

For practical use of universal equivalent static wind load

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ABSTRACT: This paper describes a method for determining the universal wind load distribution that reproduces the largest load effect on structural members. The method is then applied to a low-rise building and a high-rise building. Quasi-static load effects are investigated for the low-rise building. The largest load effects estimated by the time history response analyses are compared with those reproduced by the GLF method, the LRC method and the universal ESWL. The goal is to provide a database of the universal equivalent static wind load distribution and to develop a wind resistant design method.

KEYWORDS: Largest load effect, Equivalent static wind load, GLF method, LRC method

1 INTRODUCTION

Increasingly complicated building shapes and structural systems have increased the importance of structural design. The safety of all of structural members needs to be confirmed in the structural design stage. Conventional methods of estimating equivalent static wind loads (ESWL) are based on a certain load effect. However, in practice, it is necessary to consider several ESWLs assuming many loading patterns. The authors have proposed a Universal ESWL that simultaneously reproduces the largest load effects on all structural members, and confirmed its effectiveness and rationality by applying it to several structures[1,2]. The technical procedure of this Universal ESWL has been discussed and established. The Universal ESWL makes it possible to reproduce all largest load effects in a unique distribution. Positive and negative load effects are reproduced by a set of the Universal ESWLs. The advantages of this unique method may not yet be sufficiently recognized by many researchers and structural designers. In this study, conventional methods for estimating an ESWL and the method for estimating the Universal ESWL are applied to several structures and the usefulness of the Universal ESWL is verified.

2 EQUIVALENT STATIC WIND LOAD FOR LOW-RISE BUILDING

In standards and laws of many countries the gust loading factor (GLF) method is adapted for estimating an ESWL for low rise buildings. However, the effects of loads acting on members of a low rise building imposed by wind forces on roofs and walls are very complicated. The GLF method is basically aimed at a certain load effect, so it cannot be guaranteed that the resulting ESWL reproduces all of the largest effects. This section investigates ESWLs for a low rise building with a gable roof.

Fluctuating wind pressure data of a low-rise building and its experimental information were down-loaded from the database of the Global COE Wind Engineering Information Center at To-

kyo Polytechnic University[3]. The experimental model was 160mm wide, 240mm deep and 160mm high, and its roof pitch was 9.4 degrees. Its mean wind pressure coefficients and fluctuating wind pressure coefficients are shown in Fig.1 and Fig.2. The maximum mean wind pressure coefficient was 0.8 on the front wall and the corresponding fluctuating wind pressure coefficient was 0.4. The minimum mean wind pressure coefficient was -1.2 on the roof's windward edge and the corresponding fluctuating wind pressure coefficient was 0.4. The mean wind pressure coefficients and the fluctuating wind pressure coefficients on the leeward side of the roof and the leeward wall were small.

Low rise buildings have rigid frames and a background component of load effects would be dominant in members. A simple structural model of a low-rise building was used in this study, as shown in Fig.3. It was constructed of steel frames in the span direction and each all frames were connected by beams and braces in the cross-span direction. The background components of load effects were calculated from the structural model from a time history of fluctuating wind pressure data. Design wind speed was assumed as 30m/s at the building height. The largest load effects on members were estimated from the time history analysis (hereafter referred to as actual largest load effect). The maximum largest axial force occurred at the upper part of the windward column of the 1st floor and the maximum largest shear force and bending moment occurred at the beam's end of the middle frame as shown in Fig.3. ESWLs based on these target largest load effects were calculated by the GLF method and the LRC method. The Universal ESWL that simultaneously reproduces actual largest axial forces, shear forces and bending moments in major members was also calculated.

The ESWL estimated by the GLF method focused on a largest axial force is shown in Fig.4. It is normalized by velocity pressure at the eaves height and the mean component of the wind force coefficient is excluded from it. Although positive and negative largest load effects were estimated, an ESWL that reproduces the same sign of the mean component of load effect is shown in this figure. The gust loading factor of the largest axial force was 3.5. The mean shear force and the mean bending moment in the frame in which the target largest load effects occurred in a member transverse to the wind direction was almost zero, so the GLF method cannot be adopted for both the largest shear force and the largest bending moment.

The ESWL estimated by the LRC method is shown in Fig.5. Although two ESWLs can be estimated from the LRC method, an ESWL that produces negative values on the roof is shown in this figure. The peak factor of the largest axial force, shear force and bending moment were 6.7, 7.1 and 4.3 respectively. The ESWLs are asymmetric to the wind direction and show quite different distributions from the axial force, shear force and bending moment.

The Universal ESWL that simultaneously reproduces largest axial force, shear force and bending moment in main structural members is shown in Fig.6. In the previous study, it was confirmed using a POD eigen vector of fluctuating wind pressure that the Universal ESWL would show a natural and realistic distribution. In this Universal ESWL for low rise buildings, the 1st to 10th POD eigen modes were superimposed. Two Universal ESWLs were estimated for combination of positive and negative largest load effects. Target largest load effects on members were selected by using the same sign as the POD 1st eigen mode of load effect[1]. The Universal ESWL shows asymmetric distribution and is different from the ESWLs estimated by either the GLF method or the LRC method.

Figures 7-9 compare actual largest load effects and those reproduced by all ESWLs. The abscissa shows actual largest load effects for all members and the ordinate shows that reproduced by all ESWLs. The largest load effects are normalized by the maximum actual largest load effects. Comparatively high correlation can be seen in the comparison of largest axial forces estimated by the GLF method and the LRC method and the largest bending moments estimated by the LRC method. However, the correlations of largest shear forces decrease in the LRC method.

Comparison of largest axial force, shear force and bending moment reproduced by the Universal ESWL are shown in Fig.9. The largest load effects reproduced by the Universal ESWL shows comparatively high correlation with the actual largest load effects by the unique distribution.

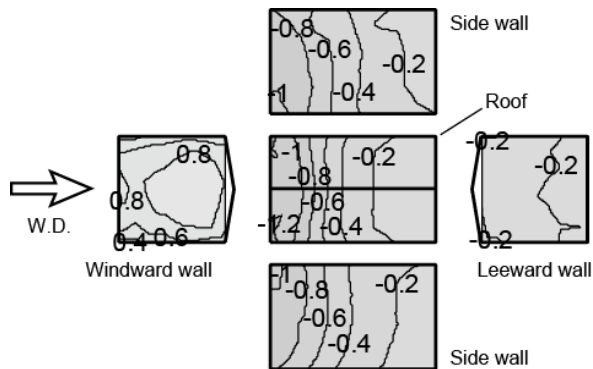


Figure 1. Mean wind pressure coefficient.

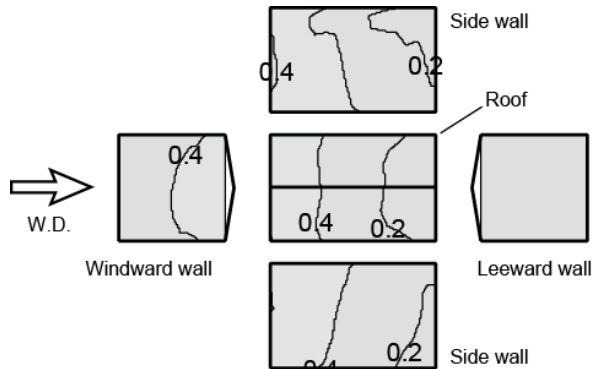


Figure 2. Fluctuating wind pressure coefficient.

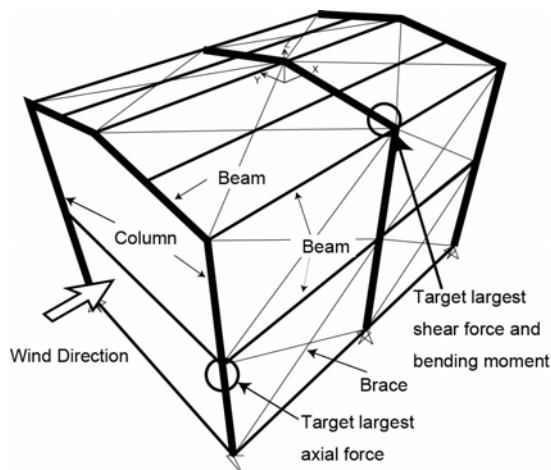


Figure 3

Figure 3. Structural model of low-rise building.

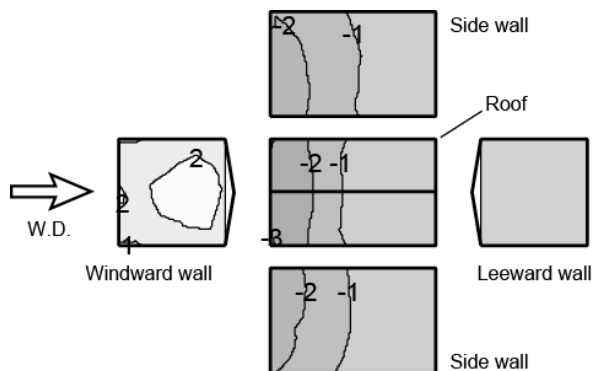


Figure 4

Figure 4. ESWL estimated by GLF method focused on target largest axial force.

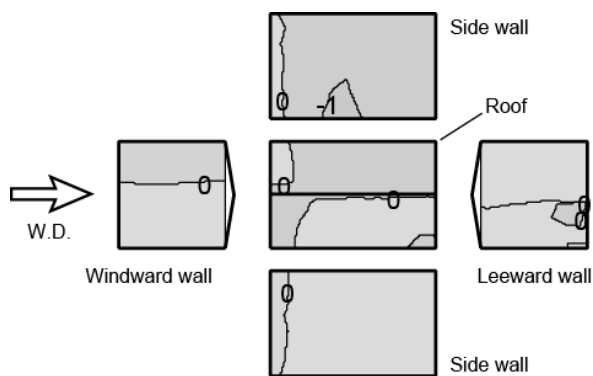
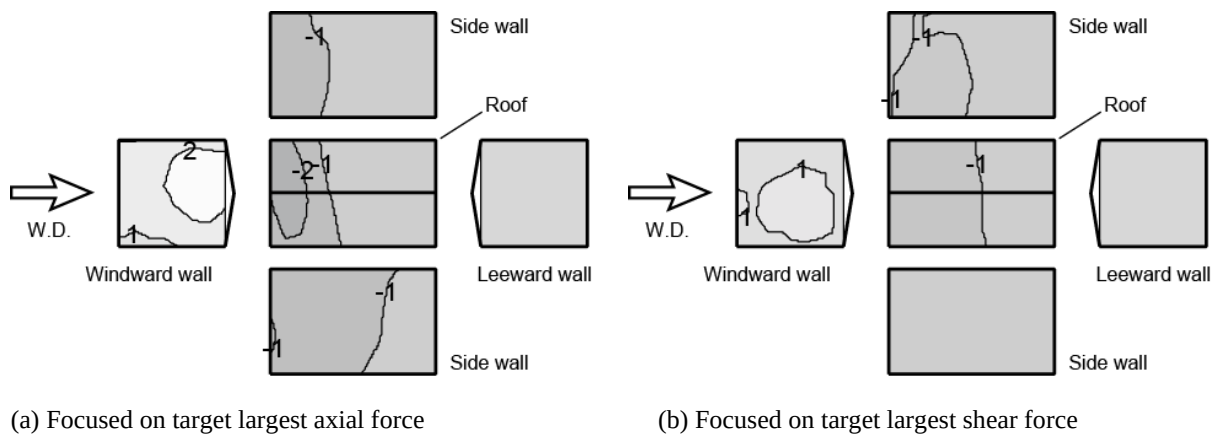


Figure 5. ESWL estimated by LRC method.

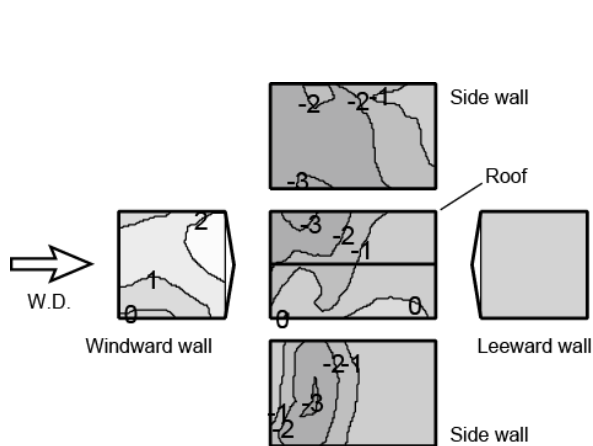


Figure 6

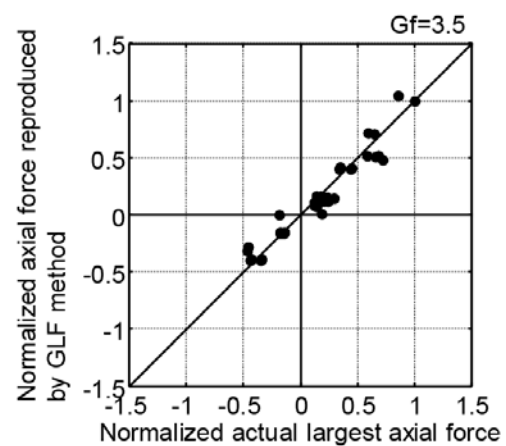
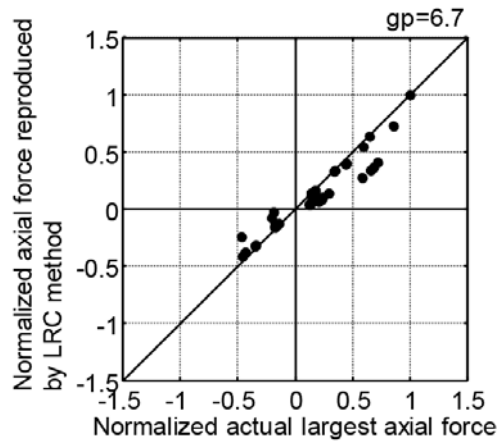


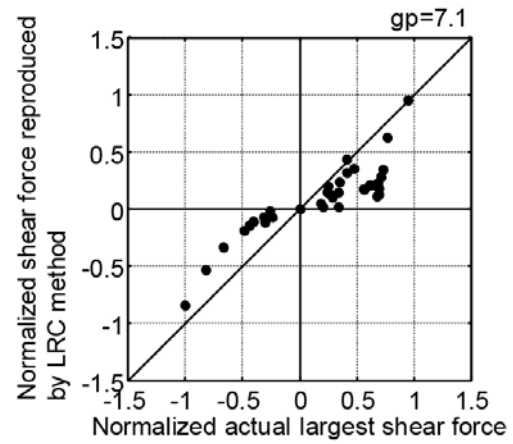
Figure 7

Figure 6. Universal equivalent static wind load.

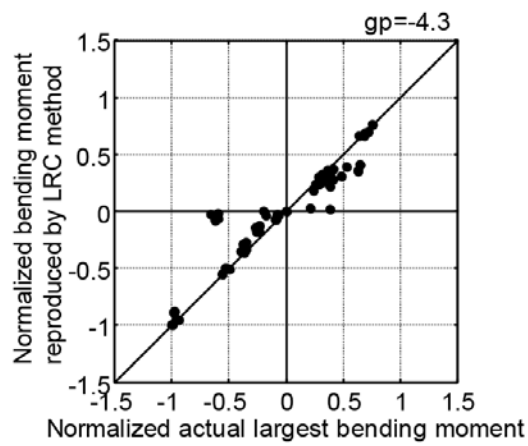
Figure 7. Comparison of largest axial force reproduced by GLF method.



(a) Focused on a largest axial force

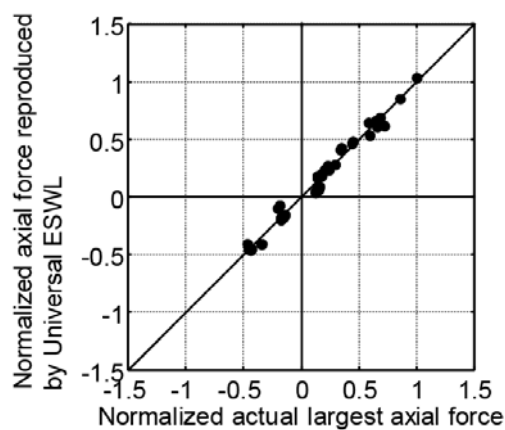


(b) Focused on a largest shear force

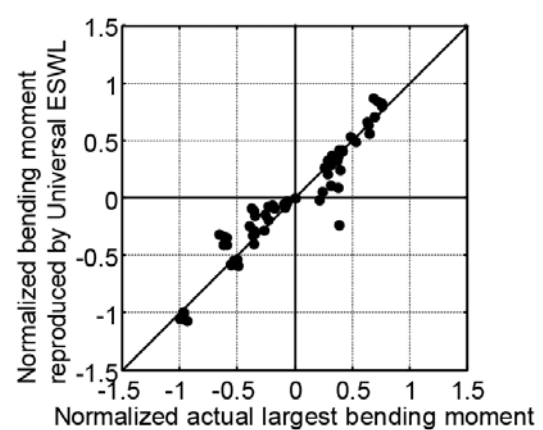


(c) Focused on a bending moment

Figure 8. Comparison of largest load effect reproduced by LRC method.

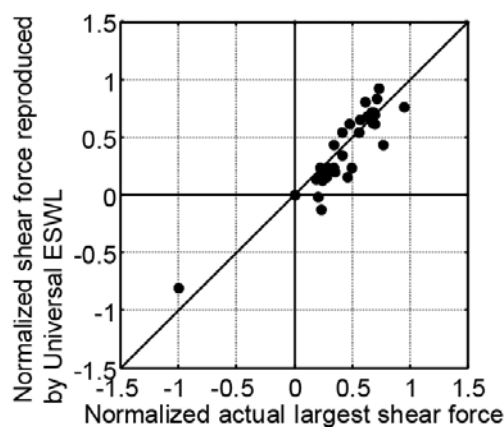


(a)

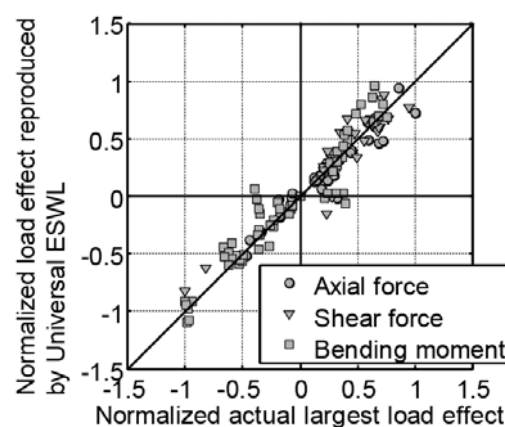


(b)

Figure 9. Comparison of largest load effect reproduced by Universal ESWL.



(c)



(d)

Figure 9(cont.). Comparison of largest load effect reproduced by Universal ESWL.

(a) Focused on largest axial force, (b) Focused on largest bending moment, (c) Focused on largest shear force, (d) Focused on largest axial force, shear force and bending moment

3 CONCLUSION

In the conventional GLF method and the LRC method, the ESWLs are estimated from a certain target load effect. From a physical point of view, mean or fluctuating wind pressure distributions have been used for the ESWLs that are expected to reproduce the largest load effects in all structural members. The more complicated the structure becomes, for example a low-rise building, the more the target largest load effects increase. A reasonable ESWL would be a complicated distribution apart from the mean or the fluctuating wind pressure distribution. The Universal ESWL automatically provides a reasonable distribution for any building structure and any combination of load effects. It may have been possible to realize a more reasonable ESWL distribution after accumulation of many structural types and designs. We have been developing the database of the Universal ESWL.

4 ACKNOWLEDGEMENTS

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5 REFERENCES

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