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Equivalent static wind load estimation in wind-resistant design of single-layer reticulated shells

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Abstract. Wind loading is very important, even dominant in some cases, to large-span single-layer reticulated shells. At present, usually equivalent static methods based on quasi-steady assumption, as the same as the wind-resistant design of low-rise buildings, are used in the structural design. However, it is not easy to estimate a suitable equivalent static wind load so that the effects of fluctuating component of wind on the structural behaviors, especially on structural stability, can be well considered. In this paper, the effects of fluctuating component of wind load on the stability of a single-layer reticulated spherical shell model are investigated based on wind pressure distribution measured simultaneously in the wind tunnel. Several methods used to estimate the equivalent static wind load distribution for equivalent static wind-resistant design are reviewed. A new simple method from the stability point of view is presented to estimate the most unfavorable wind load distribution considering the effects of fluctuating component on the stability of shells. Finally, with comparisive analyses using different methods, the efficiency of the presented method for wind-resistant analysis of single-layer reticulated shells is established.

Keywords: single-layer reticulated shells; equivalent static wind load distribution; wind tunnel test; stability; the most unfavorable distribution estimation.

1. Introduction

Single-layer reticulated shells are widely used as a spatial structural system with middle or large span. Since the structural system is sensitive to the external load distribution, wind action is a very important load in structural design considering its random characteristics, especially with the increase of span. In most cases, it should be paid more attention to than earthquake action. The actual wind load distribution for a project with such shells is not easy to be estimated suitably due to different wind directions and attack angles, effects of nearby buildings, etc., as well as its random characteristics. Unfavorable distributions may lead to different instability modes corresponding to

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different limit load-carrying capacities, and dynamic instability is also possible in some cases. At present, usually equivalent static methods based on quasi-steady assumption, as the same as wind-resistant design of other buildings, are widely used with some coefficients (Solari 1990, Xie, *et al.* 2000, etc.). Actually, considering the random characteristics of fluctuating component of wind, even with a larger empirical dynamic response coefficient, it is hard to say that the structural design is safety enough with such wind-resistant methods.

In this paper, the effects of fluctuating component of wind load on the stability of large-span single-layer reticulated shell structures are discussed at first, and several methods used to estimate the equivalent static wind load distribution in equivalent static wind-resistant design for such structural system are briefly reviewed. Then, from an engineer's point of view, a new simple and practicable method is presented to estimate the most unfavorable wind load distribution considering the effects of fluctuating component on the stability of shells. Finally, based on wind pressure distribution measured simultaneously in the wind tunnel with a rigid model, a k6-12 single-layer reticulated spherical shell is analyzed as an example with different methods to check the efficiency of the presented method.

2. Possible effects of fluctuating wind load on stability of single-layer reticulated shells

For the structural design of single-layer reticulated shells, deformation and stability are the main problems, while the strength of elements is always much smaller than the strength limit of materials, usually just up to 2/3 of the permitted stress value. During the structural analysis of single-layer reticulated shells, geometrically nonlinear behaviors are necessary to be considered. At the same time, such a structural system is very sensitive to the initial imperfections, such as the initial geometrical imperfection (For example, the lack of fitting), the initial residual stress distribution resulted from welding and/or forced fitting, etc.. On the other hand, the difference between actual external loads that the structures will be subjected to at use stage with the estimated values at design stage, which can be taken as "initial load imperfections", also have important effects on the stability of shells. All the imperfection will possibly lead to an instability mode different from the predicted mode at design stage, which is corresponding to a different, usually lower limit load-carrying capacity (Gioncu 1995, Li and Shen 2002). Such effects will become increasingly seriously as the span increases.

In equivalent static methods for wind-resistant analysis of single-layer reticulated shells, the total static external load vector $\{P\}$ in a load case including wind load can be expressed as follows:

$$\{P\} = C_D\{F_D\} + C_L\{F_L\} + C_W\{F_W\} \tag{1}$$

where, $\{F_D\}$, $\{F_L\}$, and $\{F_W\}$ are the dead load, live load and wind load vectors; C_D, C_L and C_W are the corresponding load combination coefficients, respectively. Usually, load vectors $\{F_D\}$, $\{F_L\}$ and coefficients C_D, C_L and C_W can be determined according to the load code in effect.

As for the wind load vector $\{F_W\}$, it can be divided into two parts: $\{\bar{F}_W\}$, resulting from the mean wind pressures on the surface of the shell, and $\{\tilde{F}_W\}$, from the fluctuating components of wind pressures, as shown in following equation:

$$\{F_W\} = \{\bar{F}_W\} + \{\tilde{F}_W\} \tag{2}$$

where the random characteristics of wind load can be reflected by the vector $\tilde{F}_W$.

As we all know, the incremental equations for structural nonlinear static analysis have following expression:

$$[K_t]\{\Delta u\} = \{\Delta P\} + \{R\} \tag{3}$$

where $[K_t]$ is the current tangent stiffness matrix, $\{\Delta u\}$ is the displacement incremental vector, $\{\Delta P\}$ is the external load incremental vector, and $\{R\}$ is the residual force vector in each iterative step.

To solve Eq. (3), nonlinear analysis techniques, such as the arc-length methods, are necessary to be used, especially for tracing the structural equilibrium paths. Generally, a proportional loading strategy is assumed, i.e., $\{\Delta P\}=\Delta\lambda\ \{P\}$, in which $\Delta\lambda$ is the loading incremental parameter, $\{P\}$ is the external load reference vector. Then, the limit value of λ, λ_{cr}, can be used to represent the limit load-carrying capacity of structures.

Let's decompose $[K_t]$, $\{\Delta P\}$ and $\{\Delta u\}$ in the eigenvectors' space of $[K_t]$ as

$$[K_t] = \sum_{i=1}^{n} \lambda_i \{v_i\}\{v_i\}^T \tag{4}$$

$$\{\Delta P\} = \sum_{i=1}^{n} c_i \{v_i\}, \quad c_i = \{v_i\}^T \{\Delta P\} \tag{5}$$

$$\{\Delta u\} = \sum_{i=1}^{n} \alpha_i \{v_i\} \tag{6}$$

where n is the dimension of $[K_t]$, λ_i is the i-th eigenvalue of $[K_t]$ corresponding to eigenvector $\{v_i\}$, and $\lambda_1 \le \lambda_2 \le \lambda_3 \le .... \le \lambda_n$.

Then, considering the relationship between $\{\Delta P\}$ and $\{\Delta u\}$, we can get $\alpha_i = c_i/\lambda_i$, and

$$\{\Delta u\} = \sum_{i=1}^{n} \frac{c_i}{\lambda_i} \{v_i\} \tag{7}$$

As shown in Eq. (7), if the loading incremental mode has a great influence on the instability behavior of structures, one of the coefficients c_i will be larger than others and the corresponding c_i/λ_i will increase faster comparatively. In this case, the instability mode will be the limit-point type with unique path. Considering the random characteristics of wind load, it is possible that the instantaneous external pressure distribution at different points in a certain time on the surface of shells will be most unfavorable due to the turbulence of the wind field in site. So just using the distribution of mean wind pressure may not reflect the actual effects of fluctuating component, which means that it may not lead to a most unfavorable deformation results or a most disadvantageous instability mode finally.

3. Investigation on the effects of fluctuating wind load on the stability of shell

3.1. Analysis model

A Kewitt-type single-layer reticulated shell was chosen as the analysis model in this paper, as

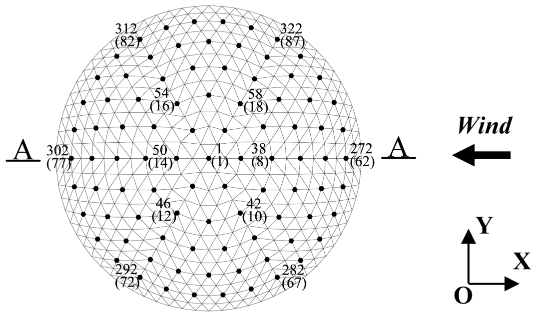

Fig. 1 Analysis model: A k6-12 single-layer reticulated spherical shell

shown in Fig. 1. The span $L = 120$ m, and the rise $f = 40$ m. The sections of all elements in the model were assumed to be 200 mm diameter tubes with 8 mm thickness ($\phi 200 \times 8$ mm). All the joints on the bottom of the shell were assumed fixed for all six degree-of-freedoms.

3.2. Wind tunnel tests with a rigid shell model

In order to know the characteristics of wind load on the analysis model, wind tunnel test on a scaled model of the shell was conducted in the boundary-layer wind tunnel (BLWT) of the Wind Engineering Research Center, Tokyo Polytechnic University. It is an open-circuit low-speed boundary layer wind tunnel with 1.8 m high, 2.2 m wide. With the spire-roughness technique, the expected wind profile, Terrain type III according to an exponent $\alpha = 0.20$ by the exponent law, was simulated successfully (Li, *et al*. 2002), as shown Fig. 2. In Fig. 2, the continuous lines without marks are based on the definitions of Architectural Institute of Japan, AIJ, $E_r = U(z)/U_{10}^{II}$, is the vertical distribution coefficient of wind speed in the flat uniformly rough (FUR) terrain, U_{10}^{II} is the wind speed at 10 m high above Terrain type II. Fig. 3 gives the longitudinal power spectral density (PSD) distribution of wind speed measured in the wind tunnel, which shows a good consistency with well-established Von Karman

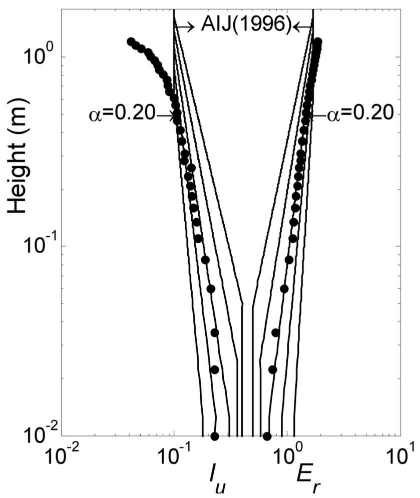

Fig. 2 Wind profiles

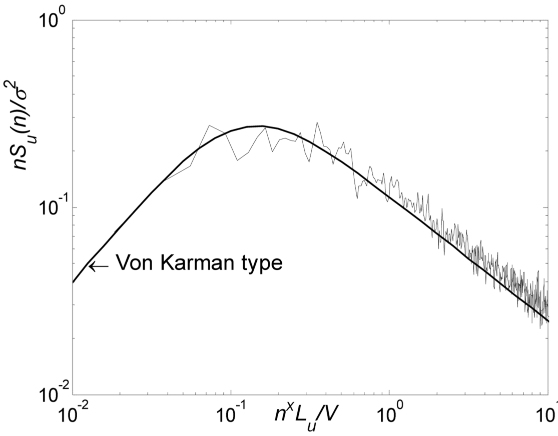

Fig. 3 Longitudinal PSD

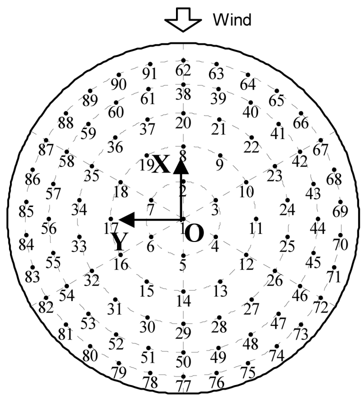

Fig. 4 Spherical shell model and numbering of the measurement taps

expression (1948). According to the length scale in the wind tunnel, 1:400, the size of the shell model and the distribution of the measurement taps on the surface are shown in Fig. 4. The test wind speed is about 10 m/s, and the sampling frequency is 1000 Hz. As usual, wind speed and corresponding velocity pressure at the height of the apex of the model are taken as the reference wind speed and the reference pressure for analyzing the wind pressure coefficients.

Fig. 5 gives the results of the mean and fluctuating wind pressure coefficient distributions measured simultaneously in the wind tunnel. From Fig. 5 we can find that, most of the area of the shell surface has suction pressure except for a small part on the windward side with positive pressure.

3.3. Effects of fluctuating wind on structural stability and limit load-carrying capacities

In order to investigate the effects of the fluctuating component of wind load on the stability of single-layer reticulated shells, different load combinations were considered. A possible proportion of dead load, live load and wind load of 1:0.25:0.5 was assumed after the corresponding load vectors were normalized by the maximum absolute values among their components, respectively at first. Then, following load

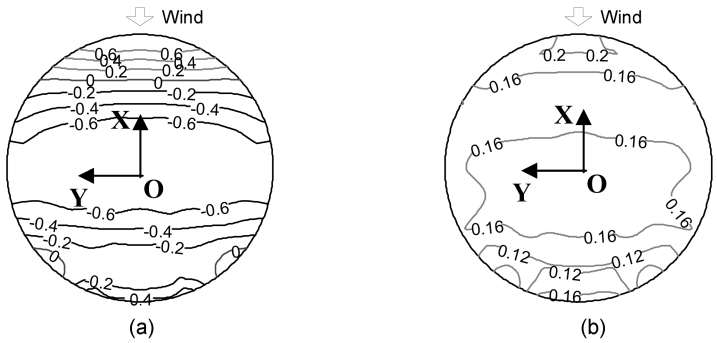

Fig. 5 Distribution of the wind pressure coefficients: (a) Mean; (b) Fluctuating

combination cases were analyzed: (a) dead load + live load (within full span); (b) dead load + live load (only within half span); (c) dead load + wind load estimated only by the mean wind pressure coefficients; (d) dead load + wind load estimated only by the maximum temporal wind pressure coefficients; (e) dead load + wind load estimated only by the minimum temporal wind pressure coefficients; (f)~(j) dead load + wind load estimated only by the temporal wind pressure coefficients at five random time points, respectively. Fig. 6 gives several typical instability modes and their corresponding instability nodes. Fig. 7 gives the load-displacement paths in stability tracing analysis

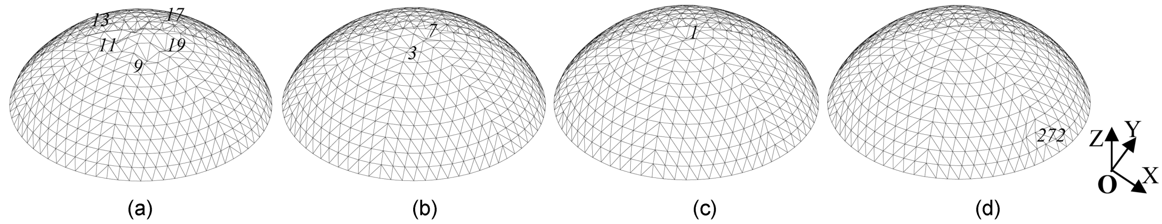

Fig. 6 Instability modes and their corresponding instability nodes: (a) Type 1 (No. 9, 11, 13, 15, 17 and 19); (b) Type 2 (No. 3 and 7); (c) Type 3 (No.1); (d) Type 4 (No. 272)

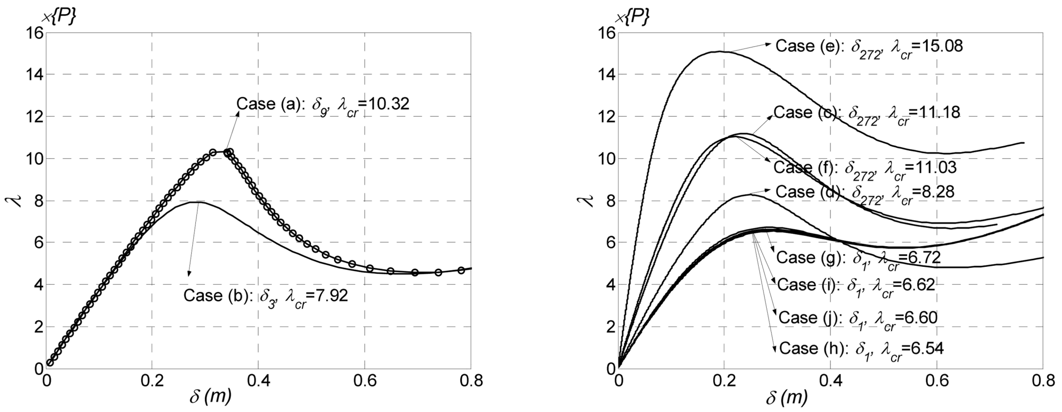

Fig. 7 Load-displacement paths in stability tracing analysis

for all the analyzed cases.

As shown in Fig. 7, the effect of the amplitude of wind load on single-layer reticulated shells can be easily understood, even with a linear extrapolation from the current loading level, i.e., $\lambda=1$. While the effects of the distribution of wind load are complex, different distributions may lead to different instability modes, and the differences among the limit load-carrying capacities corresponding to different instability modes are evident. Thus, we need to pay more attention to the distribution of wind load on single-layer reticulated shells for structural stability analysis, especially the spatial distribution of the fluctuating component, if an equivalent static load method is used.

4. Estimation on equivalent static wind load distribution

Wind load distribution estimation is critical for wind-resistant analysis of single-layer reticulated shells since it has evident effects on structural instability mode and limit load-carrying capacities. For estimating the equivalent static wind load distribution, several aspects should be considered, including the mean wind load as static effect, the fluctuating component as dynamic effect with random characteristics, and even the interaction between wind pressure and structural surface as aeroelastic effect. Here, two existing methods used in estimating the equivalent static wind load distribution for single-layer reticulated shells were briefly reviewed.

4.1. Review on existing methods

The gust factor type methods: The gust factor type methods (Solari 1990, Xie, *et al.* 2000, etc.) can be shown with a given gust factor G_f as

$$\{F_W\} = G_f\{\bar{F}_W\} \tag{8}$$

Taking the estimation method recommended by the load code for the design of building structures in China as an example, the following equation is used:

$$w_k = w_0\mu_z\beta_z\mu_s \tag{9}$$

where, w_k is the characteristic value of the equivalent static wind pressure corresponding to a point on the surface of a structure; w_0 is the reference wind pressure at the site; μ_z is the height variation factor, a modifying coefficient for the height of the point; μ_s is the shape factor, a modifying coefficient for the location of the point on the surface of shell; β_z is the wind fluttering factor to reflect the dynamic effect of wind load.

Then, the wind load vector can be obtained by multiplying by the corresponding tributary area vector of a shell, $\{A\}$, as

$$\{F_W\} = w_0\mu_z\beta_z\mu_s\{A\} = \beta_z(\mu_z\mu_s w_0\{A\}) \tag{10}$$

Here, the result of $(\mu_z\mu_s w_0\{A\})$ can be taken as the mean wind load vector, and the wind fluttering factor β_z is used as a gust factor to reflect the effects of the fluctuating component. Usually, an empirical value about 1.5~2.0 is used for all the nodes of a shell.

In such methods, it is implied that the distribution of wind force resulting from fluctuating component is as the same as that from the mean wind pressure. However, this is not true in some cases. The shortcomings of such equivalent static wind load distribution estimation methods for wind-resistant design of single-layer reticulated shells are obvious, although such methods are really simple and palatable for design engineers.

The effective static load distribution estimation method: The effective static wind load distribution for a structure can be separately derived for three components as follows (Holmes 2001):

$$\{F_i\} = \{\overline{F}_i\} + W_B\{F_{Bi}\} + W_R\{F_{Ri}\} \tag{11}$$

where, $\overline{F}_i$, F_{Bi} and F_{Ri} are the mean component, the background or sub-resonant component and the resonant component, respectively, at node i; W_B and W_R are the weighting factors given by

$$|W_B| = \frac{g_B \sigma_{r,B}}{(g_B^2 \sigma_{r,B}^2 + g_R^2 \sigma_{r,R}^2)^{1/2}} \tag{12a}$$

$$|W_R| = \frac{g_R \sigma_{r,R}}{(g_B^2 \sigma_{r,B}^2 + g_R^2 \sigma_{r,R}^2)^{1/2}} \tag{12b}$$

where, g_B and g_R are the peak factors of background and resonant component, respectively; $\sigma_{r,B}$ and $\sigma_{r,R}$ are the standard deviations of background and resonant component of a response variable of interest, r.

The mean component of wind load at node i can be estimated by

$$\overline{F}_i = \overline{C}_{pi} q_h A_i = \overline{C}_{pi} \frac{1}{2} \rho_a \overline{V}_h^2 A_i \tag{13}$$

where, $\overline{C}_{pi}$ is the mean wind pressure coefficient at node i; q_h is the reference pressure at reference height; ρ_a is the density of air; $\overline{V}_h$ is the mean reference wind speed, and A_i is the tributary area at node i.

The Load-Response Correlation (LRC) method presented by Kasperski and Niemann (1992), can be used to estimate the background or sub-resonant component of wind force as

$$F_{Bi} = g_B \rho_{r,pi} \sigma_{pi} A_i = g_B \rho_{r,pi} C'_{pi} q_h A_i \tag{14}$$

where, g_B is the peak factor of background component, normally in the range of 2.5 to 5; $\rho_{r,pi}$ is the correlation coefficient between the expected response component and the wind pressure at node i; C'_{pi} is the fluctuating wind pressure coefficient at node i.

The resonant component of wind force can be estimated based on the superposition of inertial forces corresponding to the first M vibration modes as follows:

$$\{F_{Ri}\} = \sum_j^M W_{Rj}[M]\{\phi_j\} \tag{15}$$

where, $\{\phi_j\}$ is the j-th vibration mode of the structure based on a modal analysis; W_{Rj} is the weighting factor corresponding to the j-th vibration mode.

With the effective static load distribution estimation method, the equivalent static wind load distribution can be estimated for the purpose to obtain a maximum/minimum value of a response variable of interest. However, there is still a problem: how to determine a suitable reference response initially in order to get the most unfavorable wind load distribution. It is not an easy thing, especially to a complex practical structure. In this paper, a new simple method is presented from the stability point of view, which can be used to obtain a conservative estimation of the effects of the fluctuating component on structural deformation and stability, as well as to get a suitable reference response variable for using the effective static load distribution estimation method.

4.2. The most unfavorable distribution estimation

Since the main questions in structural design of large-span single-layer reticulated shells are deformation and stability problems, and the random characteristics of the fluctuating wind load can also be viewed as a type of load imperfection, the possible instability mode of the shell can be used to give a conservative estimation on the effects of the fluctuating component of the wind load. Such a method, called as "the conformable imperfection mode method", is often used in sensitivity analysis of other imperfections, and has proved to be efficient (Li and Dong 2001). In this paper, a simple method based on the conformable imperfection mode method, called "the most unfavorable distribution estimation method", is presented.

Suppose under a load combination including the mean wind force vector $\{\bar{F}_W\}$, $[K_t]$ becomes non-positive at the $i+1$-th incremental step, which means a limit or a bifurcation point will be occurred. Then, the calculation goes back to the initial state of this step, and an eigenvalue analysis of $[K_t]$ is conducted to obtain the current possible instability modes. With the chosen possible instability mode $\{v\}$, a most unfavorable wind load distribution can be estimated by

$$\{F_W\} = \{\bar{F}_W\} + \{\varepsilon_i\}\sigma_{F_W} = \{\bar{F}_W\} + \{\varepsilon_i A_i\}g\rho_a\bar{V}_h\sigma_v \tag{16}$$

where, $\{\varepsilon_i\}$ is the normalized vector of the product, $[K_t]\{v\}$, and it can be taken as the most unfavorable distribution estimation of the fluctuating component of wind load; g is a peak factor with a range of 2.5-5.0; σ_v is the standard deviation of the reference wind speed.

In this method, the amplitude of the fluctuating load component is considered with a uniform peak factor, g, as usual. On the other hand, since the fluctuating component has random characteristics, the possible instability mode was used as a most unfavorable estimation of its distribution. Therefore, a conservative estimation of the equivalent static wind load of the fluctuating component considering the effects of wind load on structural stability can be estimated with following steps:

Step 1: Based on the load code in effect, the mean wind load vector resulting from the mean wind pressure was calculated by $\{\bar{F}_W\} = \mu_z\mu_s w_0\{A\}$;

Step 2: A stability analysis was conducted under the load combination of the total external load vector $\{P_{temp}\} = C_D\{F_D\} + C_L\{F_L\} + C_W\{\bar{F}_W\}$ as usual;

Step 3: Just before the instability point occurs in the equilibrium path, an eigenvalue analysis of $[K_t]$ is carried out to obtain the current possible instability mode $\{v\}$, usually the first eigenvector of $[K_t]$ is used. Then, a most unfavorable distribution of fluctuating wind load $\{\varepsilon\}$, can be obtained by $\{\varepsilon\}=[K_t]\{v\}$;

Step 4: After the normalization of $\{\varepsilon\}$, the estimated wind load on the shells, $\{F_W\}$, can be calculated by Eq. (16) with a given peak factor;

Step 5: A new nonlinear analysis can be conducted under the load combination according to Eq. (2) to check the strength of elements, deformation and stability of the shell as usual.

In addition, with this method, a suitable reference response variable, i.e., the displacement at the instability node, can be obtained for using the effective static load distribution estimation method.

At present, the peak factor, g, is mainly determined according to the terrain type in site and the flexibility of structures experientially with a range of 2.5~5.0. It should be pointed out that, the value of the peak factors can just lead a small different on the final analysis, and the distribution of the estimated component may give a serious effect on the final limit load-carrying capacity of the structures. On the one hand, the proportion of the estimated equivalent static component for the fluctuating component of wind load in the total external load combination will be very small relatively.

On the other hand, for single-layer reticulated shells, as well as other spatial structures which are sensitive to the distribution of external load, the effect of the amplitude of wind load is easy to be considered, such as using an amplifying factor. But for the effect of the distribution of wind load, it is difficult to be predicted. A external load with the same amplitude but a little difference in distribution may lead to a decrease up to 50% in the limit load-carrying capacity (Li and Dong 2001).

5. Comparative analyses

In order to check the efficiency of the methods mentioned in this paper for estimating the equivalent wind load distribution for single-layer reticulated shells in deformation and stability analysis, the load-carrying capacities and the instability modes of the single-layer reticulated shell model subjected to the estimated loads using different methods were comparatively analyzed. In this paper, the design basic wind pressure $w_0 = 0.5$ kN/m^2 corresponding to a design wind speed V_h about 28 m/s was assumed, then the distributed dead load will be 1.0 kN/m^2 with an assumed proportion of dead load and wind load of 1.0:0.5.

5.1. Deformation analysis

The deformation at A-A section of the spherical shell shown in Fig. 1 using above three methods was compared, as shown in Fig. 8. In the figure, the dynamic results were obtained by a standard FEM program using the wind pressure data measured simultaneously in the wind tunnel; The maximum deformation and the minimum deformation were obtained from the effective static load distribution estimation method.

From Fig. 8 we can find that, the mean results of the displacement from static analysis and from dynamic analysis are well consistent. With the method presented in the paper, the deformation of node 272 has an evident enlarged value compared with the other joints in this axis of the shell. As for the results calculated by the load code for the design of building structures in China, the upward deformation for the part with suction pressure is evident due to directly enlarging the mean wind

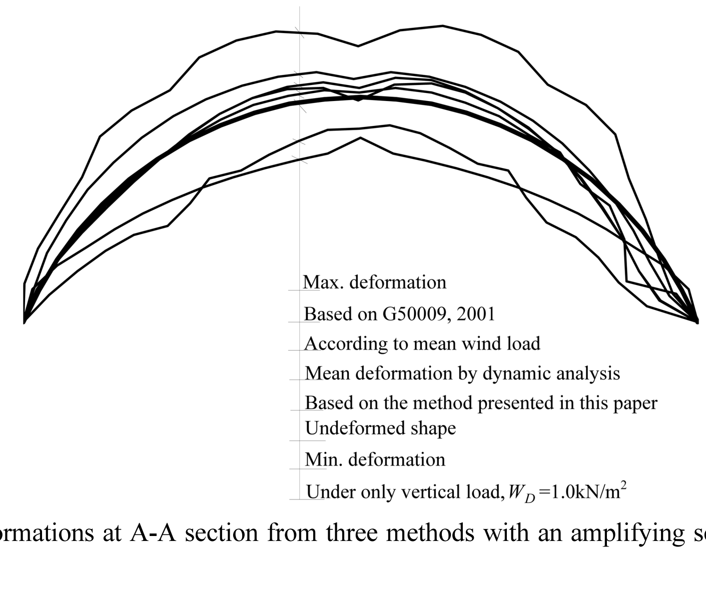

Fig. 8 Deformations at A-A section from three methods with an amplifying scale of 500:1

Table 1 Limit load-carrying capacities and instability modes based on different methods

Analysis methods	λ_{cr}	Instability mode
(a) The gust factor type method	16.2	Fig. 6(c)
(b) The effective static load distribution estimation method	11.6 (Node 1 in -*Z*)*	Fig. 6(c)
	10.1 (Node 272 in -*X*)*	Fig. 6(d)
(c) The most unfavorable distribution estimation method	4.0	Fig. 6(d)
(d) The dynamic stability analysis	10.0	Fig. 6(d)

*The reference response variable (displacement) used in the effective static load distribution estimation.

pressure distribution to reflect the effects of the fluctuating component of wind load.

5.2. Stability analysis

Stability analysis results under the combination of dead load and wind load estimated by above different methods are listed in Table 1. In Table 1, The gust factor type method is based on the load code for the design of building structures in China was used. The dynamic stability analysis was conducted based on the wind pressure data measured simultaneously in wind tunnel using a nonlinear dynamic analysis strategy introduced by Li and Tamura (2005), in which the efficiency of the method and the corresponding program has been established.

From Table 1 it can be found that, the gust factor type method is not a suitable way for estimating the equivalent static wind load distribution on single-layer reticulated shells, especially in stability analysis, since a bigger gust factor may lead to lower safety in some cases from the stability point of view. For the effective static load distribution estimation method, it is necessary to determine a suitable reference response variable initially, which can have obvious effects on the final estimated results. As shown in Table 1, it is obviously better to use δ_{272x} to get the most unfavorable distribution estimation of the fluctuating component of wind load, which leads to a most disadvantageous instability mode, giving the same results as that obtained from dynamic stability analysis. The most unfavorable distribution estimation method can give a very conservative estimation about the effects of fluctuating wind load on stability and limit load-carrying capacity. Moreover, with this method, a suitable response variable, i.e. the displacement at the instability node, can be obtained for using the effective static load distribution estimation method more efficiently.

It should be pointed out that, for structural design of single-layer reticulated shells, usually the minimum limit load-carrying capacity in stability analysis under possible load combinations should be clearly studied. Of cause, the maximum stress in the elements under each possible load combination has to be checked, but it will be very strict and a certain safety reservation in strength, say, not over 2/3 of the design stress of the materials, will be considered in practice for enough safety reservation in stability. Therefore, a conservative estimation on the limit load-carrying capacity in stability under wind load with a simple calculation, as given by the presented method, will be very helpful to structural designers. Especially at the initial design stage, the designer can well judge and adjust his initial design of the structure without the information of wind tunnel tests. A final accurate way to get the convinced value of the limit load-carrying capacity of the structure can be estimated finally by more complex methods, such the effective static wind load distribution estimation method, or even a time-consuming nonlinear dynamic analysis, based on the pressure data measured from wind tunnel tests if necessary.

6. Conclusions

The effects of fluctuating component of wind load on the structural deformation, stability and limit load-carrying capacity are necessary to be considered in wind-resistant design of large-span single-layer reticulated shells.

Since the gust factor type methods mean that the distribution of the fluctuating wind load component is as the same as that of mean wind load component, it is not a good way for estimating the equivalent static wind load on single-layer reticulated shells, as well as other spatial structural systems which are also sensitive to wind load. A bigger gust factor may lead to less safety from the stability point of view.

The effective static load distribution estimation method can be used to get a theoretically reasonable and acceptable equivalent static wind load distribution compared with the dynamic stability analysis only if the determination of the reference response variable is suitable.

The most unfavorable distribution estimation method presented by the authors can be used to give a conservative estimation of wind load effects on the deformation and stability of single-layer reticulated shells, as well as to determine a suitable response variable for using the effective static load distribution estimation method. Combined with the effective static load distribution estimation method, it can be used efficiently to estimate the equivalent static wind load distribution on single-layer reticulated shell structures for deformation and stability analysis, which was established by comparative analyses using the wind pressure data measured simultaneously in a wind tunnel.

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