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EVALUATING CRACKING BEHAVIOR OF COMPOSITE CLAY AS LINER IN LANDFILL USING EXTENSIVE SOFTWARE

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ABSTRACT

Top liners are the materials used in landfill operation on top area of landfill. Different types of materials are used as top liners, such as, geo-textile, geo-membrane, compacted clay, composite clay etc. Among them composite clay (mixture of clay and other additive materials like brick khoa, refuse plastic papers, paddy stalk etc.) as top liner is more economical than others. At the same time it reduces crack formation which is the main problem when top liner is made by using clay soil only. To investigate the cracking behavior of composite clay as top liner of local clay soils (soils which are used as top liner in Rajbandh dumping site) is the main aim of this study. Here mixture of clay soils and a suitable additive as brick khoa is used as composite clay. In this study twelve number of top liner specimens with size 30cm×6cm×8cm were prepared using six percentages of additive content. Also cracking properties of each liner specimen are compared with other specimens and specimens made by using clay soil only (control specimens) which is another aim of this study. Here crack intensity factor (CIF), which is the ratio of the surface area of cracks to the total surface area of a soil and shrinkage on all four sides of specimen are considered as controlling cracking properties. Digital image analysis technique has been used to determine CIF in this study. Overall values of CIF and shrinkage were found maximum for control specimens than other specimens. Whereas the maximum and minimum CIF obtained in the tests were 14.94% and 9.8% occurred in specimen 1 of 5% and 15% additives content. Again the maximum and minimum shrinkage obtained in the tests were 2.4cm and 1.05cm in length direction and 0.82cm and 0.5cm in width direction occurred in specimens 1 and 2 of 0% and specimen 2 of 25% and specimens 1 and 2 of 15% additives content.

Keywords: Composite Clay, Cracking Properties, CIF, Digital Image Analysis Technique, Shrinkage, additive.

INTRODUCTION

After filling is completed a final cover layer is provided with the naturally available soil from the nearby location. To minimize the cost it is desirable to obtain cover materials from the landfill site whatever possible. The most serious problem with the use of naturally available soil is its tendency to form cracks due to evaporation. Again most of the landfill sites in developing countries like Bangladesh are filled with sanitary wastes and other wastes. If top liners are weak and forms cracks, rainwater can infiltrate through these cracks and can be mixed with wastes and produce leachate due to biochemical reaction which is very much hazardous liquid. Landfill gases also produced from these sites and migrate through cracks. Sometimes geo-textile, geo-membrane, compacted clay are used as top liner. Geo-textile and geo-membrane are efficient and of no crack as the top liner, but they are expensive. Compacted clay liners also effective, but they are less susceptible to crack formation. Composite clay liner (Liner made by using mixture of clay and other materials like brick khoa, refuse plastic papers, paddy stalk etc.) is one of the batter solutions from the economic point of view.

Cracking is a complex phenomenon in materials like soils. It is a natural process involving weathering, chemical changes and biological [1]. Desiccation cracking significantly affects soil performance. Cracks create a zone of weakness in a soil mass and reduce its overall strength and stability [2]. Cracks can also create path-ways for transport of fluids, which can significantly increase the hydraulic conductivity of the soils [2]. These hydraulic changes affect the waste contaminant facilities. As cracks form as a result of drying of soil mass, drying causes shrinkage. Again type and amount of clay minerals present in a drying soil control desiccation cracking [3]. Crack formation also depends on soil thickness, surface configuration, rate of drying, total drying time etc. [4]. As soil structure is an important property which affects water storage and movement, it is necessary to measure crack size and pattern precisely [1]. Images of cracking surface are processed to determine the dimensions of crack have been widely used in present time. Size distribution of crack was estimated by using electro-optical determination which was used by Guidi in 1978 [5]. Lima (1992) also used photographic image analysis to determine soil surface cracking [6]. Photographic image analysis techniques appeared to be a useful tool to distinguish differences in crack patterns which may be useful characterizing soil cracking [1].

This study was conducted to investigate the crack behavior of composite clay as top liner. For these purpose local soils (soils which are used as top liner in Rajbandh dumping site) and suitable additive as brick khoa were used to prepare typical 12 numbers of top liners of size 30cm×6cm×8cm for different percentages of additives content. Again two top liners were prepared only using clay soil (control specimens). Cracks form on the surface of liners as a result of water loss to the atmosphere and convert the liners as drying soil mass. It is considered that in a drying soil, drying causes shrinkage and a crack initiates when the tensile stresses exceed the soil strength [1]. In this paper crack intensity factor (CIF) is mainly considered as influencing factors behind cracking behavior of soil. Although exact measurement of geometrical properties of soil cracks is not possible due to irregular and complex shape of cracks, image analysis techniques have been widely used in recent years to characterize the crack network with improved accuracy [7]. In this way an image analysis algorithm has been developed (using MATLAB®) to determine cracking area on the surface of the liners. Finally comprise different crack properties of all top liners with one another.

Properties of Soil used in the Study

The soil samples used in this study were collected at the depth on 2ft ~ 4ft from the ground surface. The soil is classified as inorganic clays of medium plasticity. Some of the basic Geotechnical Engineering properties of the soil are given in Table 1.

Laboratory Test Procedure and Analysis: The testing procedure consisted of three main steps; preparation of composite top liner specimens; drying of liner specimens and taking of images; and quantitative analysis of cracks by digital image analysis technique.

Preparation of Composite Top Liner Specimens: For preparation of composite top liner specimens, firstly all soil samples were wetted to approximately the initial water content (37.5%). The wetted soil was then left for two hours due to uniform water absorption. Saturated surface dry brick khoa (mixing material) whose Fineness modulus (FM) is 8.15 (maximum size (25mm) and minimum size (0.5mm)) were mixed with wetted soil at various percentages. In this study five percentages (5, 10, 15, 20, and

25%) of additives (brick khoa) content were used where percent weight of brick khoa is percentage of weight of wetted soil. For each percentage two liner specimens were prepared. Also two liner specimens were prepared using only soil sample (control specimens). However for preparation of liner specimens twelve number wood made rectangular shape molds were used whose internal dimensions 30cm×6cm × 8 cm. After preparation of liner specimens, they were brought to outside so that they got dry.

Table 1 Properties of soil sample

Properties	Value	Properties	Value
Initial moisture content (%)	37.50	Atterberg limits	
		Liquid limit (%)	42.50
		Plastic limit (%)	23.43
		Plasticity index	19.07
		(%)	20.56
		Shrinkage limit	
		(%)	1.68
		Shrinkage ratio	
Specific gravity	2.65	Particle size	
		analysis	2.0
		% of Sand	85.0
		% of Silt	13.0
		% of Clay	
Compaction		USCS	CL
properties	22.80	Classification	
Optimum water content (%)	14.52		
Maximum dry unit weight (KN/m^3)			

Drying of Liner Specimens and Taking of Images: The liner specimens were placed in outside in such a way, so that they got uniform sunlight. Due to evaporation of water from the liner specimens, they gradually became drying. Again drying causes shrinkage and subsequent cracking. With the increase of time, number and size of cracks increase. Also shrinkage of all four sides of the liner specimens took place. Images of all liner specimens were taken at one day interval. Also shrinkage in both length and width directions were measured by using liner scale. Images were taken by fixing the camera at a height of 45cm. from top surface of the liner specimens. And this height was maintained for all images. All the measurements and images were taken at the time of six days from the preparation of specimens, because after six days the liner specimens were completely dried.

Quantitative Analysis of Cracks by Digital Image Analysis Technique: Generally approximate methods are used to determine crack dimensions. The irregular shape and complex geometry of cracks prevent accurate measurements of length, width, and depth [2]. Also along the length of a crack, width and depth of cracks are not uniform. Cracking index which is the ratio of the area of cracks to the total surface area of a soil was proposed by Al Wahab and El-Kedrah in 1995 to quantify the extent of cracking [8]. Where crack area is the product of its length and width. But Al Wahab and El-Kedrah did not give any methods to determine length and width of cracks and they believed that length and width of cracks was determined using ruler. However Mi (1995) and Miller et al. (1998) proposed crack intensity factor (CIF) which is the ratio of the area of cracks to the total surface area of a drying soil mass to quantify the extent of cracking [9,10]. Where crack area was determined by using a computer aided image analysis program. And it is the reliable method now a day.

In this study images of liner surface are analyzed using MATLAB® to determine the area of cracks. For this purpose an algorithm has been developed. The steps of processing with algorithm are described below. Finally area of cracks is divided by total area of drying liner specimens to calculate CIF. Here image processing of a 20% additive (brick khoa) contained specimen at sixth day to extract crack area is described.

Step 1: Read the image and convert the image to binary image

In this step the RGB image (**DSC01326.jpg**) is read and then converts to binary image. Here also the darkness of crack is adjusted. Both these images are displayed which are shown in Figure 1 and Figure 2 respectively. Before the image is read it is adjusted to size 400 pixels ×300 pixels to reduce the time of analysis.

Figure 1 RGB image

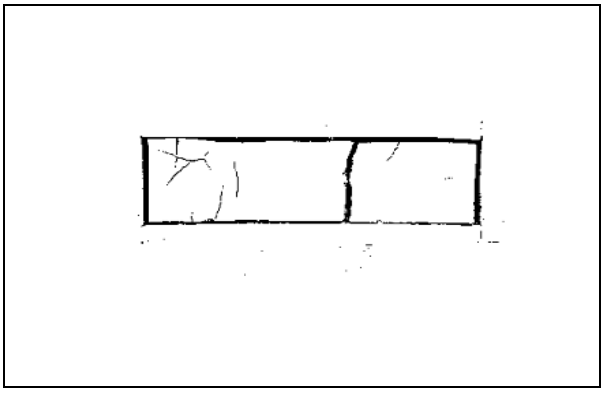


Figure 2 Binary image

Step 2: Detect the liner specimen

In this step detect boundary of liner specimen with drawing four straight lines on all four sides.

```
b=0;
b1=0;
j=200;
for i=1:1:300
    c=B(i,j);
    if c==0
        y1=i;
        b=1;
    end
    if b==1
        break
    end
```

```
for   i=300:-1:0
    c=B(i,j);
    if c==0
        y2=i;
        b=0;
    end
    if b==0
        break
    end
end
```

```
I1 = imread('D:\DSC01326.jpg');
figure, imshow(I1);
level=.30;
B = im2bw(I1, level);
figure, imshow(B);
```

Step 3: Crop the image from RGB image

After selection of the boundary of cropped image, the selected portion is cropped from the RGB image. Then display the cropped image which is shown in Figure 3.

```
topLine = x1;
bottomLine = x2;
leftColumn =y1;
rightColumn =y2;
width = bottomLine - topLine + 1;
height = rightColumn - leftColumn + 1;
PP  =  imcrop(I1,[topLine,  leftColumn,
width,height]);
figure,imshow(PP);
```

Figure 3 Crop image

Step 4: Convert the cropped RGB image to grayscale image and then convert the grayscale image to binary image

In this step cropped RGB image is converted to grayscale image and then converted to binary image. At the same time the darkness of cracks is deepened at level 0.30. Also the binary image is filtered up to 250.Both the grayscale and binary images are displayed which are shown in Figure 4 and Figure 5 respectively

.

```
i=150;

for j=1:1:400
    c=B(i,j);
    if c==0
        x1=j;
        b=1;
    end
    if b==1
        break
    end
end
```

```
for j=400:-1:0
    c=B(i,j);
    if c==0
        x2=j;
        b=0;
    end
    if b==0
        break
    end
end
```

```
K = rgb2gray(PP);
figure, imshow(K);
level = 0.30;
bw = im2bw(K,level);
bw = bwareaopen(bw, 250);
figure, imshow(bw);
```

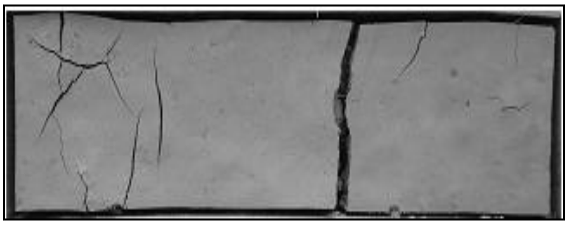


Figure 4 Grayscale image

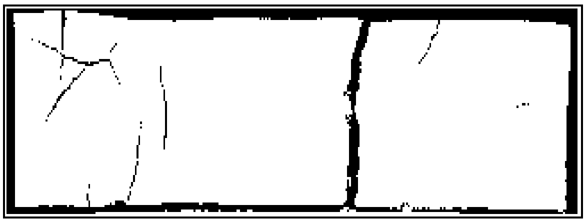


Figure 5 Binary image

Step 5: Calculation of crack area

In this step first calculate the cracked and no cracked area in pixels. Then determine the ratio of cracked and no cracked area and multiplied the ratio with real area of specimen (240cm^2) to calculate the crack area in cm^2.

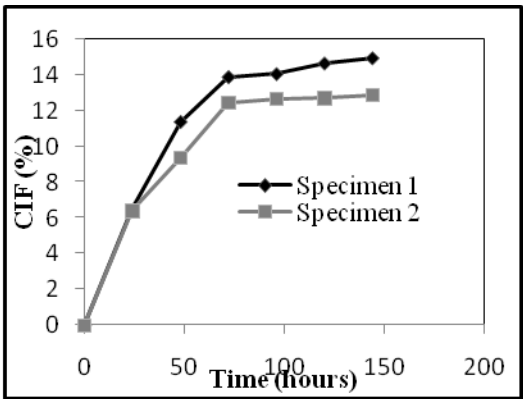
```
a1=0;    % number of black
a0=0;    % number of white
for i=1:1:height
    for j=1:1:width
        vvvv(i,j)=bw(i,j);
        if bw(i,j)==0
            a1=a1+1;
        else
            a0=a0+1;
        end
    end
end
black_pixel=a1  %no of black
white_pixel=a0 %no of white
c=a1/a0;
totarea=240;
realarea=(totarea/(a0+a1))*a1
```

RESULTS AND DISCUSSION: Crack areas of all composite clay top liner specimens were extracted accurately with program algorithm and hence calculated the CIF. Crack area and CIF for all liner specimens are shown in Table 1 and Table 2. From the crack area of all liner specimens, it can be said that crack area of liner specimen 1 for 5% additives (brick khoa) is higher than the crack area of other liner specimens. And its value is 35.8462cm^2 after 144 hours. As a result CIF value is also higher than others. From the values of crack area and CIF for all liner specimens, it can be also said that the values of crack area and CIF for all liner specimens increase with the increase of time and values at 120 hours and at 144 hours are almost same. However first variation of CIF with time is analyzed. Then variation of CIF with percentages of additive and variation of shrinkage with time are analyzed.

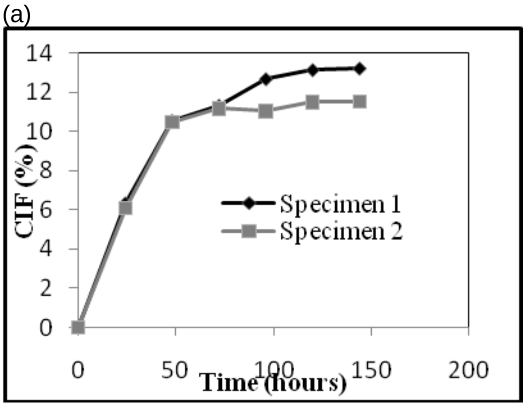
Variation of CIF with Time: Crack intensity factors (CIF) were determined using crack area of top liners which are plotted against elapsed time for various percentages of additives are shown in Figure 6. Again each percentage has two specimens. From the variation between CIF and elapsed time for all percentages it is observed that CIF of specimen 2 increases much greater than specimen 1 except for 5% and 10%. Also the rate of increase of CIF is much higher for specimen 2 of 0%, specimen 1 of 5%, and specimen 2 of 15% additives content than others and their maximum values are 14.53%, 14.94% and 14.62% respectively. Again rate of increase of CIF is much less than for specimen 1 of 15% additives content and its value is 9.8% at the end of 144 hours. Over all CIF increase rate is higher for specimens made with only clay soils.

Variation of CIF with Additives Content: Crack intensity factor (CIF) at the end of 144 hours has been plotted as a function of percentage of additives content for specimens 1 and 2 which are shown in Figure 7. In both cases with the increase of additives content first CIF decreases then increases and finally decreases. Again it can be said that at additives content of 5% to 10% crack area is less for this soil sample.

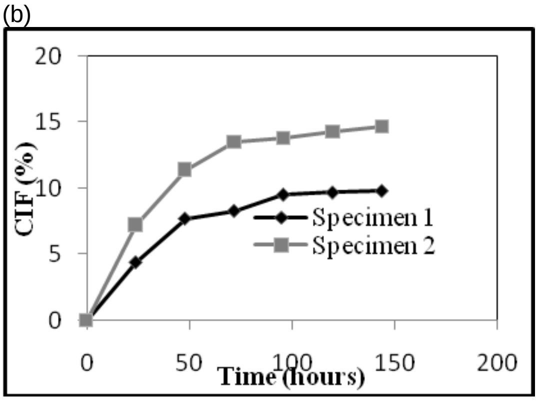
Variation of Shrinkage with Additives Content: The top liner specimens shrink to inside of molds from the inside walls because the size of liner specimens is small. But in real field this shrinkage is very negligible and in that case it is considered as crack. However in this study shrinkage is taken into consider because in this case its value is not negligible. Shrinkage occurred in both length and width directions. Again liner specimens shrink almost parallel to the inside walls of mold and its average values are used here. Both the shrinkage in length and width directions increases with time and after a time left it becomes constant. In this study after four days it became almost constant. At constant condition the values of shrinkage are plotted against additives (brick khoa) for specimens 1 and 2 which are shown in Figure 8. From the variation of shrinkage with additives content, it can be said that in length direction with the increase of additives content the values of shrinkage decreases and in width direction shrinkage values are almost constant for all additives content. Again in both cases values of shrinkage in length direction are greater than the values in width direction. Maximum value of shrinkage in length direction is 2.4 cm occurred in specimens which are made with only clay soil. Whereas maximum shrinkage in width direction occurred in specimen 2 for 15% additives content and its value is 0.82 cm.



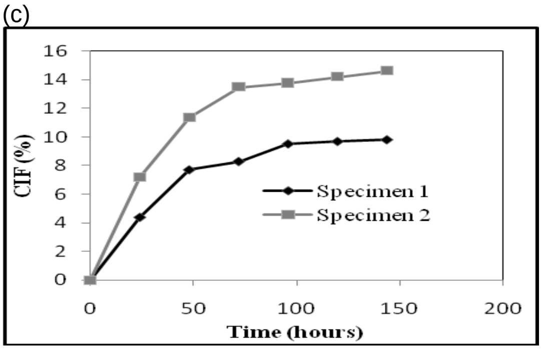
(a)



(b)



(c)



(d)

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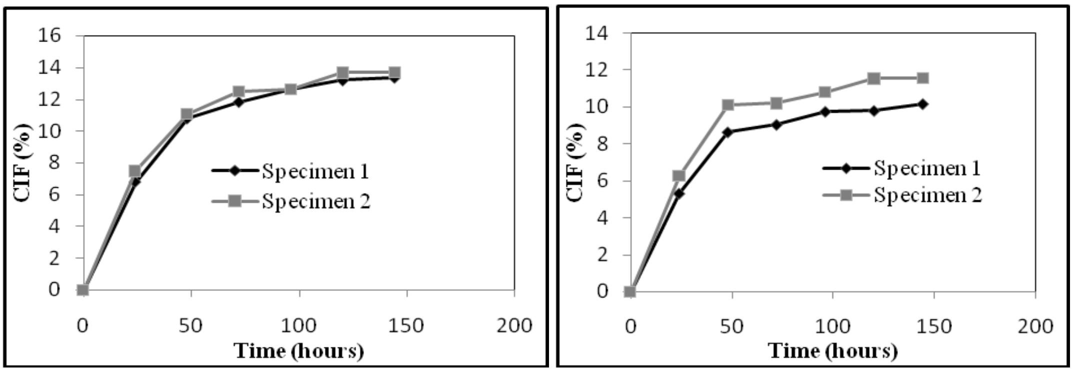

(e) (f)

Figure 6 Variation of CIF with time for additives (brick khoa) content of (a) 0% (b) 5% (c) 10% (d) 15% (e) 20% (f) 25%

Table 2 Values of crack area and CIF with time

Time (hours)	percentages of additives (brick khoa)											
	0%				5%				10%			
	specimen 1		Specimen 2		specimen 1		Specimen 2		specimen 1		Specimen 2	
	Crack area (cm^2)	CIF (%)	Crack area (cm^2)	CIF (%)	Crack area (cm^2)	CIF (%)	Crack area (cm^2)	CIF (%)	Crack area (cm^2)	CIF (%)	Crack area (cm^2)	CIF (%)
0	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
24	15.2703	6.36263	15.6764	6.53183	15.4715	6.44646	15.3361	6.39004	15.1716	6.3215	14.5727	6.07196
48	20.0368	8.34867	24.5220	10.2175	27.3149	11.3812	22.5114	9.37975	25.2820	10.5342	25.1539	10.4808
72	29.1121	12.13	29.9149	12.4645	33.3259	13.8858	29.8673	12.4447	27.1447	11.3103	26.7614	11.1506
96	31.1121	12.9634	32.5047	13.5436	33.7247	14.052	30.4460	12.6858	30.4196	12.6748	26.4551	11.023
120	32.2183	13.4243	34.7891	14.4955	35.1505	14.646	30.5308	12.7212	31.5290	13.1371	27.5615	11.484
144	32.9871	13.7446	34.8634	14.5264	35.8462	14.9359	30.8976	12.874	31.7179	13.2158	27.6231	11.5096

Table 3 Values of crack area and CIF with time

Time (hours)	percentages of additives (brick khoa)											
	15%				20%				25%			
	specimen 1		Specimen 2		specimen 1		Specimen 2		specimen 1		Specimen 2	
	Crack area (cm^2)	CIF (%)	Crack area (cm^2)	CIF (%)	Crack area (cm^2)	CIF (%)	Crack area (cm^2)	CIF (%)	Crack area (cm^2)	CIF (%)	Crack area (cm^2)	CIF (%)
0	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
24	10.5280	4.38667	17.2670	7.19458	16.3262	6.80258	18.0244	7.51017	12.7341	5.30588	15.0554	6.27308
48	18.4932	7.7055	27.2948	11.3728	25.8945	10.7894	26.6544	11.106	20.6935	8.62229	24.2794	10.1164
72	19.8860	8.28583	32.4007	13.5003	28.3793	11.8247	30.0586	12.5244	21.6698	9.02908	24.4603	10.1918
96	22.8376	9.51567	33.0356	13.7648	30.3346	12.6394	30.3761	12.6567	23.3593	9.73304	25.9164	10.7985
120	23.2423	9.68429	34.1453	14.2272	31.6464	13.186	32.8481	13.6867	23.4796	9.78317	27.6821	11.5342
144	23.5243	9.80179	35.0815	14.6173	32.0427	13.3511	32.9249	13.7187	24.3531	10.1471	27.7257	11.5524

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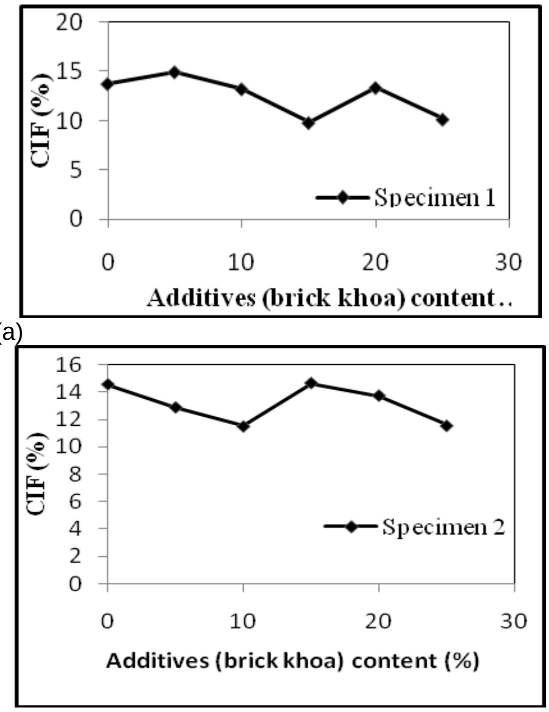
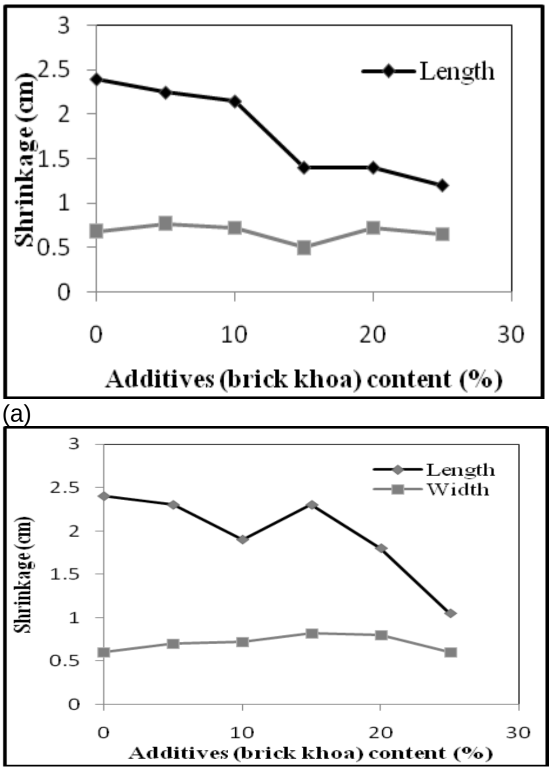


(a) (b)

Figure 7 Variation of CIF with additives content at sixth day for (a) specimen 1 (b) specimen 2



(a) (b)

Figure 8 Variation of shrinkage with additives content at fourth day for (a) specimen 1 (b) specimen 2

CONCLUSION

Result reveals that the use of additives content of 5% to 10% considerably reduced cracking formation and shrinkage for this soil sample. Other percentages also show less cracking formation and shrinkage than control specimens. So it can be recommended that, composite clay can be used as top liner materials in practical landfill sites and also in sanitary landfill sites with its greater advantages than the use of only clay soils. Additive materials can be changed depending on the availability of materials, soil conditions, cost of materials, location of landfill sites, climate and weather conditions etc. Before use of composite clay as top liner in real field, it must be analyzed for various percentages of additives for that soil to find out the suitable percentage for which cracking properties are smaller. By this way composite clay as top liner can save the environment from pollution and also the cost of landfill operations.

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