APPLICATION OF IMAGE PROCESSING TECHNIQUE FOR THE ANALYSIS OF CRACKING BEHAVIOUR OF COMPOSITE LANDFILL LINERS WITH BRICK DUST

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Abstract - This study aims to quantifying cracking behavior of composite landfill liners using image processing technique. To these attempts, in the laboratory, composite liners were prepared with brick dust at varying mixing proportions of 10, 20, 30, 40, 50 and 60% by dry weight with different water content. Result reveals cracking behavior in terms of crack intensity factor (CIF), crack density factor (CDF) and cracks area reduces with the increasing of brick dust content, while, increases with the increasing of mixing water content. In addition, CIF and cracks area reduces, besides, CDF increases with the increasing of liners thickness. The image processing technique through this study provided a better and easiest way to analyze cracking behavior of liners.

Keywords - Brick Dust, Composite Liners, Cracking Behavior, Image J, Khulna, MATLAB

I. INTRODUCTION

Desiccation cracking of landfill liners is a major problem because it causes cracks on liners in field which reduces strength and sealing function dramatically. According to [1] desiccation induces cracks on soil liners and moisture can migrate into the landfill through the cracks and leads to generate more waste leachate. Temperature distribution, non-uniform moisture content and mineralogical composition of soil are responsible for cracking characteristics on soil structures [2]. Besides, amount and types of cations in pore fluid and particle's orientation are also affect cracking behavior of liners. To overcome this, reinforcing soil masses by adding admixtures with soil were practiced by early civilizations [3]. Additionally, fly ash, lime, cement, sand, brick dust, fiber and gravel in liners reduced the tendency of cracks and shrinkage in soil mess. Researcher [4] used different proportions of brick dust with soil to study the swelling behavior and effect on engineering properties of composite soil.

It is very essential to determine the cracking behavior of liners using quick, easy and better techniques for better performance. Now-a-days an image-based analysis techniques are gaining popularity to quantify crack development and characterization. Different researchers [5, 6, 7] used image analysis technique to quantify cracking characteristics in terms of crack intensity factor (CIF), crack density factor (CDF) and cracks area of composite landfill liners. If directly measure this cracks parameters, larger error will fabricate in actual results due to irregular length, width and shape of cracks (Tang et al., 2008). In this study, a commonly available material like brick dust at varying mixing proportions were used to prepare composite landfill liners. A coding was developed in MATLAB to quantify and analyze the cracking behavior of landfill liners. Moreover, ImageJ and MS excel ware used to calculate cracking parameters. The CIF was measured from direct MATLAB coding. In addition, other cracking parameters such as CDF and cracks area were calculated through ImageJ technique and MS excel. Through this present study, a new window will may open for researchers to prepare cap and base liners easily and economically without further details analysis.

II. MATERIAL AND METHOD

To fulfill the desire goal of this study, the following procedures were performed and hence discussed in the following articles.

A. Collection of soil sample

In this study, disturbed soil samples at a depth of approximately 5 feet below existing ground surface were collected from a waste disposal site at Rajbandh, Khulna, Bangladesh. The soil samples were air dried and powdered. To prepare composite liners sieve #4 was used to sieve the powered samples. The physical and index properties were measured in the laboratory through standard method. The values of initial moisture content, optimum moisture content, maximum dry density, specific gravity, liquid limit, plastic limit, plasticity index, shrinkage limit, sand, silt and clay were 37.65%, 20%, 1.59gm/cc, 2.61, 54%, 31%, 23% and 35.11%, 4.6%, 64.7%, 30.7%, respectively.

B. Collection of Additives

Brick dust were collected from local market to prepare composite liners. The samples were air-dried and sieved using #4 sieve. The physical and index

properties of brick dust were measured in the laboratory through standard methods. The values of optimum moisture content and maximum dry density of brick dust were found 31%, and 1.46gm/cc, respectively

C. Preparations of Composite Liners

To prepare composite landfill liners varying proportions of brick dust as 10, 20, 30, 40, 50 and 60% by dry weight were mixed with soil. Experimental work has been carried out at different water content equals to optimum moisture content, plastic limit and liquid limit of mixing composite soil to ensure a uniform slurry. The diameter of steel circular mold of 30cm having different thickness of 10, 20 and 30mm were used. To ensure uniform water absorption the mixing soil pastes were kept in air tight polythene bags for 2 hours.

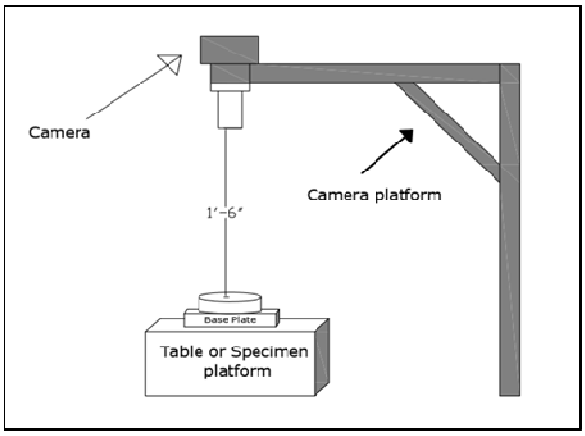


Figure 1. Camera setup for taking image

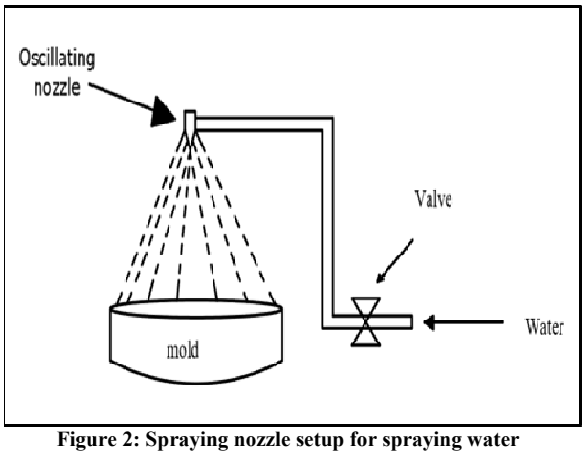


Figure 2: Spraying nozzle setup for spraying water

D. Drying and Image Taking Process

After the preparation of composite specimens, desired amount of soil slurry was poured in mold and kept the mold in the wooden chamber. The wooden chamber was connected with six heat lamps of 100W light bulbs. So that desiccation crack would be formed due to evaporation of water from liner specimens. In this stage, it was ensured that each liners specimen could get equal heat. Moreover, a thermometer was connected to the chamber to measure the variation of temperature in a regular basis and the temperature was found approximately 38º C. During drying process, a digital camera which was mounted at top of soil samples. A 1.5 feet of constant height was always maintained for taking image of one-day interval shown in Figure 1.

E. Wetting and Drying Cycles

Initially, all liner specimens were subjected to two cycles, one is drying cycle and another is wetting–drying cycle. Two cycles of wetting and drying were subjected on the prepared composite soil to simulate the cracking behavior of liners in field. In drying cycle, formation of cracks were constant after seven days (168hrs). After end of first drying cycle with constant cracks at 168hrs, desired amount of water was applied to start a wetting cycle. In the wetting cycle, approximately 250ml/day of water for 4 days were used through spraying nozzle to simulate the percolation behavior of clay shown in Figure 2. In wetting cycle, developed cracks became zero for both liners after 4 days. For this reasons, duration of drying cycle was considered 7 days as well as for wetting cycle it was 4 days.

F. Image Processing

Image processing is a method which extracts useful information from image clicked by digital camera. Generally, it is required two basic steps.

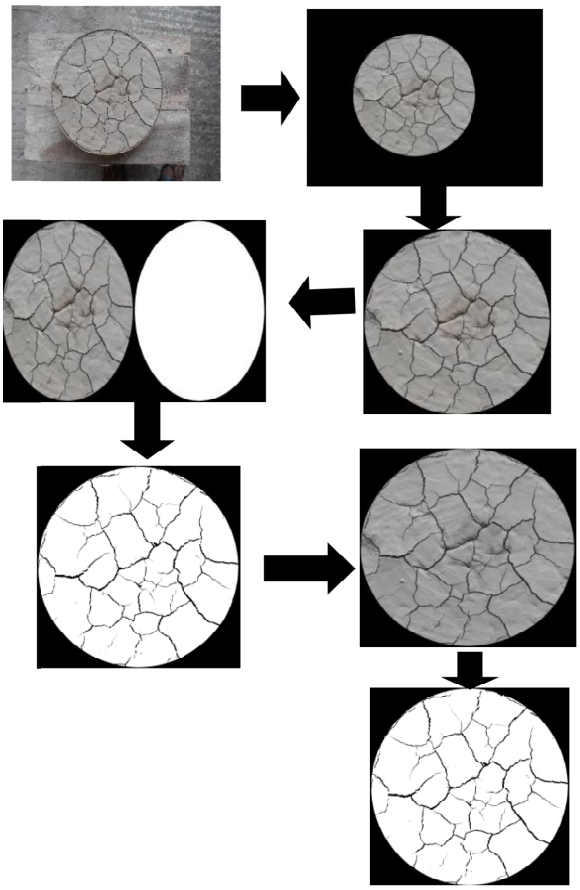


Figure 3. Image processing and analysis of a composite liners (10% brick dust with soil of 10mm thickness at water content equals to liquid limit).

In the first step, raw image was prepared for further analysis through some important stages. This include cropping unnecessary part of raw image and then to a binary image obtained by thresholding the RGB image shown in Figure 3. The second step involved the analysis of the processed image which was obtained from step 1 to quantify the cracking parameters that characterize the cracks intensity factor (CIF), total area of cracks and crack density factor (CDF).

G. Image Analysis

RGB Image obtained from camera were analyzed in MATLAB to extract important information. A coding was developed in MATLAB in such a way which counts only the area of black pixels in the image. Those black pixels were represented the area of cracks. In addition, summation of black pixels and white pixels were also calculated. Then set a program in MATLAB of the ratio of black pixels to the summation of black and white pixels which is known as CIF using the following Equation 1. ImageJ technique and MS excel were used to quantify other relevant cracking parameters like CDF and cracks area. For the determination of diameter of reduced specimen, a known distance like diameter of mold in the selected image was marked by straight line and set a scale in ImageJ by using option (Analyse-Set scale-Give value 30cm). The length of reduced specimen in same image was determined by going command (Analyze-measure). In addition, other cracking parameters like CDF and area of cracks were calculated through MS excel. The value of CDF was computed using Equation 2. The authors of the accepted manuscripts will be given a copyright form and the form should accompany your final submission.

Results and discussion

$$\text{CIF}\ (\%) = \frac{\text{Crack area} * 100}{\text{Reduced specimen area}} [1]$$

$$\text{CDF}\ (\%) = \frac{(\text{Crack area} + \text{shrinkage area}) * 100}{\text{Reduced specimen area}} \quad [2]$$

III. RESULTS AND DISCUSSION

The variation of engineering properties of soil slurry at varying mixing proportions of brick dust as well as the effects of cycles, thickness, moisture and admixture content on cracking parameters like CIF, CDF, cracks area of liners with brick dust were analyzed and hence presented in the following articles.

A. Atterberg's Limit

Figure 4 reveals the relationship between Atterberg's Limit in terms of liquid limit (LL), plastic limit (PL) and plasticity index (Pl) of composite soils and varying mixing percentages of brick dust content. With the increasing of brick dust content in liners, the Atterberg's limit in terms of LL, PL and PI are reduced. For control soil, it was observed 55, 31 and 24% for LL, PL and PI, respectively. The values of LL were measured 52, 51, 49, 47, 46 and 43% for the changing proportions of brick dust like10, 20, 30, 40, 50 and 60% in liners, respectively. In addition, 30.53, 30.04, 29.42, 28.77, 28.09 and 27.37% for PL as well as 21.47, 20.96, 19.58, 18.23, 17.91 and 15.62% for PI were found for the mixing percentages of brick dust content as 10, 20, 30, 40, 50 and 60%, respectively.

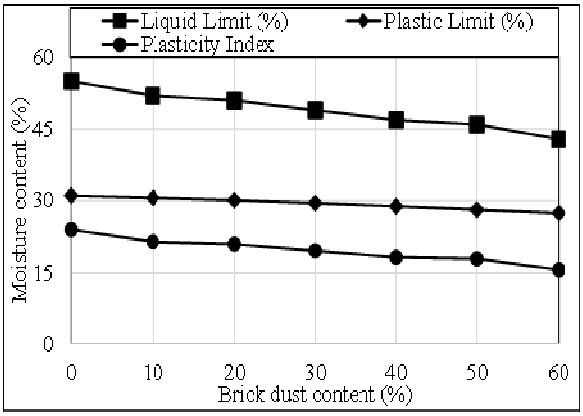


Figure 4: Atterberg's Limit of composite soil replacement with brick dust content.

B. Compaction Characteristics

Figure 5 clarifies the variation of dry density to stabilized soil and optimum moisture content (OMC) with changing proportions of brick dust content. Due to presence brick dust in soil, the weight of the compacted composite soil increases with the increasing of compacting efforts. As a result, dry density of composite soil increases due to increasing of brick dust content. It was found 1.59gm/cc dry density as well as 20% OMC for control soil. Additionally, dry density increases, while, OMC decreases with the increasing of brick dust content in stabilized soil. The values of dry density were measured 1.65, 1.67, 1.69 1.71, 1.76 and 1.81gm/cc, for changing proportions of brick dust content as10, 20, 30, 40 50 and 60%, respectively. However, OMC were found 19, 18, 17.5, 17, 17 and 16.5% for brick dust content as10, 20, 30, 40 50 and 60%, respectively, respectively.

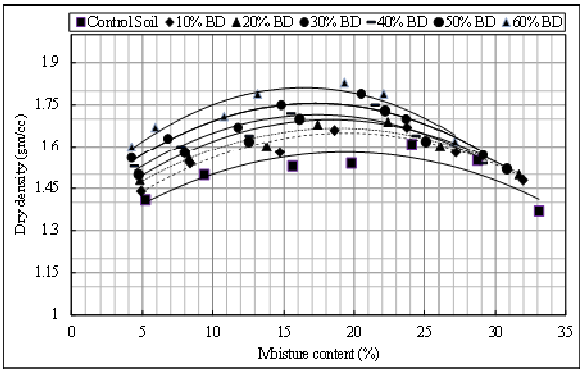


Figure 5: Variation of MDD with brick dust content

***C.* Crack Intensity Factor**

The variation of CIF with drying and wetting cycles, mixing proportions of brick dust (BD) content, water

content and liners thickness were observed and hence discussed in the following articles.

C.1. Effect of Cycles and Mixing Brick Dust Content

Figure 6 depicts the comparison of CIF with in relation of drying and wetting times and changing percentages of brick dust (BD) content at moisture content equals to OMC having liners thickness 10mm. The intensity of cracks are varied with changing of mixing water content and brick dust content in the liners. CIFs were subjected very low during 1st drying cycle and it was less than 2%. It was applied approximately 250ml/day water to circulate wetting cycle. In this study, series of drying and wetting cycles were performed on the liner specimens to simulate the climatic effect on landfill liners in field. The cracks on liner were reducing due application of water and became zero after 4 days. After 1st wetting cycle the intensity of cracks were increased significantly than that of 1st drying cycle.

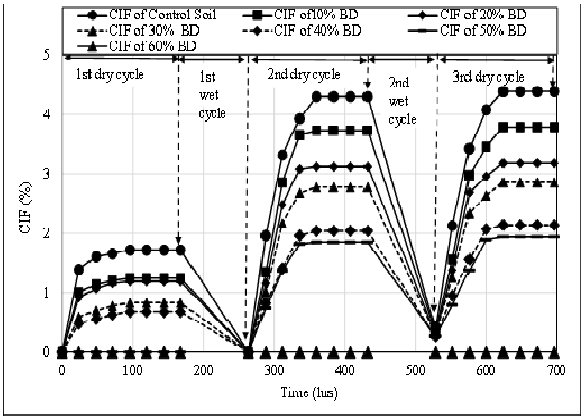


Figure 6: Variation of CIF with drying and wetting cycles with BD having 10mm thickness at OMC.

From Figure 6 it was observed that development of cracks were rapidly at the beginning of drying cycles and the cracks were propagated gradually after the rapid cracking development period. At control soil, CIF was measured 1.72% during 1st drying cycle. This value reached to 4.30 and 4.39% in the 2nd and 3rd cycles, respectively. The rearrangement of fabric diminishes of soil and eventually ceases subsequent to one or two drying and wetting cycles. As a result, with the multiple drying and wetting cycles experiment, the intensity of cracks did not change significantly after 2nd wet and dry cycles. In addition, the intensity of cracks didn't reduced to 0%. Because, the application of water on liners soil surface didn't results in closing all of cracks. It was observed, proportions of brick dust content are related to CIF. The values of CIF were reduced due to increase of brick dust content in liners specimen. Since, brick dust has very low capacity of swell and shrink. This low capacity of swell and shrinking potential reduced cracking tendency on the liners. Therefore, it was measured lower CIF with the increasing of brick dust content in liners. The intensity of cracks were measured 1.25, 1.19, 0.83, 0.68 and 0% in the 1st drying cycle for liners with 10, 20, 30, 40 and 50% brick dust content, respectively. Moreover, this values were reached to 3.73, 3.12, 2.78, 2.04 and 1.85% in the 2nd drying cycle for 10, 20, 30, 40 and 50% brick dust content, respectively.

C.2. Variation with Thickness and Moisture Content

Figure 7 elucidates the comparison of CIF having with three liners thickness like 10, 20 and 30mm at varying water content equals to OMC, PL and LL for 10% brick dust. The intensity of cracks are depend on liners thickness and moisture content. With the increase of moisture content in the liners, the CIF were reduced and while reduced with the increasing of liner thickness. On the application of temperature on liners water are evaporated from the soil. Since water are evaporated from specimen, very small soil particles are moved inwards rapidly due to high cohesion behavior of soil particles. This inwards movement of soil particles will be more, if the mixing percentages of water content is more or proportions of solid particles are less. More inwards movement of solid particle leads more cracks on the liners. Therefore, the values of CIF in liners was found higher at mixing water content equals to LL than that of liners with OMC and PL. In addition, the tendency of cracking behavior were seen higher in thinner specimen due to high rate of desiccation. Thus, the values of CIF reduces with the increasing of liners thickness. CIF was measured 1.25, 1.98 and 5.39% having 10mm; 0.62, 1.01 and 4.67% with 20mm as well as 0.59, 0.84 and 4.24% having 30mm liners thickness at water content equals OMC, PL and LL, respectively.

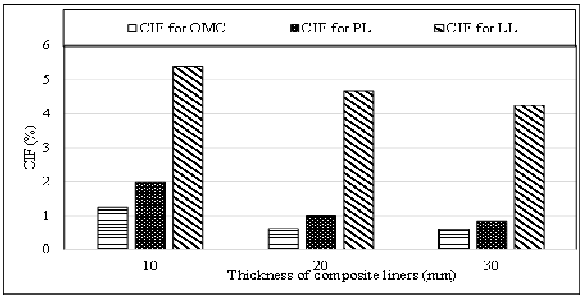


Figure 7: Variation of CIF with 10% BD Content at OMC, PL and LL for all the Specimen Thickness

D. Cracks Area

The variation of cracks area with changing percentages of brick dust (BD) content, moisture content and liners thickness were observed and hence discussed in the following articles.

D.1. Variation with admixture Content and Moisture Content

The variation of cracks area at varying moisture content equals of OMC, PL and LL having with 10mm liners thickness for brick dust content are shown in Figure 8. The behavior of cracks are depend on swell, shrink and cohesions of soil. Brick dust has very low

capacity of swell and shrink. This low capacity of swell and shrinking potential reduced cracking tendency on the liners. Therefore, it was detected lower area of cracks with the increasing of brick dust content in the liners. From Figure 8 it was clearly observed that cracks area were reduced due to increase of brick dust content, while, increased with water content in liners. It was observed 8.60, 8.20, 5.75, 4.73 and 0% cm2 cracks area at OMC as well as 13.52, 11.85, 9.41, 8.00 and 4.31 cm2 at PL for 10, 20, 30, 40 and 50% brick dust content, respectively. This values were increased due to increasing of water content in the liners. Cracks area were found 34.97, 29.28, 24.71, 19.25 and 10.47 cm2 for 10, 20, 30, 40 and 50% brick dust content, respectively. No cracks were generated for 60% brick dust content with all water content.

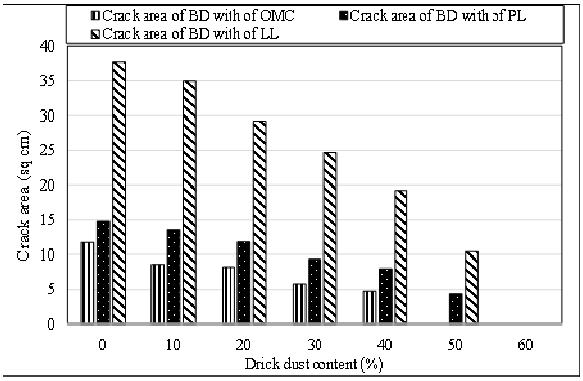


Figure 8: Variation of crack area of stabilized soils with BD content at varying mixing water content

D.2. Variation with Moisture Content and Liners Thickness

Figure 9 illuminates the variation of cracks area having liners thickness of 10, 20 and 30mm at different water content equals OMC, PL and LL for 10% brick dust content. Cracks area related to water content and liners thickness. More cracks were detected with the increasing of moisture content while less cracks were seen due to increasing of liners thickness.

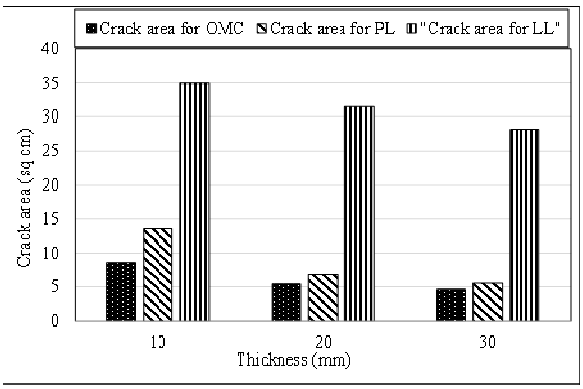


Figure 9 Variation of crack area with BD Content at OMC, PL and LL for all the Specimen Thickness

On the application of temperature on liners water are evaporated from the soil. Since water are evaporated from specimen, very small soil particles are moved inwards rapidly due to high cohesion Behavior of soil particles. This inwards movement of soil particles will be more, if the mixing percentages of water content is more or proportions of solid particles are less. More inwards movement of solid particle leads more cracks on the liners. As a result, crack area in specimen was found higher at mixing water content equal LL than that of OMC and PL. In addition, the tendency of cracking Behavior are seen higher in thinner specimen due to high rate of desiccation. The area of cracks were found 8.60, 13.52 and 34.97cm2 having with 10mm liner thickness at water content equals to OMC, PL and LL, respectively. In addition. It was measured 5.44, 6.82 and 31.53cm2 for 20mm liners as well as 4.59, 5.57 and 28.12cm2 for 30mm liner thickness at water content equals to OMC, PL and LL, respectively.

E. Crack Density Factor

The CDF is defined as the percentages of surface shrinkage area in the liners specimen. Surface shrinkage area is the summation of cracks and shrinkage area. The variation of CDF with mixing proportions of brick dust (BD) content, water content and liners thickness were observed and hence discussed in the following articles.

E.1. Variation with Specimen Thickness and Moisture Content

Figure 10 reveals the comparison of CDF having liner thickness of 10, 20 and 30mm at varying water content equals to OMC, PL and LL for 10% brick dust content. The thickness of liners and mixing water content effect the density of cracks. CDF were increased due to increase of moisture content and liner thickness.

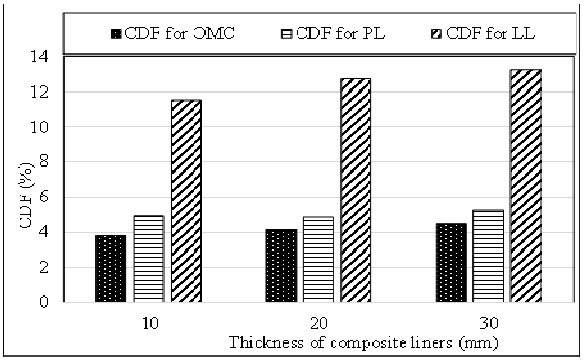


Figure 10: Variation of CDF of stabilized soils with BD content at varying mixing water content and specimen thickness

On the application of temperature on liners water are evaporated from the soil. Since water are evaporated from specimen, very small soil particles are moved inwards rapidly due to high cohesion behavior of soil particles. This inwards movement of soil particles will be more, if the mixing percentages of water content is more or proportions of solid particles are less. More inwards movement of solid particle leads more cracks and shrinkage on the liners. In addition, increases of

liners thickness lead to the uneven drying of liners specimen which increases surface shrinkage area in the specimen. Therefore, the density of cracks are increased due to increase of moisture content and liners thickness. Figure 10 depicts the values of CDF were 3.81, 4.96 and 11.51% having 10mm liner thickness as well as 4.14, 4.87 and 12.71% with 20mm thickness at water content equals to OMC, PL and LL, respectively. In addition, 4.50, 5.25 and 13.22% were measured for 30mm liners thickness at water content equals to OMC, PL and LL, respectively.

E.2. Variation with Admixture Content and Moisture Content

Figure 11 depicts the relationship between CDF with percentages of brick dust content and different mixing moisture content equals to OMC, PL and LL for 10mm liners thickness.

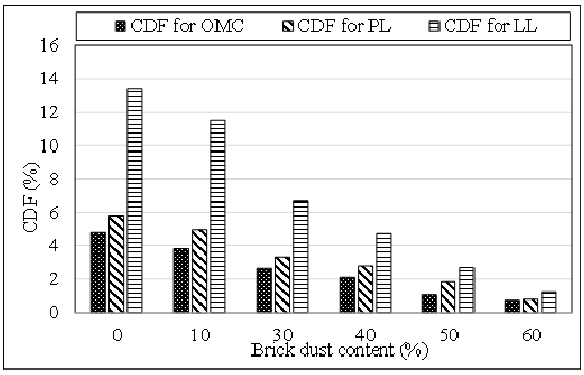


Figure 11: Variation of CDF of stabilized soils with BD content at varying mixing water content

Addition of low shrinking admixtures means reduction of percentage of high shrinkage materials in the mixtures. Therefore, the percentages of overall surface shrinkage in liners specimen are reduced with the increasing proportions low shrinking material like brick dust in the specimen. Figure 11 reveals density of cracks were reduced due to increase of brick dust content and increased with moisture content. It was found 11.511, 8.48, 6.66, 4.70, 2.71 and 1.22% at moisture content equals to LL for 10, 20, 30, 40, 50 and 60% of brick dust content, respectively. This values were reduced with the decreasing of water content in the liners.

IV. CONCLUSION

The cracking behavior such as CIF, CDF and cracks area decreases in relation to the increasing of brick dust content, while, CIF, CDF and cracks area increases with the increasing of mixing water content in liners. In addition, CIF and cracks area reduces, while, CDF increases with the increasing of liners thickness. With the multiple wetting-drying cycles, amount of cracking did not change significantly after 2nd wetting-drying cycle. Through this study, a new window will may open for other researchers to prepare cap and base liners in waste landfill easily and economically specially in least developed Asian countries like Bangladesh.

REFERENCES

[1] H. Soltani-Jigheh, M. Asadzadeh, and V. Marefat, “Effects of tire chips on shrinkage and cracking characteristics of cohesive soils,” Turkish Journal of Engineering & Environmental Sciences, DOI: 10.3906/muh-1302-14, pp. 259-271, 2014.

[2] S.P. Singh, S. Rout, and A. Tiwari, “Quantification of desiccation cracks using image analysis technique,” International Journal of Geotechnical Engineering, DOI: 10.1080/19386362.2017.1282400. ISSN: 1938-6362, pp. 01-06, 2017.

[3] D. Freitage, “Soil randomly reinforced with fibers,” Journal of Geotechnical Engineering-ASCE; 112(8), pp. 823–826, 1986.

[4] S. N. Bhavsar, H. B. Joshi, P. K. Shrof, and A. J. Patel, “Effect of burnt brick dust on engineering properties on expensive soil,” International Journal of Research in Engineering and Technology, Vol. 03, Issu:04, pp. 433-441, 2014.

[5] R. Auvray, S. Rosin-Paumier, A. Abdallah, and F. Masrouri, “Quantification of soft soil cracking during suction cycles by image processing,” European Journal of Environmental and Civil Engineering, 18, (1), pp. 11–32, 2014.

[6] C. Tang, B. Shi, C. Liu, L. Zhao, and B. Wang, “Influencing factors of geometrical structure of surface shrinkage cracks in clayey soil,” Eng. Geology, 101(3-4), pp. 204-217, 2008.

[7] A. Tiwari, “Quantification of crack and shrinkage using image analysis,” M.Sc. Thesis, Department of Civil Engineering, National Institute of Technology, Rourkela, India. 2015.

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