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Plane grid structure damage location identification by model curvature

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Abstract

The mode curvature is good identification effect for one-dimensional beam damage location. The whole plane grid structure modal shape similar to 2D bending plate , also similar to beam in each dimension, therefore, the beam damage location identification by curvature mode method can be improved for plane grid structure. The damage location identification method is established by computation and integration the two directions of the damaged structure modal curvature changes. Through the simulation examples proved the feasibility of this method.

Keywords: plane grid structure; structure damage identified; mode of vibration; modal curvature

1. The Curvature Mode analysis fore plane grid structure

An important standard, for a well parameter of structure damage identification, is not only the use more less information and identifying minimal damage, but also can avoid excessive interference information as too sensitive. In addition, in the practical detection, it is difficult to measure high order modal. Therefore, structural dynamic detecting damage method should be avoided using a high order mode as much as possible. In fact, the high order mode is sensitive mainly for small local damage and the low

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order mode is sensitive mainly for damage area. A suitable method is possible to detect structural damage area by using a limited number of low order modes.

Plane grid structure's members are bore axial force. Its deflection shape similar to plates, the curvature is the main mode by the vertical load. As this reason, the method of curvature mode analysis could be used for plane grid structure.

The beam curvature mode method, for one dimension analysis, can be extended to two dimension plane grid structures and the X and Y direction curvatures are calculated as follow:

$$c_{i,m}^{x} = \frac{y_{i,m+1} - 2y_{i,m} + y_{i,m-1}}{l_x^2} \tag{1}$$

$$c_{i,m}^{y} = \frac{y_{i,m+1} - 2y_{i,m} + y_{i,m-1}}{l_y^2} \tag{2}$$

$c_{i,m}^{x}$, $c_{i,m}^{y}$ curvature of i mode m nodal point in x, y direction

$y_{i,m}$ displacement of i mode m nodal point

l_x, l_y mean length of between tow adjacent nodal point in x, y direction

2. The curvature mode formula for plane grid structure damage identification

We may use the nominal modal curvature parameters to expand damage curvature variation.Use the differential to get the formula:

$$\boldsymbol{c}_{m,nominate}^{2} = \frac{\boldsymbol{c}_{m-1}^{2} + 4\boldsymbol{c}_{m}^{2} + \boldsymbol{c}_{m+1}^{2}}{6} \tag{3}$$

$c_{m,nominate}^{2}$ nominal curvature of m nodal point

c_{m}^{2} square of the curvature of m nodal point

It's difficult to identify the damage location for large Plane grid structure by the nodal point's curvature, as it could not be measured the curvature or displacement of mode at each node. In order to adapt practical engineering, the whole structure is divided into K segments along the X and Y directions. The j segments lengths are l_j^x and l_j^y. Then "average" modal curvatures of the section or region are calculated to identify the damage in which area. This is prepared for distinguish the specific location of damage. In order to identify the damage area, and consider the contribution of modes on the curvature at the same time, the formulas are improved based on modal curvature index of segments as follows:

$$c_j^x = \frac{1}{n}\sum_{i=1}^{n} c_{i,j}^{x2} l_j^x \qquad c_j^y = \frac{1}{n}\sum_{i=1}^{n} c_{i,j}^{y2} l_j^y \tag{4}$$

$$CMI_j^x = \left| c_j^{ux} \Big/ \sum_{j=1}^{k} c_j^{ux} l_j^x - c_j^{dx} \Big/ \sum_{j=1}^{k} c_j^{dx} l_j^x \right| \tag{5}$$

$$CMI_j^y = \left| c_j^{uy} \Big/ \sum_{j=1}^{k} c_j^{uy} l_j^y - c_j^{dy} \Big/ \sum_{j=1}^{k} c_j^{dy} l_j^y \right| \tag{6}$$

Considering the modal curvature index comprehensive effect in X、Y direction, the improved modal curvature index of j segment is obtained:

$$CMI_j = \sqrt{(CMI_j^x)^2 + (CMI_j^x)^2} \tag{7}$$

CMI_j improved modal curvature index of j segment

CMI_j^x 、CMI_j^y curvature index of j segment in x， y direction

c_j^x 、c_j^y 1~n modes together nominal curvature of j segment in x， y direction

c_j^{ux} 、c_j^{uy} 1~n modes together nominal curvature of j segment in x， y direction before damage

c_j^{dx} 、c_j^{dy} 1~n modes together nominal curvature of j segment in x， y direction after damage

$c_{i,j}^2$ nominal curvature of i mode j segment

n considering modes

3. The damage location identification example

The example structure is the positive four pyramid space truss structure with the surrounding supporting, plane size 30m x 18m, grid number 10x 6, grid height 2m, cross-sectional area of the top rod 1.717 $\times 10^{-3}$m^2 cross-sectional area of The bottom rod 1.308$\times 10^{-3}$m^2,the cross-sectional area of the middle rod $\times 10^{-3}$m^2,the elastic modulus of the material in good condition 2$\times 10^{11}$Pa, Poisson's ratio 0.3, density 7800kg/m^3, grid model in Figure 1, use the finite element software simulation before and after damage modal analysis. Truss structural damage identification segment division as shown in figure 2.

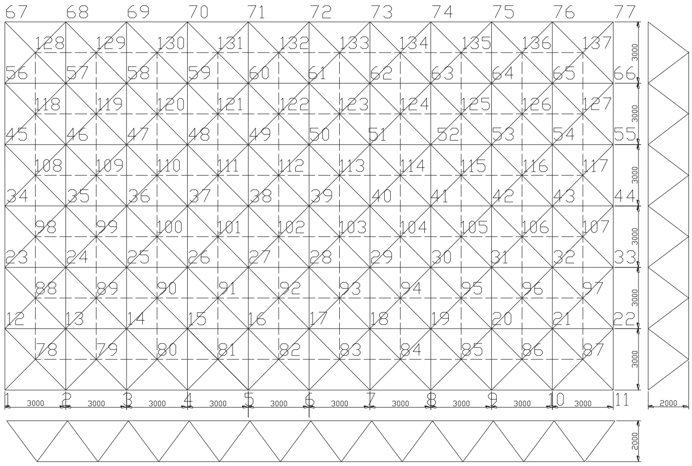

Fig.1 structure diagram

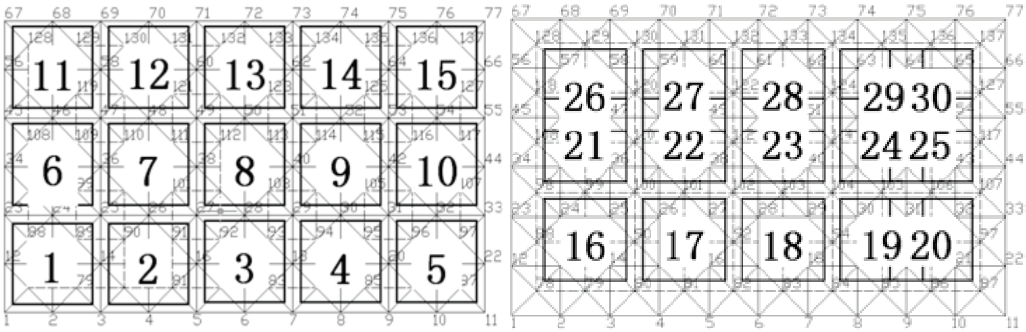

Fig.2 The divided segment for damage identification (a) The divided segment on top of truss structure (b)The divided segment at bottom of truss structure

In this example, the single damage position and multiple damage position are mainly discussed, including the different damage degree. The ability of the method improved curvature mode damage identification is tested and verified.

3.1. single position damage identification

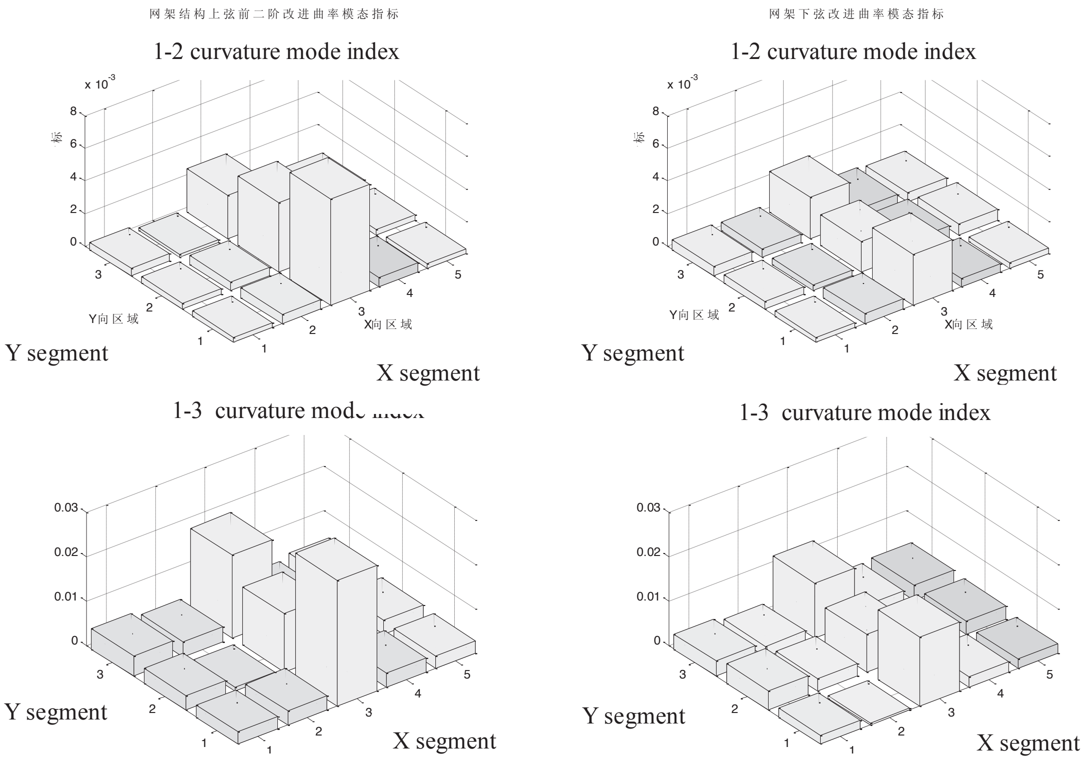

Fig.3 the member 168 damage 10% on bottom chord of truss structure (the high index corresponding the damage region)

Figure 3 shows the improved curvature mode index could identify the damage location and the first two order modes are enough. The improved modal curvature index variation caused by the middle rod is similar to the top and bottom rod and cause improved modal curvature index mutation of corresponding top and bottom member area .Thus we should put the damage region in the web member into consideration while considering damage area.

3.2. Multiple position damage identification

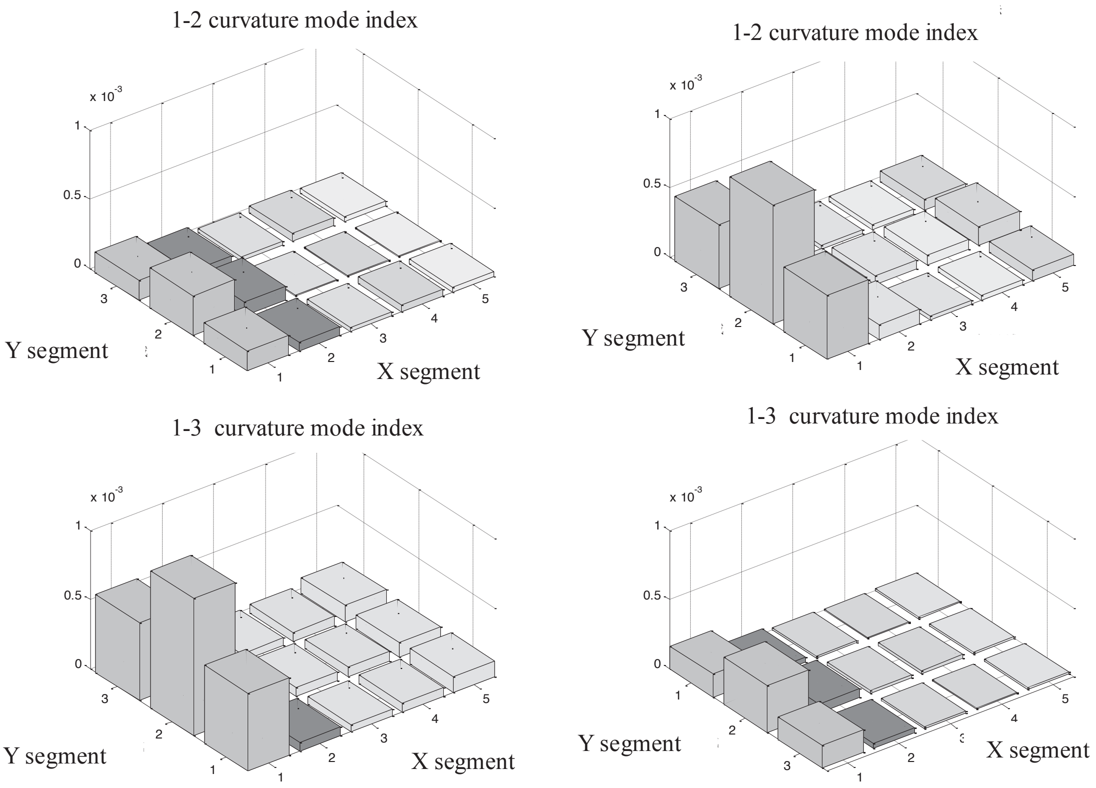

Fig.4 the member 94,105 damage 10% degree on top chord of truss structure(the high index corresponding the damage region)

For different positions and different degrees of damage, improved curvature mode index can clearly display damage larger rod 168 damage area, improved curvature mode index is smaller for rod 94 and rod 105 region .If increase possible the damage region, damage region could be identified roughly and using few mode of lower order (two or three order) could give a well effects.

4. Conclusion

Based on mode curvature theory which is researched for the feasibility of curvature mode in truss structural damage detection, the suitable curvature index is put forward for improvement of identifying the damage location. According to the example, the index could only need few modes to indentify damage region and get well effect. For the practical test, it will greatly help to save the time and cost.

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