Factors Affecting the Performance of Geomembrane as an Enhancement Measure for Seepage Control in Solar Pond

Mohamed Nower, Ashraf Elashaal, El-serafy S.

Abstract — In the context of realizing solar ponds, geotextile membranes should be precisely selected to ensure their efficient performance. Accordingly, this research was initiated to enhance the solar ponds performance by utilizing appropriate geo-membrane identities. Primarily, literature in the field of geo-membrane design was assembled and scrutinized. An experimental work was conducted, where a solar pond was constructed in Shakshouk Research Station in Fayoum. Experiments were executed, where each experiment geo-membrane sheets identities were altered. The utilized geo-textile sheets types (i.e. welded so as not welded and while so as black) were inspected in the Construction Research Institute Laboratory in the National Water Research Center (NWRC). These inspections determined their tensile strength and punching resistance. The results indicated that black geo-membrane provided efficient solar ponds, where its temperature reached 90 °C. The results flagged-out that white geo-membrane provided 40 °C. In addition, welded geo-membrane performed better than not welded in terms of its tensile strength and punching resistance. Accordingly, geo-membrane selection should consider its identities (i.e. color and strength).

Index Terms— Solar Ponds, welded, strength, geo-membrane.

1 Introduction

In the future, it is expected to consume more energy (i.e. 10 million oil barrels will increase to be 400 oil barrels during 1900-2030). Accordingly, more pollution is anticipated. These forced decision makers to replace traditional energy by clean energy (i.e. solar ponds) with no emissions. They flagged-out the importance of investigating the factors affecting the solar pond efficiency (i.e. geo-membrane identities).
Many standards and codes flagged-out the identities of the geo-membrane and their design. Among them are the following:

- ASTM (D 1004)
- ASTM (D 1238)
- ASTM (D 1505)
- ASTM (D 1603)

Many researchers investigated the characteristics of the geo-membrane. Among them are the following:

[1] documented that the increase in the energy demand, increased the need for investigating the efficiency of renewable energy (i.e. solar ponds).

[2] reported that energy sources have a dominating role in world mobilization towards a secure sustainable energy track. Among these renewable energy, is the solar energy, which is the friendliest and cleanest solution to environment pollution.

[3] designated that solar energy investigations should progress rapidly.

[4] signposted that the main challenge is how to store solar energy for use, upon request. The source further added that solar energy is the best technique that could overcome the problem by collecting and storing the solar energy.

[5] solar ponds are a large shallow water bodies, with a tight bed. They are heated by solar radiation.

[6] mentioned that solar ponds are divided into two groups (i.e. non-convective and convective).

[7] flagged-out that a solar pond with salt gradient is a non-convective type, which relies on concentration gradient (i.e. by depth).

[8] stated that the salt-gradient zone is essential to its efficient performance.

[9] flagged-out that the vital features of solar ponds should include the following:

- They should possess high solubility with high density.
- They must fulfill the compatibility of solubility and temperature.
- They ought to be transparent to allow the penetration of solar radiation.
- They should be environmentally friendly and do not have negative impact on groundwater.
- They must be near the site to decrease the total cost.

2 Expermintal Work

The experimental work encompassed two phase descrip-

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tion are phase (1) inspects the utilized geo-membrane identities to designate its strength, its punching resistance and its characteristics and phase (2) carries out experiments after constructing the solar pond and conducts measurements to signpost its temperature and its concentration profile.

2.1 Inspecting Utilized Geo-Membranes Identities

This section elaborates phase (1) of the experimental work. It is to be flagged-out that four types of membranes with different identities were tested. These were welded, not welded, black and white color of Geomembrane

It is to be further remarked that the identities of the geo-membranes were inspected before being installed on the solar pond bed. Figures (1) to (4) provide the implemented test devices of the Construction Research Institute.

Fig. 1. Geo-Membrane test material

Fig. 2. Preparation sample of Geo-Membrane

Fig. 3. Catch the geo-membrane sample in the test

Five inspections were achieved for the membrane (i.e. thermal expansion, resistance puncture, permeability and color). Their descriptions are as follows:

- Thermal expansion: This test was realized along a slope, where the membrane expands due to assemblage roughness. If this were recovered by cooling, stress would cause creep or thinning.
- Puncture resistance: This test was accomplished to determine the geo-membrane resistance to puncture, as it is placed over sharp edged material. Puncture causes geo-membrane damage that leads to leakage. This resembles the puncture of animal claws or beaks.
- Ultra-Violet (UV) resistance: This test was achieved to designate geo-membrane response to subjected solar heat. This is attributed to the fact that chemical reactions and physical changes lead to early failure, which causes polymer degradation. This indicates its depletion and signifies its lifespan.
- Permeability: This test was carried out to inspect the permeability of the geo-membrane, which is measured according to ASTM E-96, in order to make sure that it does not allow fluid transmission through its holes. The sample is fixed to the trim of an aluminum cup with the test liquid, where the cup is placed in a chamber with fixed humidity and temperature.
- Geo-membrane color: This test was achieved in order to signpost the difference between the white and black membranes, in terms of the attained temperature.
- Geo-membrane strength: This test was accomplished to designate the strength of the different utilized geo-membranes.

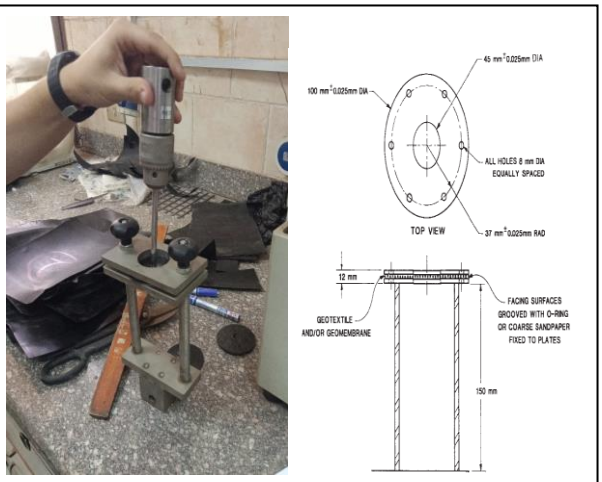

Fig. 4. Punching test

2.2 Solar Pond Construction and Measurements

This section particularizes phase (2) of the experimental work, where its steps proceeded, as follows:

- Step (1): A solar pond (12 x 12 m) was constructed in Shakshouk Research Station in Fayoum, figure (5).
- Step (2): The pond bed was covered with a geo-membrane that was changed after each experiment.
- Step (3): The pond was filled with salt water in layers in such a way to ensure the salinity gradient with higher concentration at the bottom.
- Step (4): The pond was left in the sun to allow its penetration into the pond.
- Step (5): Measurements were undertaken to document the salt gradient and temperature on regular basis.
- Step (6): The pond was emptied, a different geo-membrane, with different identities, was placed and the experiment was replicated, starting from step 3.

Fig. 5. Shakshouk Research Station in Fayoum

3 Analysis and Discussing Expermintal results

The test results for the different types of the utilized membranes were obtained, plotted, figures (6) to (9), analyzed and discussed, as follows:

- The thermal expansion test of geo-membrane indicated that it expanded by 500 cm at a temperature variation of 10 to 40 °C.
- The punching test provided a punching resistance curve according to ASTM by Construction Research Institute Laboratory in National Water Research Center, figure (6).
- The permeability test indicated that the geo-membrane permeability values ranged between 1×10^{-12} and 1×10^{-15} m/s . This indicated that their diffusion is very low.
- The color test indicated that the white geo-membrane reflects sunlight and the measured temperature was between 20 and 35 °C, while the black recorded 70 °C. The tests indicated that at a temperature of 30-36 °C, the black geo-membrane temperature recorded a temperature of 70-80 °C; figure (7).
- The geo-membrane strength tests provided stress-strain curves for welded and non welded of the geo-membrane, according to ASTM, figures (8) and (9).

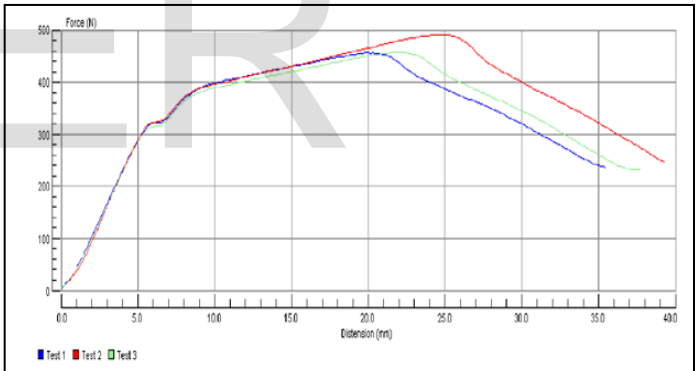

Fig. 6. Punching test results

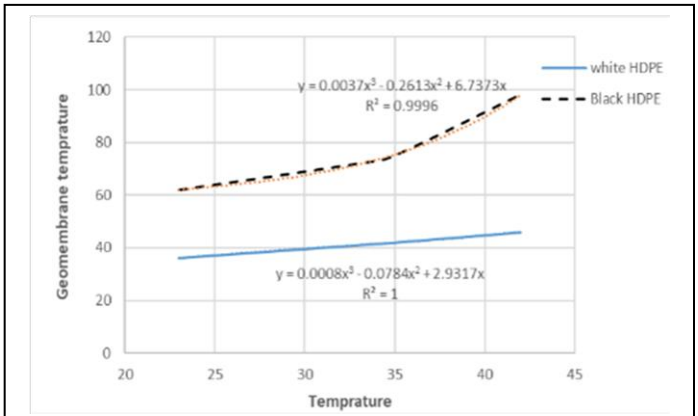

Fig. 7. Color test results

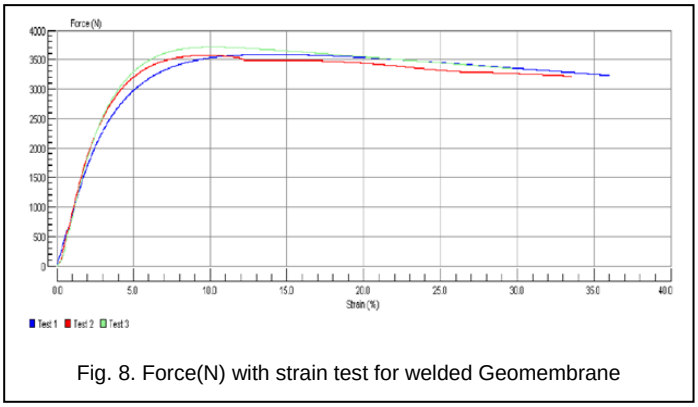

Fig. 8. Force(N) with strain test for welded Geomembrane

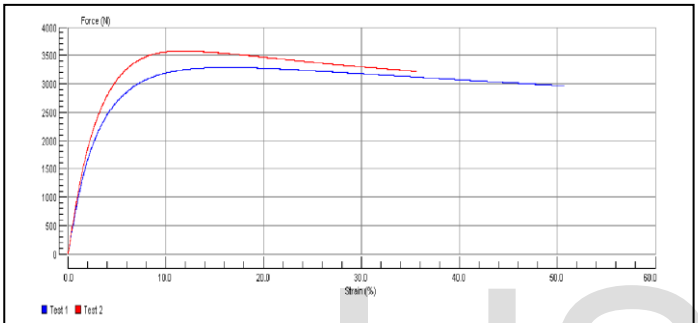

Fig. 9. Force(N) with strain test for Geomembrane without weld

4 Conclusion

Based on the obtained results, the following conclusions were deduced:

- Black geo-membrane enhances the solar pond efficiency (i.e. Black geo-membrane qualifies the solar pond to reach a temperature of 90° C, while the white color enables the pond to reach a temperature of 40° C).
- Welded geo-membrane improves the solar pond efficiency as its strength reaches 18.1 KN/m, while the not welded recorded 17.1 KN/m.
- High punching strength of geo-membrane augments solar ponds performance.
- Geo-membrane with low permeability boasts solar pond efficiency.
- The black geo-membrane is described by following equation where (y_1) is black color of Geo-Membrane measure by Celsius temperature and (X) is surrounding air temperature

$$y_1 = 0.0037X^3 - 0.2613X^2 + 6.7373X$$

- The white geo-membrane is described by following equation where (y_2) is white color of Geo-Membrane measure by Celsius temperature and (X) is surrounding air temperature

$$y_2 = 0.0008X^3 - 0.0784X^2 + 2.9317X$$

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