WIND PRESSURE DISTRIBUTION ON L-SHAPE LOW-RISE BUILDINGS WITH CYLINDRICAL ROOFS

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Low-rise buildings are generally made with various roof forms like the convex cylindrical roof with various shapes i.e. geometrical shapes. Wind flow characteristics may vary for different roofs with various geometrical shapes. Codal information of such type of geometrical roofs are limited which are available only for single-span with limited wind angles, whereas no such information is available for such roof forms. Therefore, present research work was carried out on detailed experimental studies of L-shape cylindrical roofs under different wind incidence angles in an open circuit boundary layer wind tunnel and models studied are made with Perspex sheets. Results obtained are useful for designer while designing buildings with cylindrical roof forms and are presented in this paper in the form of contour plots and cross-sectional distributions of mean pressure coefficients.

Keywords: Wind Pressure Coefficients, Wind Incidence Angles, Boundary Layer Flow, Pressure Points, Perspex Sheet, Open Circuit Wind Tunnel.

1 INTRODUCTION

Wind load evaluation requires the information of mean wind pressure coefficients and design wind speeds, which are mainly obtained from various wind codes of practices, Wind codes of India (IS:875-Part-3, 1987), Britain (BS: 63699, 1995), America (ASCE: 7-02, 2007), Australia/New Zealand (AS/NZS: 1170.2, 2011) and Europe (EN 1991-1-4, 2005), these codes provide the information of pressure coefficients on convex cylindrical roofs whereas Indian code provides the information of cylindrical roof resting on ground level. Enough research publications are available for isolated cylindrical roofs whereas no such information of geometrical shape of convex cylindrical roofs are available in any of the roof forms in any code of practices. Ahuja, Krishna and Pande (1990) studied experimental investigation of wind pressure distribution on concave cylindrical roof. Kumar (1991) and Amareshwar (2005) studied effects of rise-to-span ratio and height-to-span ratio onwind loads on convex shape cylindrical roofs but with single span only. Kasperski (2008) provided information related to two building models for two different rise of parabolic shaped arch namely, 2.5 m and 5 m respectively so as to obtain wind pressure on walls and parabolic roof surface. But these research publications are also limited to single span roof and 2-span roofs only. No such information's are available for geometrical roof forms in any research publications and code of practices.

2 EXPERIMENTAL PROGRAMME

2.1 Details of Models

Two-span prototype rectangular plan low-rise building with circular cylindrical roof is assumed to have length = 20 m, width = 10 m, eaves height = 7.5 m and rise = 5 m. Rigid models of the building are made up of Perspex sheet at a geometrical scale of 1:50 (Figure 1 and Photo. 1). Thus, the model has length = 400 mm, span = 200 mm, eave height = 150 mm and rise= 100 mm. The shape of the convex type cylindrical roof follows the segment of a circle. Seventy seven pressure points are provided on the roof surface in 7 sections with 11 pressure points on each section (Figure 2) at 15^0 intervals so as to obtain good pressure distribution on the roof surface.

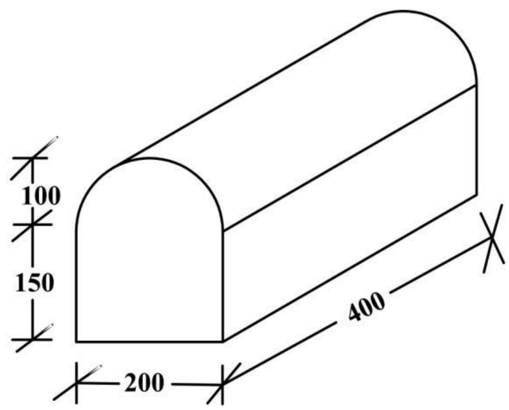

Figure 1. Model dimensions.

Photo. 1 The Model.

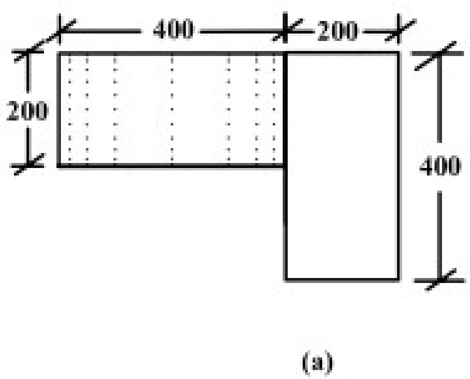

Figure 2. Cylindrical roof building models arranged in different L-Shape orientations

2.2 Wind Flow Characteristics

The experiments are carried out in an Open Circuit Boundary Layer Wind Tunnel at Indian Institute of Technology Roorkee, India. The wind tunnel has a test section of 15 m length with a cross sectional dimensions of 2 m (width) x 2 m (height). Flow roughening devices such as vortex generators, barrier wall and cubical blocks of size 150 mm, 100 mm and 50 mm are used on the upstream end of the test section to achieve mean wind velocity profile corresponding to terrain category 2 as per Indian standard on wind loads. The model is placed at the centre of the turn table and is tested under free stream wind velocity of 10 m/sec measured at 1 m height above the floor of the tunnel.

2.3 Measurement Technique

Two rectangular plan buildings with convex type cylindrical roof can be placed close to one another so that they form L-shape in plan (Figure 3). In such a situation values of wind pressure on the roof of one building will be influenced by the presence of another building under certain wind incidence angles. This article deals with the experimental study carried out to measure wind pressure distribution on roof of two buildings arranged in L-shape under 5 wind incidence angles namely 0º, 45º, 180º, 225º and 270º. First of all, the building model with pressure tappings i.e., instrumented building model is placed at the centre of the turntable inside the wind tunnel in such a way that length of the model becomes parallel to wind direction. The non-instrumented building model is placed behind the instrumented building model on downstream side in such a way that the length of the non-instrumented cylindrical roof model is facing perpendicular to the direction of wind (Figure 3 and Photo. 2). This arrangement is considered as 0º wind direction. Wind pressure measurements are made at all 77 pressure points. Then, turntable where L-shape model is already placed is rotated in such a way that wind hits the model at other four directions namely 45º, 180º, 225º and 270º. Wind pressure measurements are made again so as to have information of pressure distributions on one of the two building models (Figure 3a). Wind pressure values measured at all 77 points for each 5 angles are then converted to mean wind pressure coefficient values and contours as well as cross-sectional variations are plotted further. After measuring wind pressure distribution on one of two buildings, positions of instrumented and non-instrumented models are interchanged (Figure 3). Values of wind pressures at all pressure points are measured again in this arrangement for all 5 wind incidence angles.

Photo. 2. Models of two buildings with convex type cylindrical roof arranged in L-shape : Fashion-1 placed inside the wind tunnel at 0º wind incidence angle

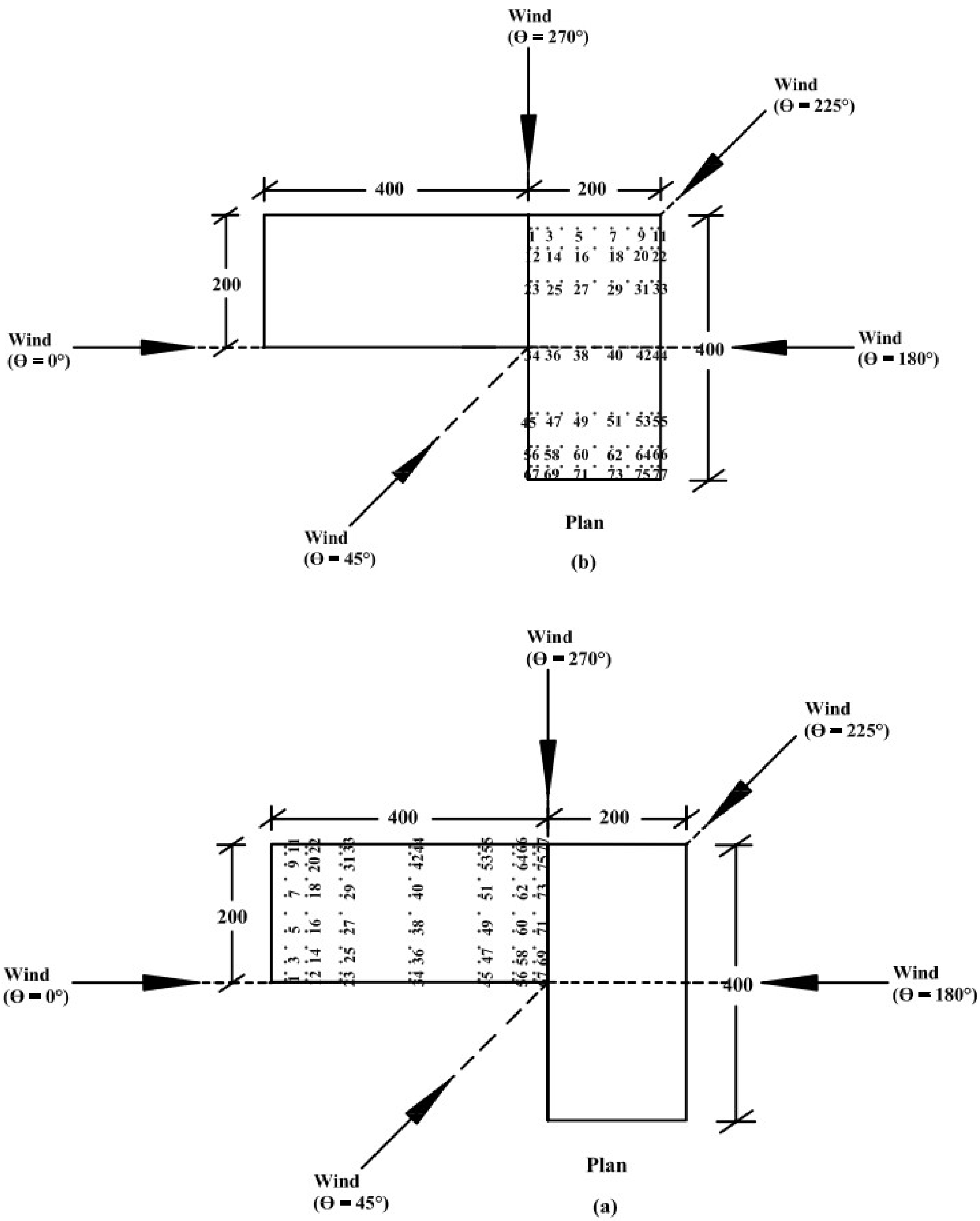

Figure 3 Wind directions on the model of two buildings with convex type cylindrical roof arranged in L-shape

(All dimensions are in mm)

3. RESULTS AND DISCUSSION

Figures 4 - 8 represent the variations of mean wind pressure coefficients (C_p) in the form of contour plots over the roof surfaces of two buildings with cylindrical roof under different wind incidence angles. Cross-sectional variations of C_p along seven sections on each building (Figure 9) are shown in Figures 10 - 14.

It is observed from Figures 4 and 10 that at 0^o wind incidence angle, entire roof of the windward building (i.e. building no. 1) is subjected to suction only with maximum suction near windward edge decreasing towards the leeward edge. Presence of leeward building, i.e. building no. 2 affects wind pressure distribution near the leeward end of building 1 and makes it different from that of isolated case. Therefore, wind pressure distribution on this roof is more or less identical to that on single span building with maximum suction near the ridge line. However, since half of the length of windward eave is being shielded by windward building, wind pressure distribution near the windward eave is different for two halves. Whereas unshielded part is subjected to pressure although of small value, shielded part is subjected to suction only.

At 45^0 wind incidence angle, wind pressure distribution on the roof of windward building i.e. building 1 (Figure 5) is quite identical to the case of isolated building at same wind incidence angle. So far as the roof of leeward building i.e. building no. 2 is concerned, shielded part of windward eave is subjected to higher suction as compared to unshielded part (Figures 5 and 11). Contours of the mean wind pressure coefficients (C_p) on roof surfaces of both the buildings under 180^0, 225^0 and 270^0 wind incidence angles are shown in Figures 6, 7 and 8 respectively. Corresponding values of C_p on various cross-sections (Figure 9) are shown in Figures 12 to 14 respectively. It is observed from these figures that values of mean wind pressure coefficients are highly influenced by wind incidence angle. Designers, therefore, need to consider most critical values of wind loads for the design of structural systems, claddings and fasteners.

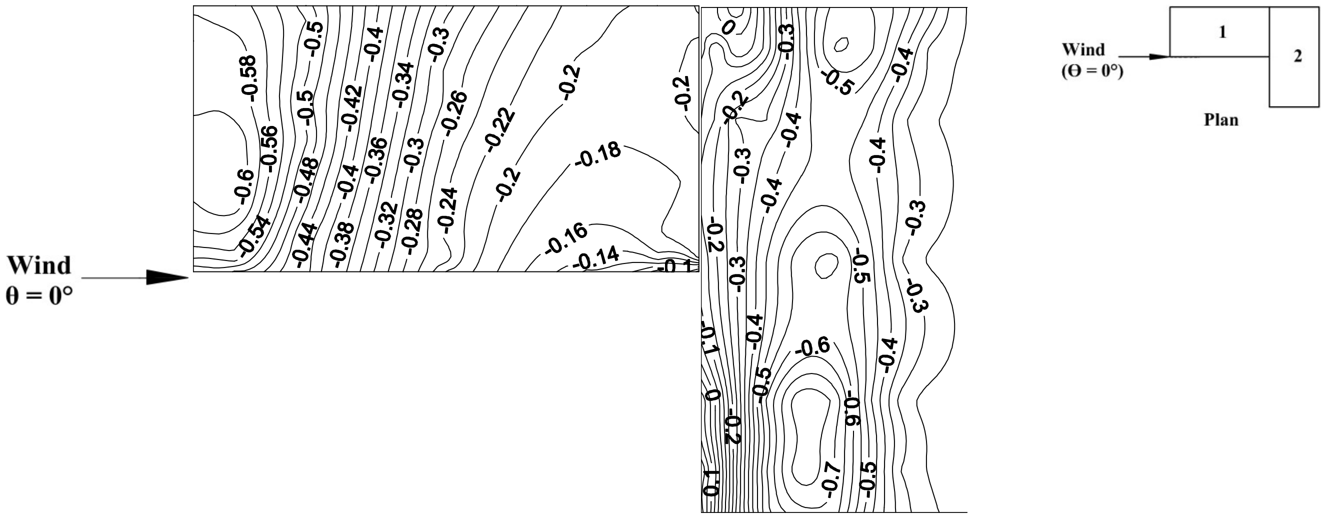

Figure 4. Contours of mean wind pressure coefficients (C_p) on the roof of two buildings with cylindrical roof arranged in L-shape at 0⁰ wind incidence angle

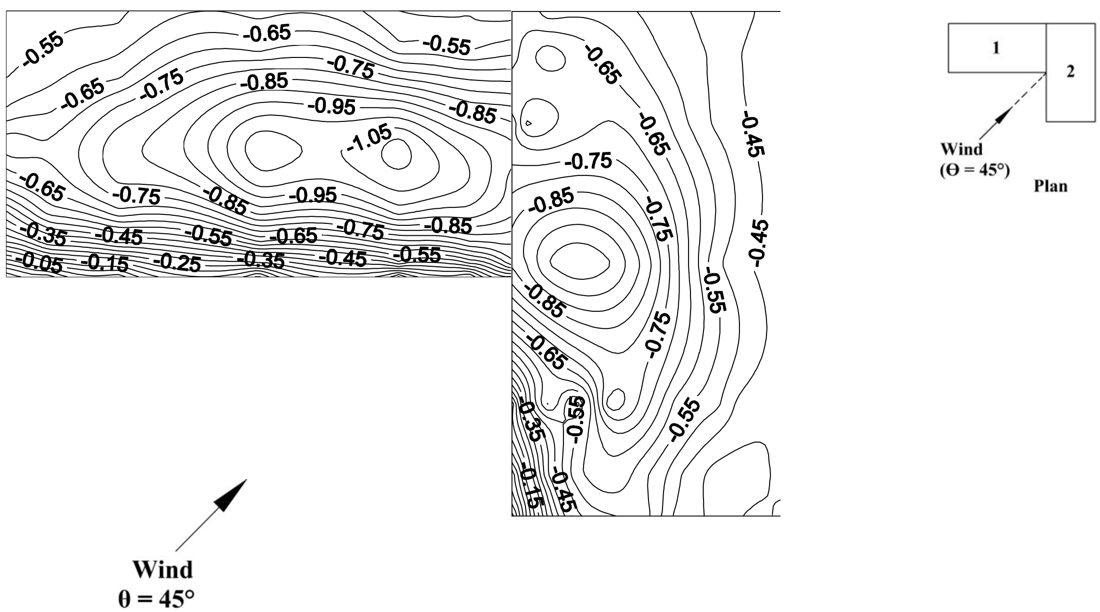

Figure 5. Contours of mean wind pressure coefficients (C_p) on the roof of two buildings with cylindrical roof arranged in L-shape at 45⁰ wind incidence angle

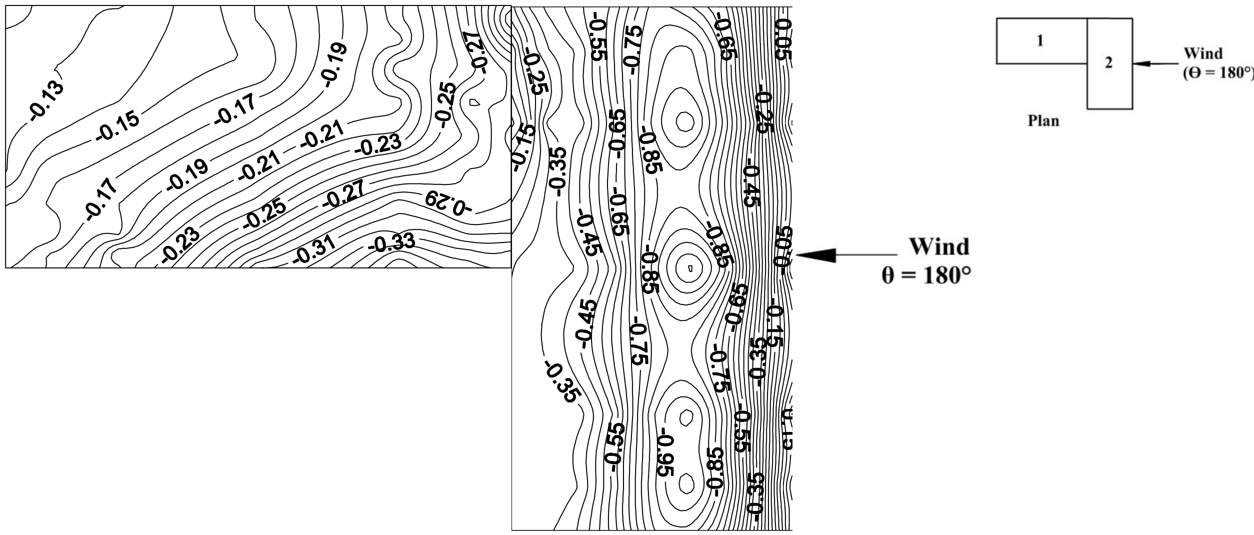

Figure 6. Contours of mean wind pressure coefficients (C_p) on the roof of two buildings with cylindrical roof arranged in L-shape at 180⁰ wind incidence angle

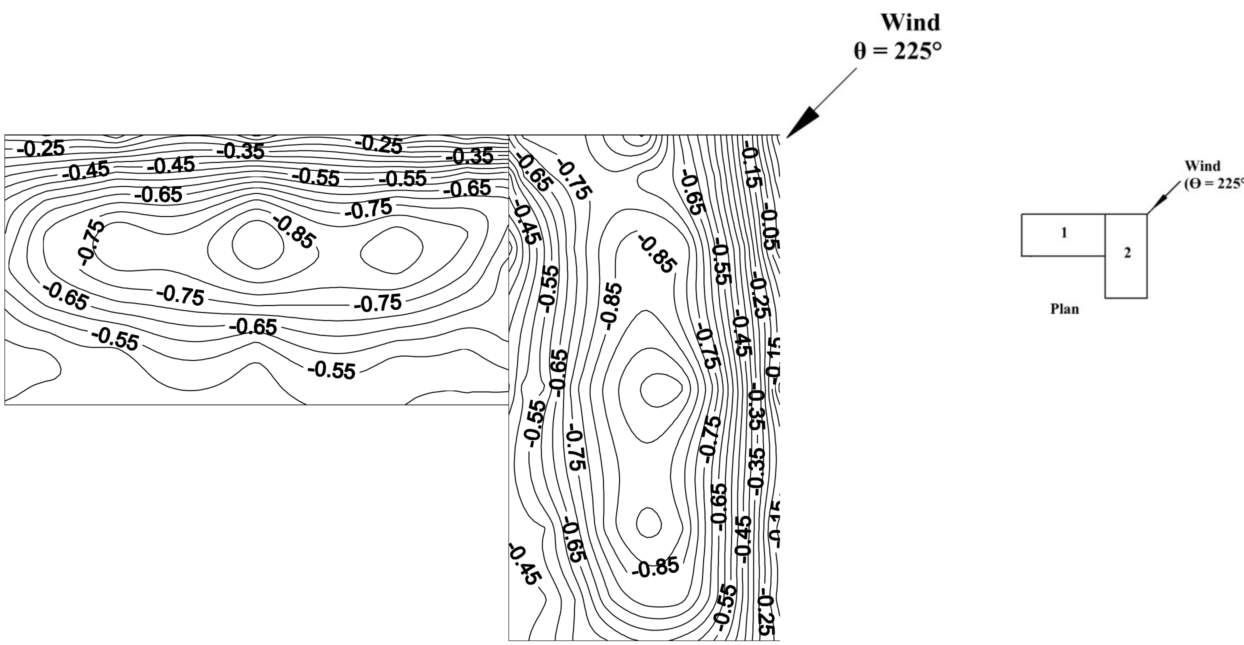

Figure 7. Contours of mean wind pressure coefficients (C_p) on the roof of two buildings with cylindrical roof arranged in L-shape at 225⁰ wind incidence angle

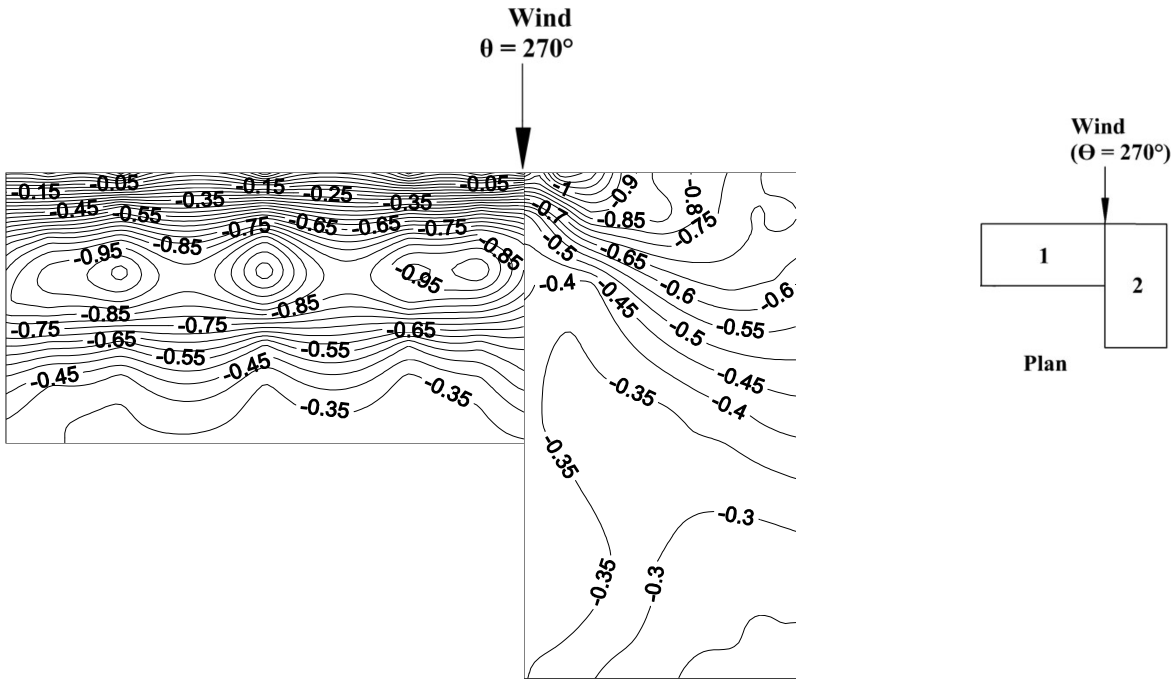

Figure 8. Contours of mean wind pressure coefficients (C_p) on the roof of two buildings with cylindrical roof arranged in L-shape at 270° wind incidence angle

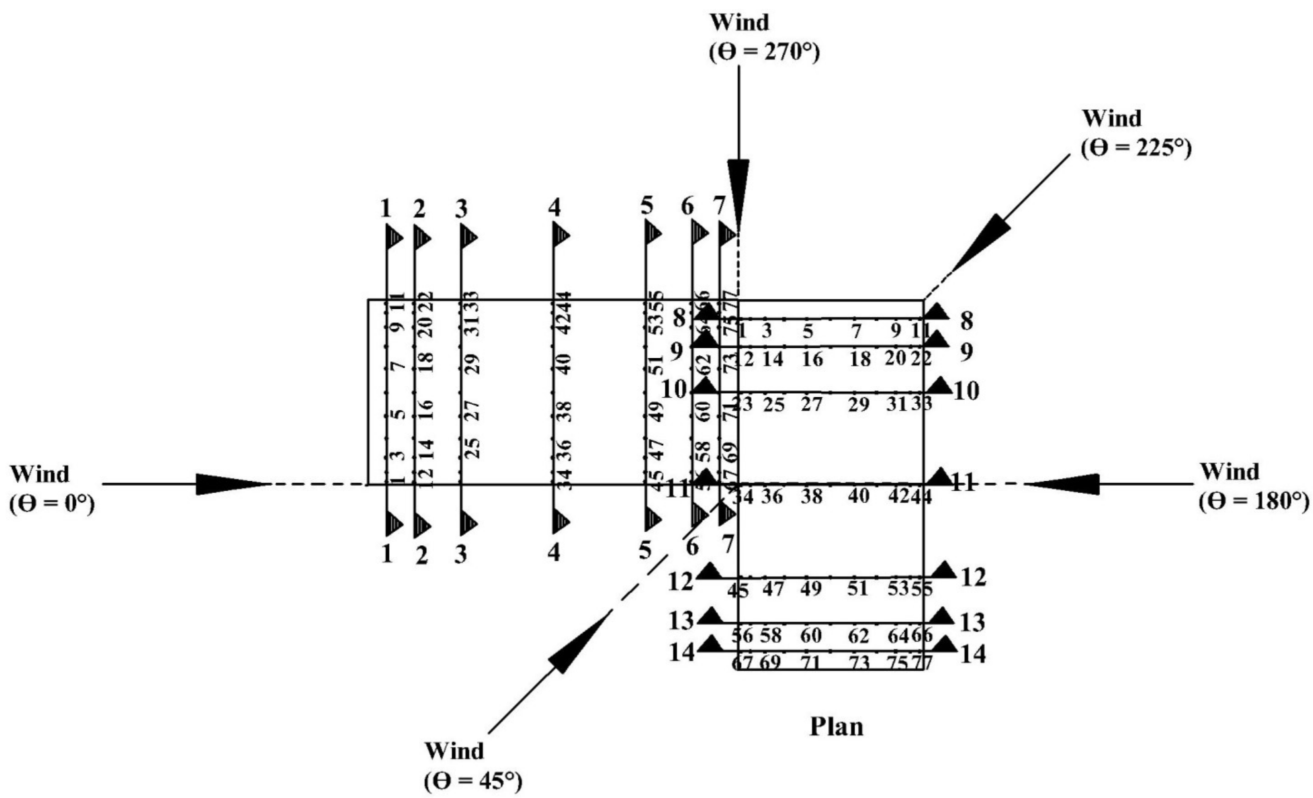

Figure 9. Plan of two buildings with cylindrical roof arranged in L-shape showing various sections

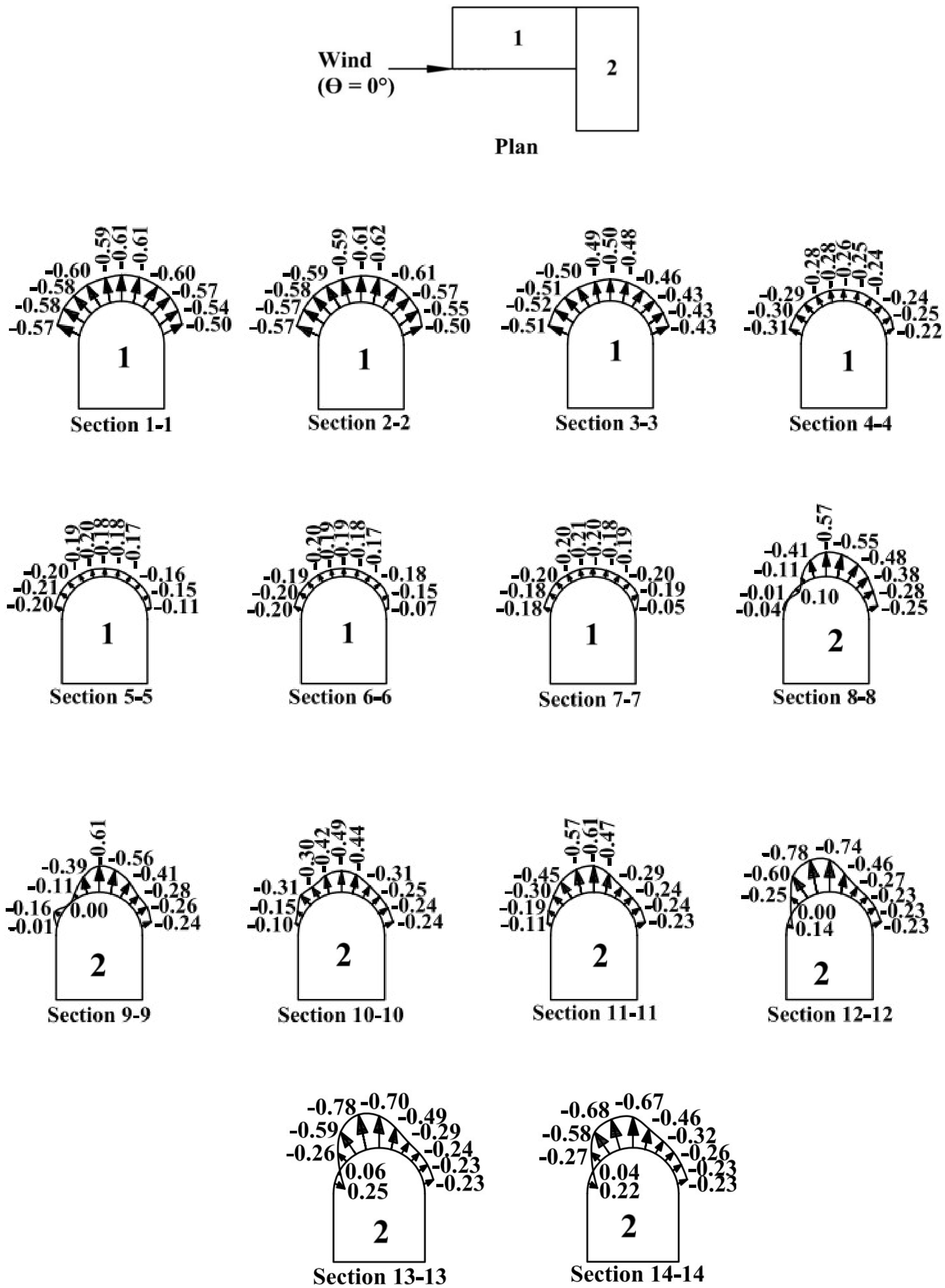

Figure 10. Cross-sectional variations of mean wind pressure coefficients (C_p) on the roof of two buildings with cylindrical roof arranged in L-shape at 0^0 wind incidence angle

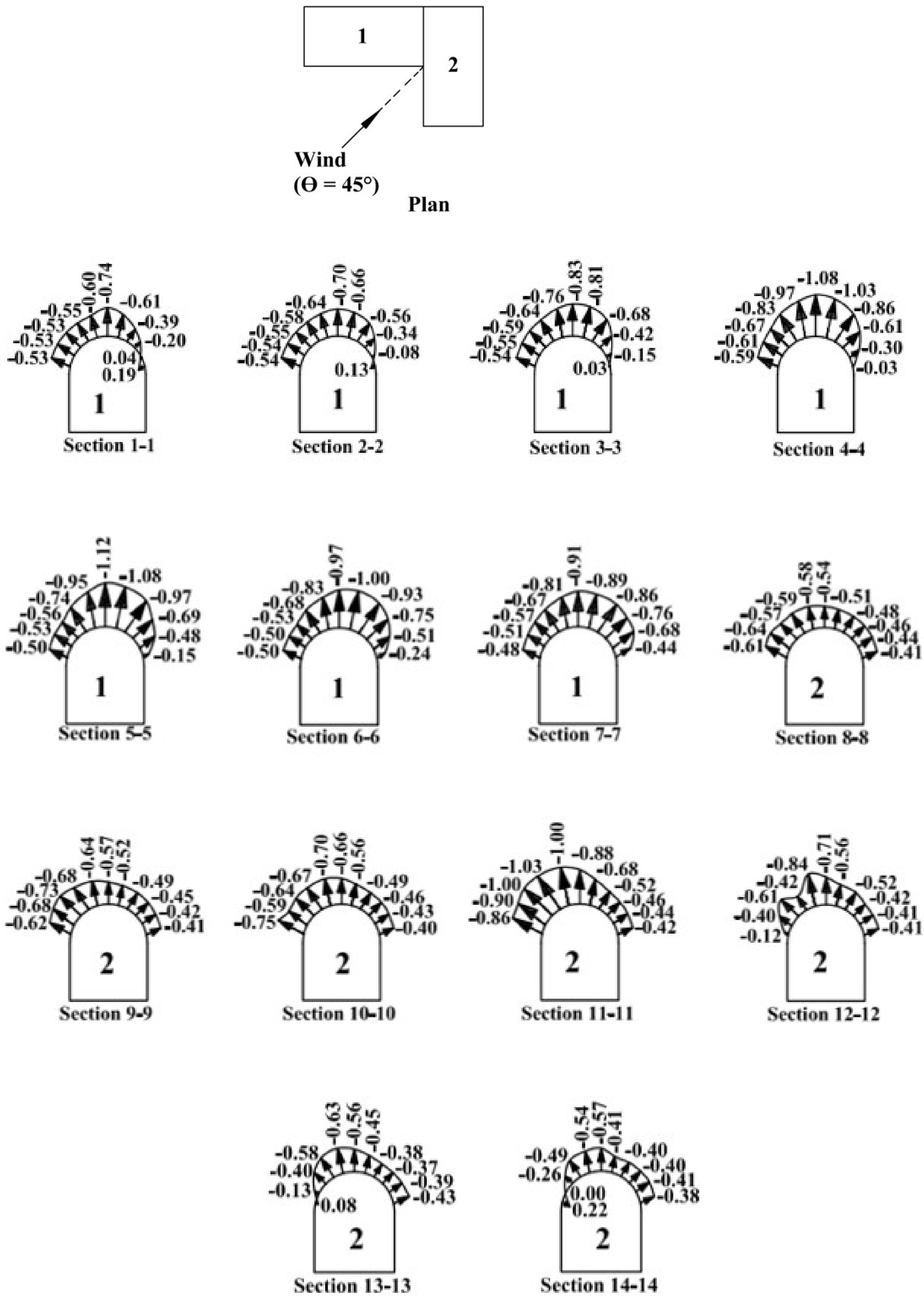

Figure 11. Cross-sectional variations of mean wind pressure coefficients (C_p) on the roof of two buildings with cylindrical roof arranged in L-shape at 45^0 wind incidence angle

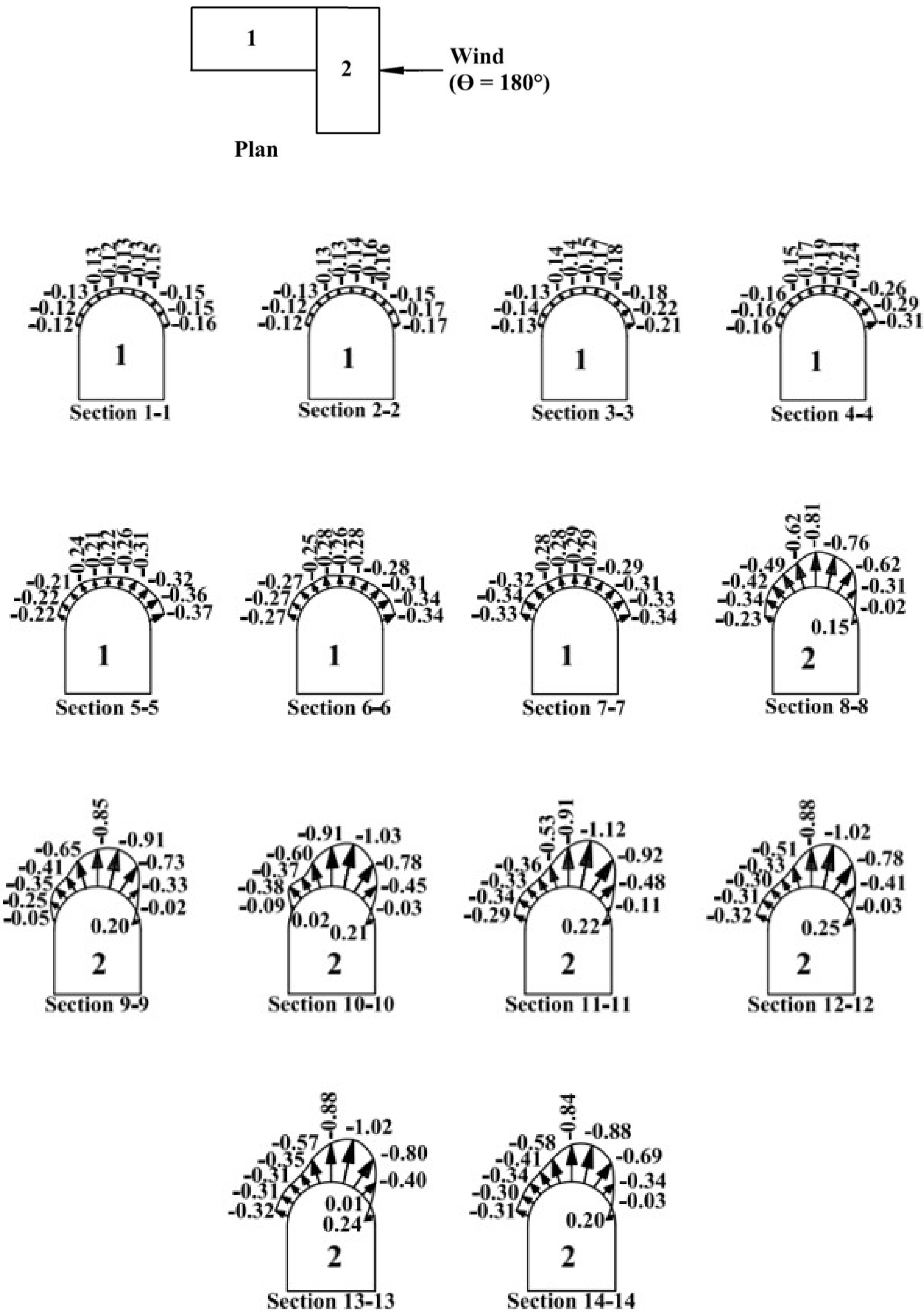

Figure 12. Cross-sectional variations of mean wind pressure coefficients (C_p) on the roof of two buildings with cylindrical roof arranged in L-shape at 180^0 wind incidence angle

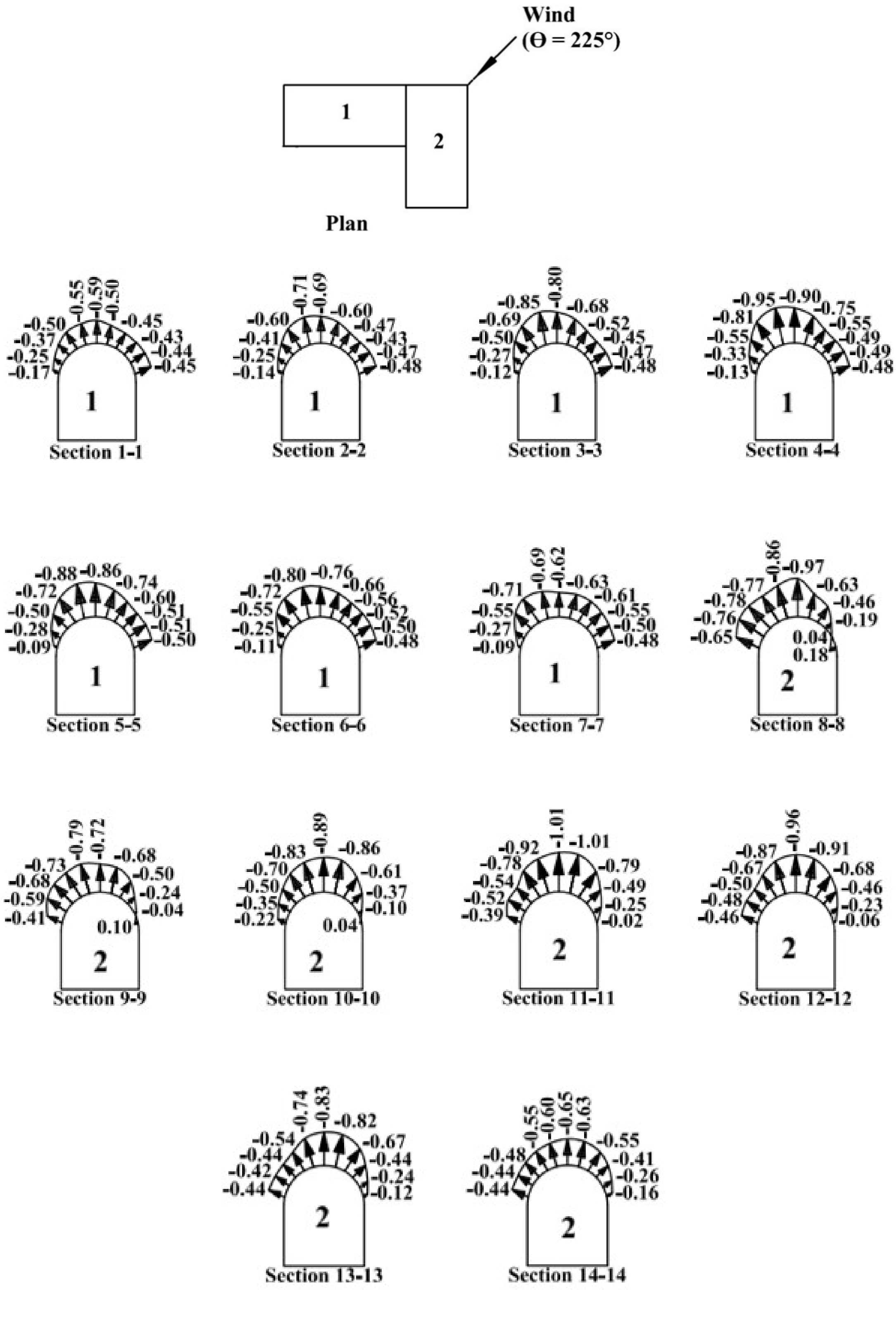

Figure 13. Cross-sectional variations of mean wind pressure coefficients (Cp) on the roof of two buildings with cylindrical roof arranged in L-shape at 225⁰ wind incidence angle

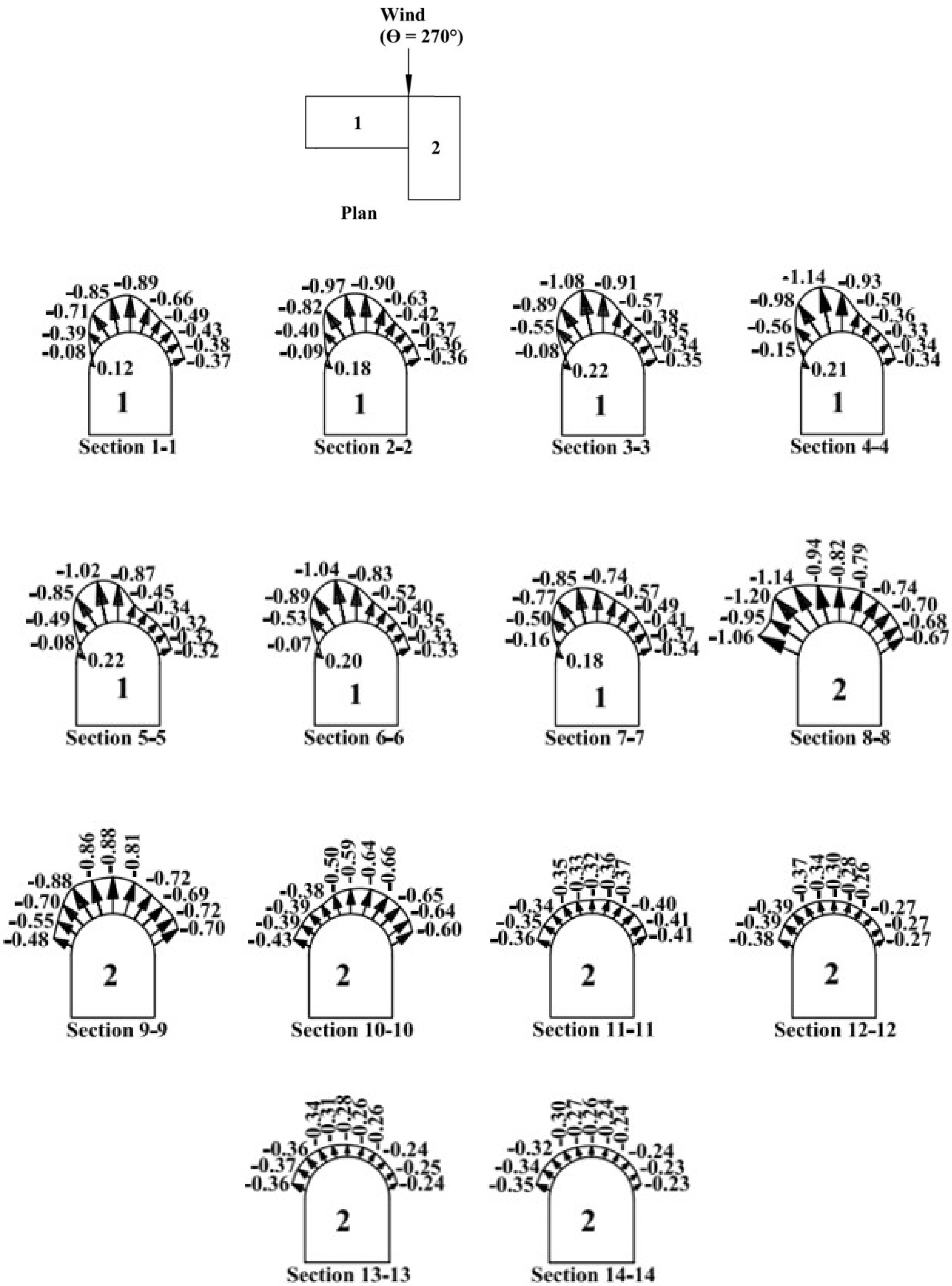

Figure 14. Cross-sectional variations of mean wind pressure coefficients (Cp) on the roof of two buildings with cylindrical roof arranged in L-shape at 270° wind incidence angle

4. CONCLUSIONS

The information given in the standards on wind loads of various countries for wind pressure distribution on low-rise cylindrical roof buildings are for limited wind incidence angles only and thus are not sufficient for the safe and economical design of similar buildings by the structural designers. The experimental results obtained indicate that the values of wind pressure coefficients are highly influenced by the wind incidence angles. Designers need to consider the most critical direction of wind for design of the structural system of such type of curved roof. Wind pressure distribution on windward span in case of two-span building remain almost same as in the case of single-span building. Leeward span in case of two-span building is subjected to almost uniform suction with maximum value being almost half of that on windward span. There is advantage of shielding by windward span on wind pressure distribution on leeward span. Different alphabetical shapes of roof show entirely different pattern of wind pressure distribution.

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