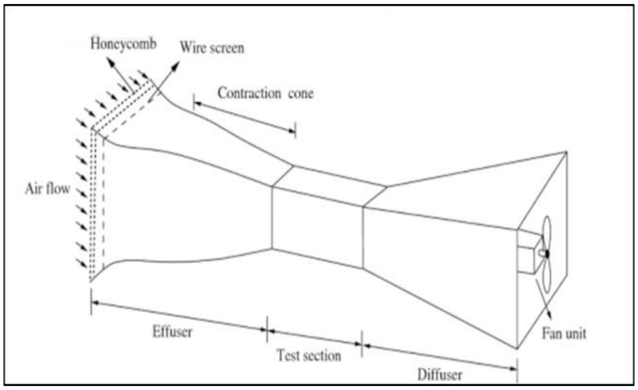
Wind erosion is one of the main factors for soil and environmental degradation, air pollution, and suspended particles transport in arid and semi arid areas. Transporting and excavating these sands in geotechnical engineering causes serious environmental problems like soil erosion, and air and water pollution. Soil particles erode when shear stress exerted by the wind against the ground surface exceeds the forces tending to hold the particles. Microbial-induced carbonate precipitation (MICP) technique is considered as an environmental and ecological friendly ground improvement and also a soil reinforcing method. By spraying the bacteria and cementation solutions onto the surface of sands, calcium carbonate ($CaCO_3$) is generated and suddenly precipitated into the pore space among sand particles. CaCO3 also crystallizes in sand pore space as the moisture evaporates, increasing the strength of MICP-treated sand, then improving its geotechnical properties also.

II. OBJECTIVES

- To find out the eroded soil mass for different wind velocity.
- To find out the eroded soil mass for different molar concentration of cementation solution
- To investigate the effect of bacterial concentration on strength of MICP treated sand.
- To determine optimum molar concentration for reducing wind erosion in MICP treated samples
- To determine optimum molar concentration providing higher shear strength in MICP treated samples
- To compare the effect of MICP treated samples with different curing periods
- To compare the suitability of surface percolation and mixing methods

III. MATERIALS AND METHODOLOGY

Collection of materials include the collection of sand, Bacillus subtilis Bacteria, Calcium chloride and Urea for making cementation solution.MS steel is used for making wind tunnel apparatus. Determine both engineering and index properties of the collected sand. Bacteria was collected from the Department Of Agricultural Microbiology, College Of Horticulture, Kerala Agricultural University, Thrissur. It has the ability to induce the hydrolysis of urea (ureolysis) in naturally occurring environments under the right conditions through secretion of an enzyme urease. This process of ureolysis, through a chain of chemical reactions, leads to the formation of calcium carbonate precipitates. This is known as Microbiologically Induced Calcite Precipitation (MICP).



Experimental Set Up

The wind tunnel setup consist of a test section of 0.4m length,0.3m width and 0.4m height. At the end of test section an anemometer was installed to measure the wind speed. The wind speed can be continuously and uniformly adjusted between 0-10 m/s . Wind is provided with a 75W fan. All samples are of same dimensions with 0.15m length,0.10m width and 0.05m height. The wind speeds are 3m/s,6.5m/s and 10m/s generally called as low, medium and high speed of fan.The sand collection time was taken as 5 minute. The molar concentrations used in the study are 0.5M, 1M and 2M. Three concentrations of bacterial solution were used such as 10^7,10^8 and 10^9 cells/ml. Curing periods were taken as 4,7,14, and 21days.

IV. RESULT AND DISCUSSION

The tests for index properties and Engineering properties of soil were carried out as per IS specification. Specific Gravity, Grain Sieve Analysis, and Relative Density Test had been conducted in Geotechnical Engineering laboratory.Specific gravity of soil was determined based on IS 2720 (part 3) - 1980, specific gravity of Soil is obtained as 2.63. The relative density values obtained for loose, medium and dense conditions are 1.73g/cc, 1.75g/cc and 1.76g/cc respectively. The uniformity coefficient, Cu was obtained as 2. Since sandy soil with Cu value greater than 6 are classified as well graded soil, the sand used for this test was not well graded, but poorly graded. The coefficient of curvature, Cc obtained from particle size distribution curve was 1.15. Since sandy soil with Cc lies between 1 to 3 classified as well graded soils, therefore sand used for this test was not well graded, but poorly graded (SP).Properties of sand weretabulatedintable4.1.

Table 4.1 Properties of Sand

Properties	Value	IS Codes
Effective Particle Size		
D10 (mm)	0.25	IS:2720 (Part 4) - 1985
D30 (mm)	0.38	
D60 (mm)	0.5	
Uniform coefficient , C_u	2	
Coefficient of curvature,	1.15	
Gradation of sand	SP	
Specific gravity	2.63	IS 2720-PART III-

Laboratory experiments were conducted by varying parameters likespeed of wind, bacterial concentration, molar concentration, and curing time of the soil sample. Figure 4.1,4.2 and 4.3 shows the shear behavior of MICP treated soil

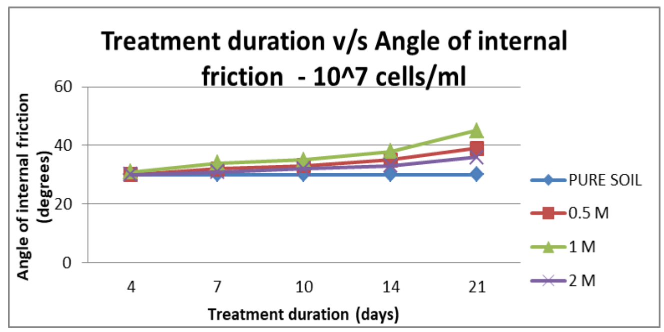


Fig 4.1. Graph showing Treatment duration vs. Angle of internal friction for 10^7 cells/ml

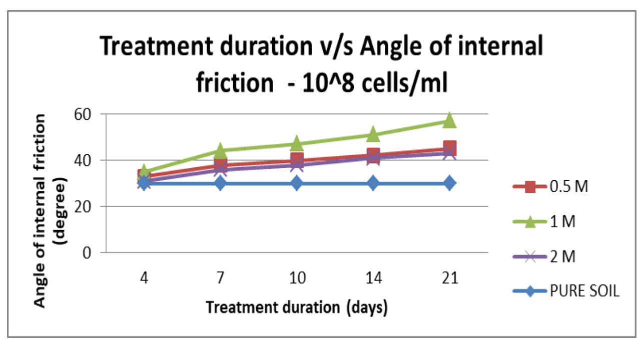


Fig 4.2 Graph showing Treatment duration vs. Angle of internal friction for 108 cells/ml

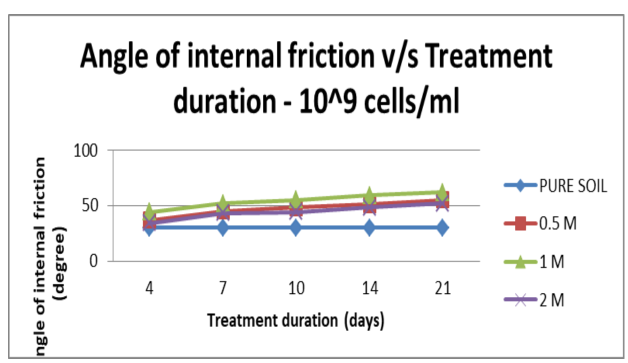


Fig 4.3 Graph showing Treatment duration vs. Angle of internal friction for 10^9 cells/ml

Fourth day test, for the case of 0.5M treated sample there is a decrease in erodedmass due to the precipitation of calcium carbonate in the sample (Fig. 4.4). As the molar concentration increases the mass of eroded sand again decreased in 1M compared to 0.5M specimen. As the molar concentration increased from 1M to 2M the mass of eroded sand gets increased and a trend of increase is seen. It is due to the lower precipitation of calcium carbonate.

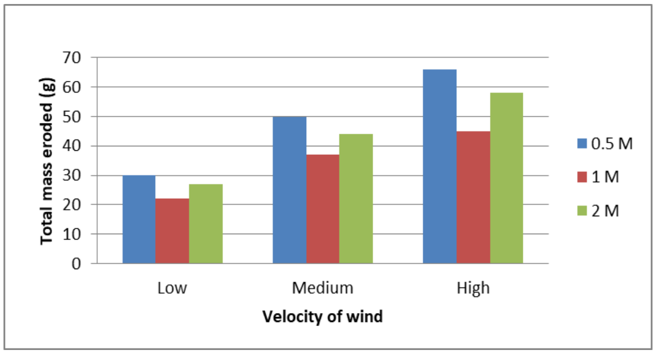


Fig 4.4: Graph showing variation of total mass eroded with wind velocity for 10^7 cells/ml, 4 day test

Also the total mass eroded is least for the 1.0 molar concentration added sample (Fig.4.5). It is due to the high precipitation of calcium carbonate in the sample and due to formation of sand clusters in the specimen which can reduce erosion of sand.

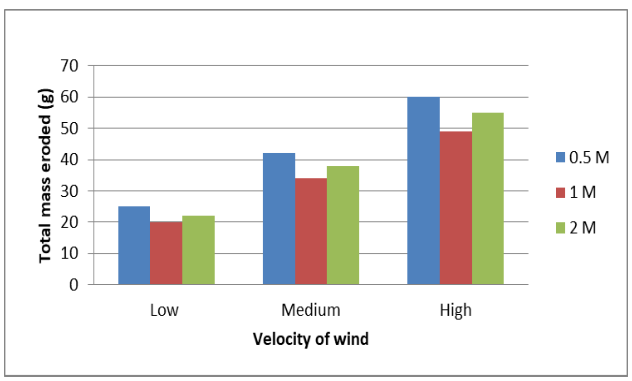


Fig 4.5: Graph showing variation of total mass eroded with wind velocity for 10^8 cells/ml, 4 day test

Also the total mass eroded is least for the 1.0 molar concentration added sample (Fig.4.6). It is due to the high precipitation of calcium carbonate in the sample and due to formation of sand clusters in the specimen which can reduce erosion of sand.

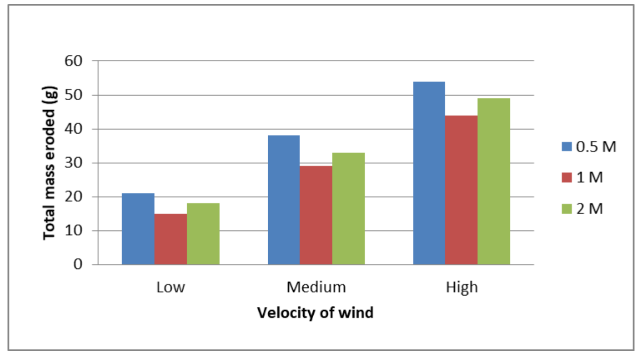


Fig 4.6: Graph showing variation of total mass eroded with wind velocity for 10^9 cells/ml, 4 day test

Seventh day test, for the case of 0.5M treated sample there is a decrease in eroded mass due to the precipitation of calcium carbonate in the sample (Fig. 4.7). As the molar concentration increases the mass of eroded sand again decreased in 1M compared to 0.5M specimen. As the molar concentration increased from 1M to 2M the mass of eroded sand gets increased and a trend of increase is seen. It is due to the lower precipitation of calcium carbonate

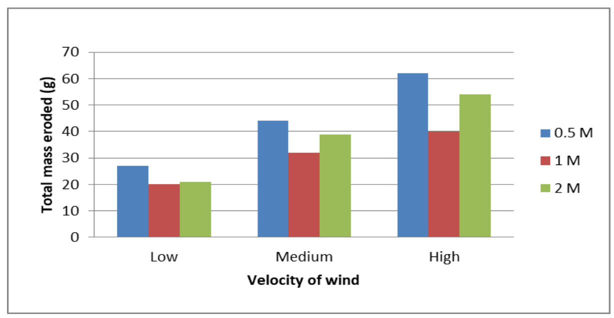


Fig 4.7: Graph showing variation of total mass eroded with wind velocity for 10^7 cells/ml, 7 day test

Also the total mass eroded is least for the 1.0 molar concentration added sample (Fig.4.8). It is due to the high precipitation of calcium carbonate in the sample and due to formation of sand clusters in the specimen which can reduce erosion of sand.

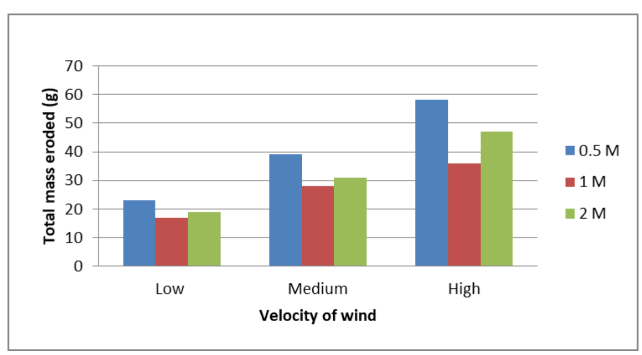


Fig 4.8: Graph showing variation of total mass eroded with wind velocity for 10^8 cells/ml, 7 day test

Also the total mass eroded is least for the 1.0 molar concentration added sample (Fig.4.9). It is due to the high precipitation of calcium carbonate in the sample and due to formation of sand clusters in the specimen which can reduce erosion of sand.

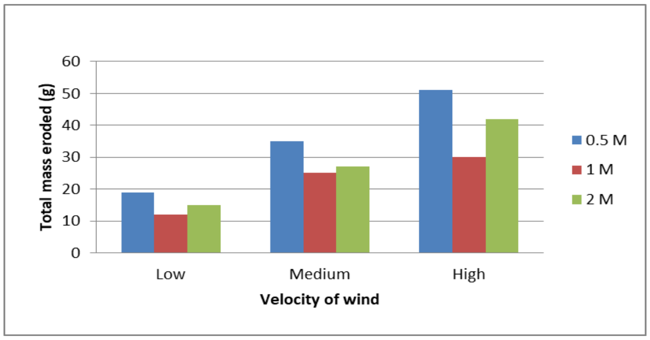


Fig 4.9: Graph showing variation of total mass eroded with wind velocity for 10^9 cells/ml, 7 day test

Fourteenth day test, for the case of 0.5M treated sample there is a decrease in eroded mass due to the precipitation of calcium carbonate in the sample (Fig. 4.10). As the molar concentration increases the mass of eroded sand again decreased in 1M compared to 0.5M specimen. As the molar concentration increased from 1M to 2M the mass of eroded sand gets increased and a trend of increase is seen. It is due to the lower precipitation of calcium carbonate.

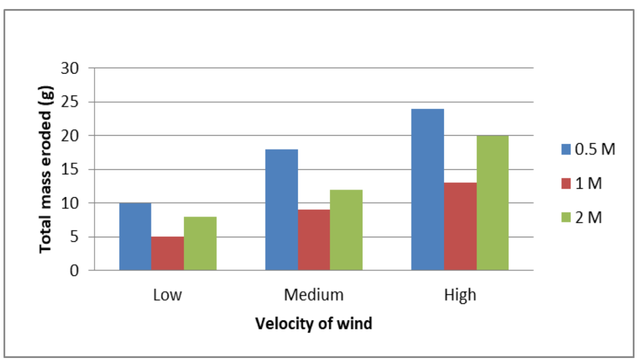


Fig 4.10: Graph showing variation of total mass eroded with wind velocity for 10^7 cells/ml, 14 day test

Also the total mass eroded is least for the 1.0 molar concentration added sample (Fig.4.11). It is due to the high precipitation of calcium carbonate in the sample and due to formation of sand clusters in the specimen which can reduce erosion of sand.

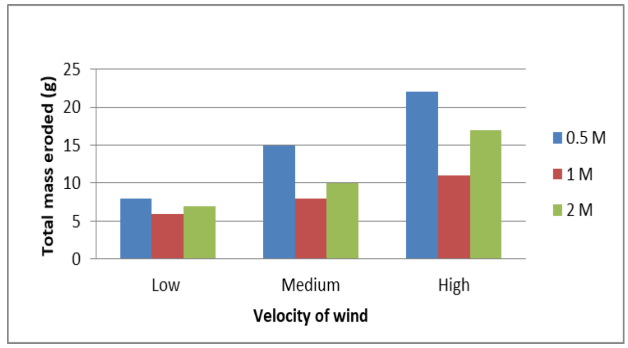


Fig 4.11: Graph showing variation of total mass eroded with wind velocity for 10^8 cells/ml, 14 day test

Also the total mass eroded is least for the 1.0 molar concentration added sample (Fig.4.12). It is due to the high precipitation of calcium carbonate in the sample and due to formation of sand clusters in the specimen which can reduce erosion of sand.

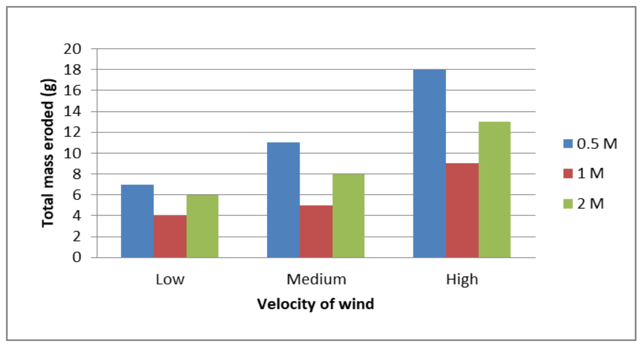


Fig 4.12: Graph showing variation of total mass eroded with wind velocity for 10^9 cells/ml,1 4 day test

Twenty first day test, for the case of 0.5M treated sample there is a decrease in eroded mass due to the precipitation of calcium carbonate in the sample (Fig. 4.13). As the molar concentration increases the mass of eroded sand again decreased in 1M compared to 0.5M specimen. As the molar concentration increased from 1M to 2M the mass of eroded sand gets increased and a trend of increase is seen. It is due to the lower precipitation of calcium carbonate.

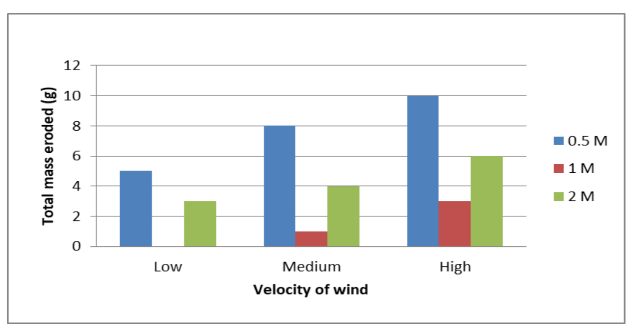


Fig 4.13: Graph showing variation of total mass eroded with wind velocity for 10^7 cells/ml, 21 day test

Also the total mass eroded is least for the 1.0 molar concentration added sample (Fig.4.14). It is due to the high precipitation of calcium carbonate in the sample and due to formation of sand clusters in the specimen which can reduce erosion of sand.

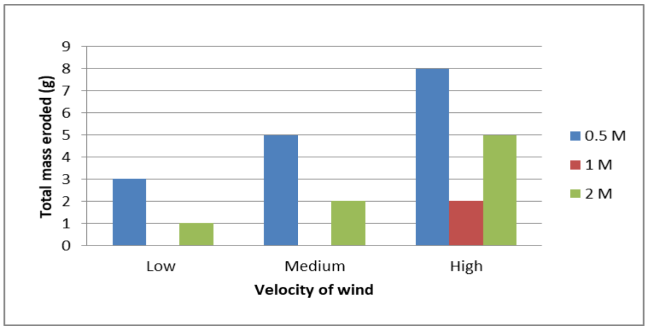


Fig 4.14: Graph showing variation of total mass eroded with wind velocity for 10^8 cells/ml, 21 day test

Also the total mass eroded is least for the 1.0 molar concentration added sample (Fig.4.15). It is due to the high precipitation of calcium carbonate in the sample and due to formation of sand clusters in the specimen which can reduce erosion of sand.

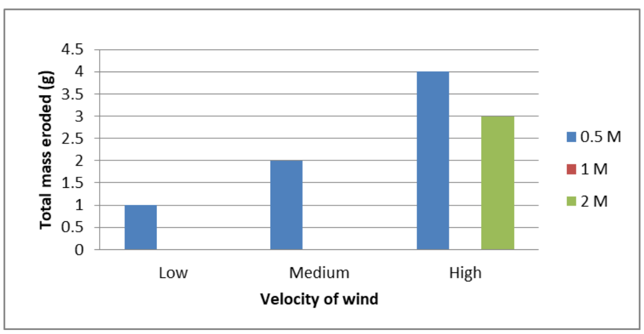


Fig 4.15: Graph showing variation of total mass eroded with wind velocity for 10^9 cells/ml, 21 day test

V. CONCLUSIONS

Based on the experimental observations and discussions of the erosion testconducted, the following conclusions are made

- Wind Erosion was found to be less severe in the MICP treated samples than in the untreated samples under thesame wind speed.
- Erosion was severe in case of 0.5M specimens
- As the molar concentration increased, sand dislodging has been reduced and the gaps in between the sample has also reduced.
- Also when the curing period increased, sand dislodging has been reduced and the gaps in between the sample has also reduced.
- A cementation concentration 1M can bring down the erosion to a negligible level.
- As the bacterial concentration increases the mass of the eroded soil decreased.
- The average calcium carbonate precipitation content increases steadily with increasing cementation concentration. More calcite precipitation corresponds to less erosion weight.
- The formation of clusters of cemented sand particles is fundamentally responsible for the reduction in wind eroded soil mass.
- Combining the 4,7,14 and 21 days test results it is clear that the and total mass eroded is least for the twenty first day test results.

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