ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 6, June 2017

Wind Induced Pressure Measurements of Solar Panels in a Group Using Wind Tunnel Experiments

[1] N.Suriya Lekshmi, [2] P.A. Edwin Fernando
[1] PG student, Akshaya College of engineering and technology Coimbatore
[2]Assistant Professor, Akshaya college of engineering and technology, Coimbatore

***Abstract*— The present investigation is to use the waste product from steel industry which is helpful in cement production if it is ground at a fineness of cement which also helps to reduce the carbon emission. Ground Granulated Blast Furnace Slag (GGBFS) is used as a mineral additive for concrete production and substitutes for cement, it behaves as a binder material along with cement.The optimum dosage of GGBFS as cementitious material is characterized by high compressive strength, low heat of hydration, resistance to chemical attack, better workability, good durability and cost-effective.This paper presents a laboratory investigation on optimum level of ground granulated blast-furnace slag on compressive strength of concrete.18 concrete mix sample were cast with water to cementitious material (w/cm) ratio 0.32 and 0.30 each; using GGBFS as partial replacement of cement from 0% to 50% at an interval of 10%. The specimens were cured for 28 days in potable water. The compressive strength of concrete is examined.The test results revealed that the compressive strength of concrete mixtures containing GGBFS increases as the amount of GGBFSincrease, upto certain limit. The optimum dosage of GGBFS is found at. This can be explained by the presence of unreacted GGBFS, behaves as a filler material in the paste and not as a binder.**

***KEYWORDS*: High Strength Concrete, Ground Granulated Blast Furnace Slag,Compressive Strength**

I.INTRODUCTION

The global electricity generation is to be almost double from 18.8 trillion kWh in 2007 to 35.2 trillion kWh in 2035 to meet the electricity demand caused by population growth and the particularly in the developing countries. Fossil fuels, coal and natural gas have been the major energy source contributing almost 70% of the energy supply for the power generation to meet this growing demand. This will have severe consequences on the global climate which could pollute the living environment of the future generations. Due to the harmful effects of fossil fuels on the environment, there is a growing impetus on limiting their use and switching to clean alternative energies such as solar, wind and hydro energy, to meet the energy needs and reduce the consumption of fossil fuels and their carbon content. One of the alternative renewable energy source is the photovoltaic (PV) solar cells that convert the sunlight directly into electricity. Sets of solar cells are combined to make a solar panel. They are installed by mounting them to a support structure as standalone units or as an array of PV units. One of the main obstacles in the wide spread of PV solar panels is its risk associated with its partial or complete damage by wind. At present, the impact of wind loading on the PV panels (stand alone or array format) is not well understood due to the lack of information and so it prevents the design of the solar panels to mitigate this risk. These panels are installed with an inclination angle inclined to the horizontal. It is said that the wind strikes on an inclined solar panel, it flows around it and induces unequal pressure on its two surfaces. Thus they experience the drag force in the direction of the wind and lift force in the direction perpendicular to the wind. These forces can result in torque which would damage the panel structure in case of strong . It is said in the National Building Code of Canada that the structures should be designed so that they can withstand pressures and suction from the strongest wind generated in that area based on wind statistics

II.MODEL DETAILS

The solar panels are simple rectangular low rise structures with different panel configurations according to its use. The solar panel is designed as a scaled model with the aspect ratio of 10and a scale of 1:20.The panel dimensions are 125cm X 12.5 cm. (Length X width).The panels are fabricated using acrylate material. The pressure ports are distributed in 5 rows along the length in one side of the panel. A group of six arrays of panels are used to study the interference effects. The spacing between the solar panels is taken as 2B where B is the width of the panel. Only one of the model is instrumented. The Pressure coefficients are measured for the isolated case and for group effect with two different inclination angles.

III. WIND TUNNEL TESTING

The testing is done in the Boundary layer wind tunnel. Initially the instrumented model is tested for various inclination angles of 00 300,450,900. Then the solar panels are arranged in an array and they are tested for inclination angles of 300 and 450.The instrumented model is laced in front and the others at the back. The testing is done in the

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 6, June 2017

wind speed of 12.5m/s located at the upstream side of the tunnel. Then the location of the dummy models are changed in each case randomly so that the instrumented model is at the last position in the last case

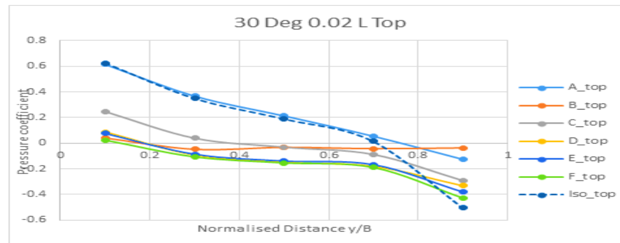
IV.RESULTS AND DISCUSSION

A.Pressure distribution in an isolated solar panel

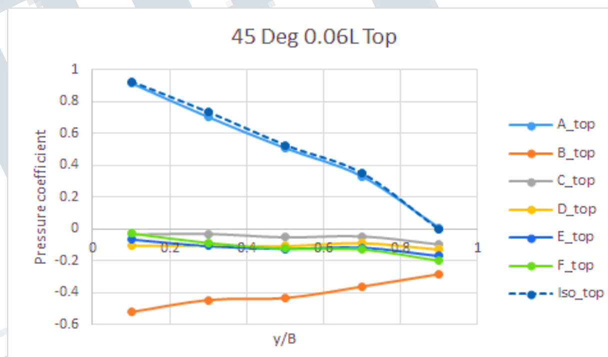
An isolated solar panel is first used for the pressure coefficient calculations at various inclination angles. These coefficients are calculated by velocity corresponding to the model height. The pitot tube is fixed as reference height and the static pressure is measured from it. The pressure tubes are very long and so the mean coefficient of pressure are determined. Variation of pressure coefficients along the center of the span x/L =0.02, 0.06, 0.14, 0.3 and 0.5 is calculated in top and bottom surfaces with respect to the normalized distance y/B respectively and for various inclination angles 300,450,600,900 respectively. It is observed that for the various x/L =0.02, 0.06, 0.14, 0.3, and 0.5 values the pressure coefficient varies from 0.8 to 0.6 at y= 0.1B and approaches to 0 at y=0.9B. Similar values are observed for the inclination angle of 900 at the top and bottom surfaces respectively. Small values of suction pressures are observed in 900(of magnitude 0.1) and the maximum suction pressures are obtained at y=0.1B for angle 900. Constant suction pressures for the various inclination angles are observed. Suction pressures are observed in the bottom surfaces of the panel for the different inclination angles.

B. Pressure distributions on the top surfaces of the panels at various distances

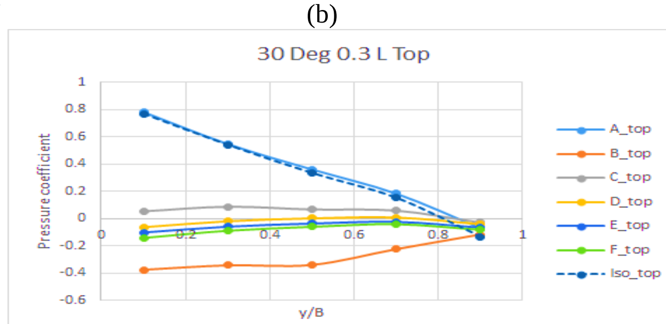
The variation of the pressure coefficients in the solar arrays at x=0.02L,0.06L,0.14L,0.3L,0.5L in different locations (A, B, C, D, E and F) for different inclination angles of 300 and 450 given in the figures. The isolated case is also plotted in the same graph to give a comparison between the isolated and the group effect. The pressure distribution in the front (A location) is similar to that of the isolated case in both the inclination angles for all the x values. Small changes are observed in other locations (B, C, D, E, and F) in compared to that of isolated case. Maximum suction pressures are observed in the location B in case of 300 inclination but it is not exactly same for the angle 450.The pressure distributions in other locations (C,D, E, and F) are more or less similar for the two inclination angles. Maximum negative pressure is obtained for 450.This is the same in the top surfaces of the panels for all normalized distances x/L.



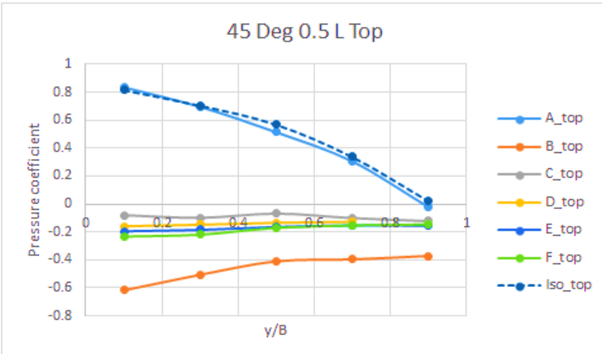
(a)



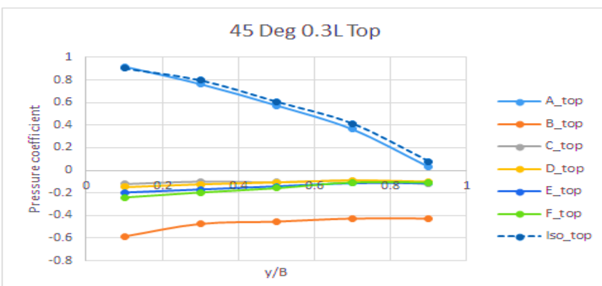
(b)



(c)



(d)

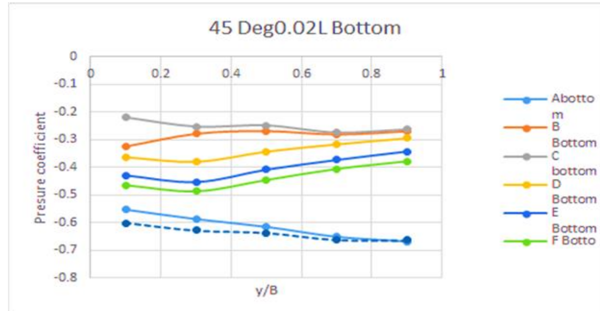


(e)

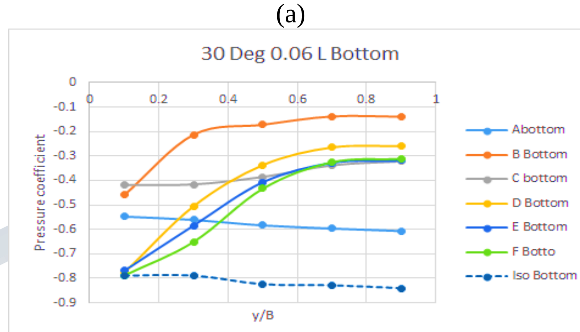
Fig. 2 Pressure distributions on the top surfaces of the Solar arrays (a) 300 0.02L top (b) 450 0.06L top (c) 300 0.3 L top (d) 450 0.5L top (e) 450 0.5Ltop

C. Pressure distributions on the bottom surfaces of the panels at various distances

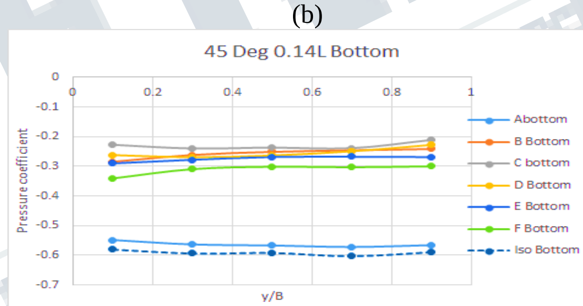
Variation of pressure coefficient distributions on bottom surfaces at x= 0.02L, with different angle of inclinations (30°, 45°) for different locations (A, B, C, D, E and F) in a group of solar arrays are given in Figure. Uniform suction pressure distributions similar to isolated case are observed for inclination angle of 45°.Small changes from the isolated case is observed in the angle of 300.Maximum suction values are observed angles of 30° for the isolated case is observed. So the magnitude of pressure is more in isolated case than the interference case. Suction pressures are predominant in the bottom surfaces of the panel for the different inclination angles at various distances x/L



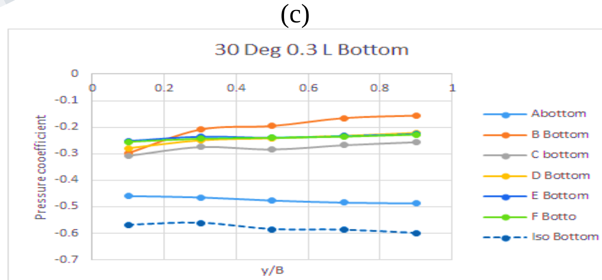
(a)



(b)



(c)



(d)

Fig. 3 Pressure distributions on the bottom surfaces of The Solar arrays (a) 450 0.02L bottom (b) 300 0.6L bottom (c) 450 0.14 L bottom (d) 300 0.3L bottom

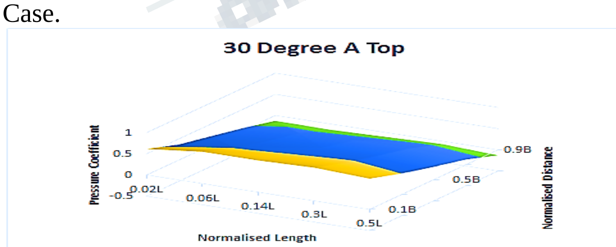
D.Pressure distributions for the isolated solar panel as a surface

IFERP
connecting engineers... developing research
ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering
(IJERMCE)
Vol 2, Issue 6, June 2017

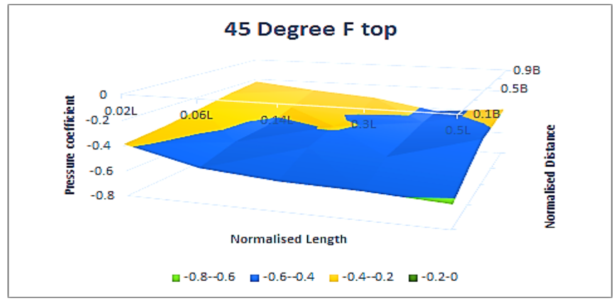
The variations in the pressure distributions for the isolated case of the solar panel for different inclination angles (300,450,600, and 900) is shown in the figure. The graph is plotted as a surface with the normalized distances x=0.02L,0.06L, 0.14L,0.3L,0.5L, in X axis,
y= 0.1B, 0.3B, 0.5B,0.7B, 0.9B in Z axis and the Pressure coefficients in the Y axis. With the graphs plotted it is observed that for 300 angle inclination, the more number of pressure values are between 0-0.5.The maximum value of pressure coefficients are observed in 0.1B for various values of x/L in terms of magnitude. Suction pressures are observed in 0.9B for all values of x/L. For 450 angle inclination more values are between 0.5-1. The maximum value of pressures are observed in 0.1B for the values of x/L as similar to that of 300.Only a small change is observed between the values of 0.1B and 0.3B.Negative values are observed for 0.9B.For 600 angle inclination the maximum number of pressure lies between 0.5-0.1 similar to that of 450.Maximum pressure coefficients are observed in 0.1B and 0.3B compared to all the other distances. For 900 most of the pressure values are between -0.5-0.The maximum values of pressure in terms of magnitude is observed in 0.1B. Suction pressure of 0.1 magnitude is observed in this angle.

E. Pressure distributions in the arrays when the panels are at different locations

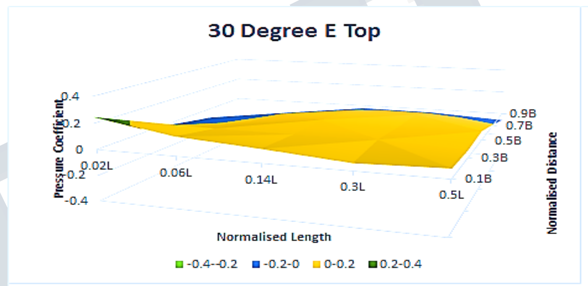
The pressure distributions on the solar arrays arranged in the tandem configuration such that the instrumented panel (A) is in the fixed location and the other panels(B,C,D,E and F) occupies different locations for different inclination angles is plotted in a graph as a surface to observe the results. Changes are observed in the values for two inclination angles. Most of the pressure coefficients in 300 lies in the range of 0-0.5.But in the case of 450 the values are in the range of 0.5-1.So maximum values are observed in 450.For angle 300 the maximum pressure coefficients are observed in 0.1B and it is observed in 0.1B and 0.3B in case of 450.Negative values are observed in 0.9 B. So this case matches well with the isolated
Case.



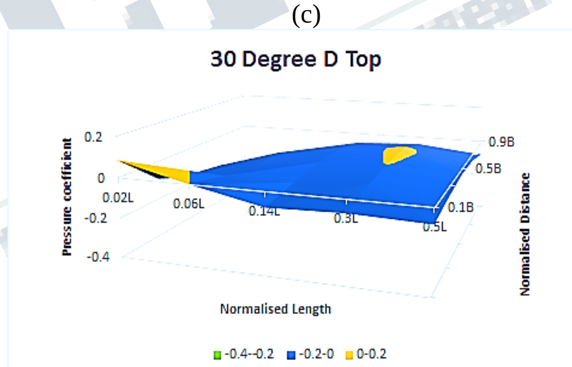
. (a)



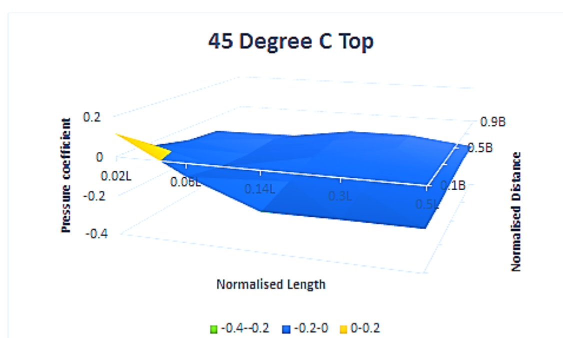
(b)



(c)



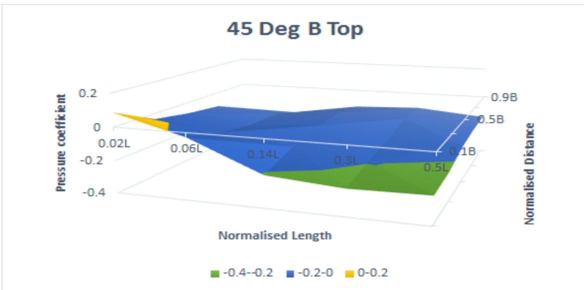
(d)



(e)

IFERP
connecting engineers... developing research

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 6, June 2017



(f)

Fig 4 Pressure distributions when the panels are at differentLocations (a) A at top (b) F at top (c) E at top (d) D at top (e) C at top (f) B at top

V. ACKNOWLEDGEMENT

I am thankful to the Council of Scientific and Industrial Research-Structural Engineering Research Centre, Chennai as this project is done in the campus under the guidance of Mr. G. Ramesh Babu, Principal scientist, Wind Engineering laboratory ,CSIR-SERC

REFERENCES

[1] Chowdhury Mohammad Jubayer and Horia Hangan (2016), ‘A numerical approach to the investigation of wind loading on an arrayof ground mounted solar photo voltaic (PV) panels’ ,Journal of wind engineering and industrial aerodynamics, Vol. 153, pp.60-70.

[2] Aly Mousaad Aly (2016), ‘On the evaluation of wind loads on solar panels: The scale issue’, Journal of Solar Energy, Vol.135, pp.423-434.

[3] Ted Stathopoulos, Ioannis Zisis & Eleni Xypnitou (2014), ‘Local and overall wind pressure and force coefficients for solar panels’, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 125, pp.195-206.

[4] Aly Mousaad Aly & Girma Bitsuamlak (2013), ‘Aerodynamics of ground-mounted solar panels: Test model scale effects’, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 123. pp.250-260.

[5] Andreas Schellenberg Joe Maffei , Karl Telleen & RobWardc (2013), ‘Structural analysis and application of wind loads to solar arrays’, Journal Wind Engineering and Industrial Aerodynamics, Vol.123, pp. 261-272

[6] Jinxin Cao, Akihito Yoshida, Proshit Kumar Saha &Yukio Tamura (2013), ‘Wind loading characteristics of solar arrays mounted on flat roofs’, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 123, pp. 214-225.

[7] S. Behera, A. K. Mittal, A. Gupta, S.K. Bhattacharyya,& D. Ghosh (2013),’ Wind Forces on Inclined Solar Panels on Flat Roofs’ ,Proceedings of Eighth Asia-Pacific Conference on Wind Engineering.

[8] Gregory A. Kopp , Steve Farquhar &Murray J. Morrison (2012),’ Aero dynamic mechanisms for wind loads on tilted, roof-mounted, solar arrays’, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 111, pp.40-52

.