

METHOD FOR ASSESSING SAFETY RISK IN CONSTRUCTION ENGINEERING OF EXISTING BUILDING

TECHNICAL FIELD

The present invention relates to the technical field of construction safety and, in particular, to a method for assessing a safety risk in construction engineering of an existing building.

BACKGROUND

Currently, the method for assessing risks of existing buildings such as historic buildings in China includes assessing risks of fire, lightning strike and earthquake hazards. This method involves assessing the risk of adverse influence of these natural disasters on the existing buildings and formulating preventive measures. However, little effort is devoted to the assessment on structural safety risk in renovation or expansion of damaged existing buildings. During the renovation or expansion of an existing building, structural safety of the building has an impact on the progress of the renovation or expansion project. In particular, for existing buildings such as landmarked historic buildings, buildings listed as world heritage sites and the like, structural safety during construction has an impact on the management and control during construction. Therefore, there is an urgent need in the art for a method for assessing a safety risk in construction engineering of an existing building, which can provide early warning for a structural safety risk associated with the existing building construction project.

SUMMARY OF THE INVENTION

A technical problem to be solved by the present invention is to provide a method for assessing a safety risk in construction engineering of an existing building, which can

provide early warning for a structural safety risk associated with the existing building construction project.

In order to solve the above technical problem, a subject matter of the present invention lies in a method for assessing a safety risk in construction engineering of an existing building, which comprises: creating a finite element model representing the structure of the existing building; defining a main body of the existing building according to the finite element model, the main body comprising columns, beams and truss rods; and assessing a safety risk of the existing building using a reserve load strength ratio of the main body, wherein the reserve load strength ratio of the main body is calculated according to the formula:

$$\varphi = \frac{1}{3} \times (\sum_{i=1}^{N_{\text{column}}} \varphi_i^{\text{column}} w_i^{\text{column}} + \sum_{i=1}^{N_{\text{beam}}} \varphi_i^{\text{beam}} w_i^{\text{beam}} + \sum_{i=1}^{N_{\text{rod}}} \varphi_i^{\text{rod}} w_i^{\text{rod}}),$$

where:

φ is the reserve load strength ratio of the main body of the existing building;

$\varphi_i^{\text{column}}$ represents reserve load strength ratios of the columns;

w_i^{column} represents safety risk weight factors of the columns in the main body of the existing building;

φ_i^{beam} represents reserve load strength ratios of the beams;

w_i^{beam} represents safety risk weight factors of the beams in the main body of the existing building;

φ_i^{rod} represents reserve load strength ratios of the truss rods;

w_i^{rod} represents safety risk weight factors of the truss rods in the main body of the existing building;

i represents the i -th structural member of the columns, the beams and the truss rods in the main body of the existing building and is a natural number greater than 0; and

N is the total number of the columns, the beams and the truss rods in the main body of the existing building and is a natural number greater than 0,

wherein the reserve load strength ratio of each of the columns, the beams and the truss rods is calculated according to the formula:

$$\varphi_i = \frac{\sigma_{pi}^r - \sigma_i^r}{\sigma_{pi}^r - [\sigma_i^r]}$$

where:

φ_i is the reserve load strength ratio;

σ_{pi}^r is an ultimate load strength;

σ_i^r is an actual load strength;

$\sigma_{pi}^r - \sigma_i^r$ is an ultimate reserve load strength;

$[\sigma_i^r]$ is a nominal allowable load strength;

$\sigma_{pi}^r - [\sigma_i^r]$ is a nominal allowable reserve load strength;

r denotes a “real structural member”;

p denotes an “ultimate limit of load strength”; and

when $\sigma_i^r < [\sigma_i^r]$, φ_i is equal to 1,

wherein the safety risk weight factor of each of the columns, the beams and the truss rods in the main body of the existing building is calculated according to the formulae:

$$w_i^{\text{column}} = \frac{|\sigma_i^{\text{column}}|}{\sum_{i=1}^N |\sigma_i^{\text{column}}|},$$

where σ_i^{column} is load strength of the i -th column against an axial force;

$$w_i^{\text{beam}} = \frac{|\sigma_i^{\text{beam}}|}{\sum_{i=1}^N |\sigma_i^{\text{beam}}|},$$

where σ_i^{beam} is load strength of the i -th beam against a bending moment; and

$$w_i^{\text{rod}} = \frac{|\sigma_i^{\text{rod}}|}{\sum_{i=1}^N |\sigma_i^{\text{rod}}|},$$

where σ_i^{rod} is load strength of the i -th truss rod against an axial force,

and wherein if the reserve load strength ratio of the main body is less than 1, then the existing building is determined to be associated with a safety risk, which is classified into one of the following classes:

Class I: when $X \leq \varphi < 1$;

Class II: when $Y \leq \varphi < X$; and

Class III: $\varphi < Y$,

where X is a boundary value between Classes I and II, and Y is a boundary value between Classes II and III.

Additionally, in this method provided in the present invention, if $X=0.85$ and $Y=0.6$, then the safety risk may be classified

into Class I when $0.85 \leq \varphi < 1$, or

into Class II when $0.6 \leq \varphi < 0.86$, or

into Class III when $\varphi < 0.6$.

Additionally, in this method provided in the present invention, if $X=0.8$ and $Y=0.7$, then the safety risk may be classified

into Class I when $0.8 \leq \varphi < 1.0$, or

into Class II when $0.7 \leq \varphi < 0.8$, or

into Class III when $\varphi < 0.7$.

Additionally, in this method provided in the present invention, a loading condition and corresponding load strength of the columns, beams and truss rods in the main body of the existing building may be determined through monitoring structural deformation of the existing building in real time, the load strength being reflected in the finite element model, and structural reanalysis may be performed on the existing building using the finite element model to determine a real-time reserve load strength ratio of the

main body of the existing building.

Additionally, in this method provided in the present invention, monitoring structural deformation of the existing building may comprise monitoring angles of inclinations of walls with respect to a roof truss, displacement of walls relative to the roof truss and foundation settlement.

Compared to the prior art, in the method for assessing a safety risk in construction engineering of an existing building according to the present invention, the reserve load strength ratio of the main body of the existing building is used to assess whether the existing building is associated with a safety risk, and early warning is provided against such a structural safety risk in the construction engineering of the existing building. As such, process management and control of the construction engineering of the existing building is made possible, ensuring smooth progress of the construction engineering of the existing building.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic flow chart of a method for assessing a safety risk in construction engineering of an existing building according to an embodiment of the present invention; and

Figs. 2 to 3 are a schematic flow chart and a schematic block diagram a of a method for assessing a safety risk in construction engineering of an existing building according to another embodiment of the present invention.

DETAILED DESCRIPTION

The present invention will be described in detail below with reference to the accompanying drawings.

Referring to Fig. 1, embodiments of the present invention provide a method for

assessing a safety risk in construction engineering of an existing building, which includes the steps below.

Step 101: Creating a finite element model representing the structure of the existing building.

Step 102: Defining a main body of the existing building according to the finite element model. The main body includes, but is not limited to, columns, beams, truss rods and other structural members.

Step 103: Assessing a safety risk of the existing building using a reserve load strength ratio of the main body.

In Step 103, the reserve load strength ratio of the main body can be calculated according to formula (1) below:

$$\varphi = \frac{1}{3} \times (\sum_{i=1}^{N_{\text{column}}} \varphi_i^{\text{column}} w_i^{\text{column}} + \sum_{i=1}^{N_{\text{beam}}} \varphi_i^{\text{beam}} w_i^{\text{beam}} + \sum_{i=1}^{N_{\text{rod}}} \varphi_i^{\text{rod}} w_i^{\text{rod}}) \quad (1)$$

Where:

φ represents the reserve load strength ratio of the main body of the existing building;

$\varphi_i^{\text{column}}$ represents reserve load strength ratios of the columns;

w_i^{column} represents safety risk weight factors of the columns in the main body of the existing building;

φ_i^{beam} represents reserve load strength ratios of the beams;

w_i^{beam} represents safety risk weight factors of the beams in the main body of the existing building;

φ_i^{rod} represents reserve load strength ratios of the truss rods;

w_i^{rod} represents safety risk weight factors of the truss rods in the main body of the existing building;

i represents the i -th structural member of the columns, beams and truss rods in the

main body of the existing building and is a natural number greater than 0; and

N is the total number of the columns, beams and truss rods in the main body of the existing building and is a natural number greater than 0.

The reserve load strength ratios $\varphi_i^{\text{column}}$, φ_i^{beam} , φ_i^{rod} of the columns, beams and truss rods in formula (1) above can be calculated according to formula (2) below. That is, the reserve load strength ratio of any of the columns, beams and truss rods in the main body of the existing building can be obtained by substituting the following parameters of the structural member into formula (2) below:

$$\varphi_i = \frac{\sigma_{pi}^r - \sigma_i^r}{\sigma_{pi}^r - [\sigma_i^r]} \quad (2)$$

Where:

φ_i is the reserve load strength ratio;

σ_{pi}^r is ultimate load strength;

σ_i^r is actual load strength;

$\sigma_{pi}^r - \sigma_i^r$ is ultimate reserve load strength;

$[\sigma_i^r]$ is nominal allowable load strength;

$\sigma_{pi}^r - [\sigma_i^r]$ is nominal allowable reserve load strength;

r denotes “real structural member”;

p denotes “ultimate limit of load strength”; and

when $\sigma_i^r < [\sigma_i^r]$, φ_i is equal to 1.

The safety risk weight factors w_i^{column} , w_i^{beam} , w_i^{rod} of the columns, beams and truss rods in the main body of the existing building in formula (1) above can be calculated according to formulas (3) to (5) below:

$$w_i^{\text{column}} = \frac{|\sigma_i^{\text{column}}|}{\sum_{i=1}^N |\sigma_i^{\text{column}}|} \quad (3)$$

where σ_i^{column} is load strength of the i -th column against an axial force;

$$w_i^{\text{beam}} = \frac{|\sigma_i^{\text{beam}}|}{\sum_{i=1}^N |\sigma_i^{\text{beam}}|} \quad (4)$$

where σ_i^{beam} is load strength of the i -th beam against a bending moment; and

$$w_i^{\text{rod}} = \frac{|\sigma_i^{\text{rod}}|}{\sum_{i=1}^N |\sigma_i^{\text{rod}}|} \quad (5)$$

where σ_i^{rod} is load strength of the i -th truss rod against an axial force.

Referring to Figs. 2 and 3, the method for assessing a safety risk in construction engineering of an existing building according to embodiments of the present invention may further include the step below.

Step 104: Determining a loading condition and corresponding load strength of the columns, beams and truss rods in the main body of the existing building through monitoring structural deformation of the existing building in real time, reflecting the load strength in the finite element model, and performing structural reanalysis of the existing building using the finite element model to derive a real-time reserve load strength ratio of the main body of the existing building according to formula (1) in Step 103.

For example, through monitoring structural deformation of the existing building in real time, under a certain structural deformation condition of the existing building, the ultimate load strength σ_{pi}^r , the actual load strength σ_i^r , the nominal allowable load strength $[\sigma_i^r]$ and other parameters can be measured using technical means well known in the art. The structural reanalysis means reanalysis and recalculation of the reserve load strength ratio of the main body of the existing building based on the load strength of the various structural members under the structural deformation condition of the existing building.

In the method for assessing a safety risk in construction engineering of an existing building according to embodiments of the present invention, since the reserve load strength ratio can be calculated in real time based on real-time monitoring, timely assessment on safety risk is made possible in the construction engineering of the

existing building, enabling rapid determination of whether there is a safety risk associated with the existing building.

Monitoring structural deformation of the existing building may include, but is not limited to, monitoring angles of inclinations of walls with respect to a roof truss, displacement of walls relative to the roof truss and foundation settlement. The structural deformation can be measured using technical means well known in the art. For example, the angles of inclination can be measured using an inclinometer; the displacement can be measured using a distance sensor; and so forth. The structural deformation of the existing building can be measured by additional use of a crack meter, a static level gauge and other measuring instruments well known in the art.

According to embodiments of the present invention, the finite element model can intuitively reflect structural deformation of the existing building and the loading condition and corresponding load strength values of the various structural members in the main body thereof, thus facilitating process management and control of construction engineering of the existing building by construction operation managers.

In the method for assessing a safety risk in construction engineering of an existing building according to embodiments of the present invention, when the reserve load strength ratio of the main body is less than 1, it is determined that the existing building is associated with a safety risk. In this case, the construction operator may be prompted to take a risk countermeasure in the construction engineering of the existing building.

In the method for assessing a safety risk in construction engineering of an existing building according to embodiments of the present invention, the safety risk of the existing building may be classified into one of the following classes:

Class I: when $X \leq \varphi < 1$;

Class II: when $Y \leq \varphi < X$; and

Class III: when $\varphi < Y$.

X is a boundary value between Classes I and II, and Y is a boundary value between Classes II and III.

For example, if $X=0.85$ and $Y=0.6$, then the safety risk is classified into

Class I when $0.85 \leq \varphi < 1$, or

Class II when $0.6 \leq \varphi < 0.86$, or

Class III when $\varphi < 0.6$.

If $X=0.8$ and $Y=0.7$, then the safety risk is classified into

Class I when $0.8 \leq \varphi < 1.0$, or

Class II when $0.7 \leq \varphi < 0.8$, or

Class III when $\varphi < 0.7$.

Embodiments of the present invention are not limited to three safety risk classes or the aforementioned particular values of the boundary values X and Y, and these may vary depending on the natural geological environment where the existing building is in. Classifying the safety risk of the existing building into one of several classes can facilitate the adoption of different temporary protection measures for the respective safety risk classes.

According to embodiments of the present invention, a database of reserve load strength ratios of the main body of the existing building calculated under different structural deformation conditions of the building may be established, and structural deformation may be plotted versus the reserve load strength ratio by linear interpolation, thus more intuitively showing the relationship between structural deformation and the reserve load strength ratio. From the plot, boundary values between safety risk classes for the construction engineering of the existing building can be identified.

According to embodiments of the present invention, the reserve load strength ratio of the main body of the existing building can reflect an overall reserve load strength

ratio of the existing building. The reserve load strength ratios of the various structural members that are closer to 1 will result in better structural safety performance and a reduced safety risk of the existing building.

According to embodiments of the present invention, a plurality of sets of monitored data can be chosen as initial calculation conditions for the various structural members in the main body of the existing building to derive a plurality of sets of reserve load strength ratios. After that, based on reserve load strength ratios of the various structural members under different monitored deformation conditions, the reserve load strength ratios of the structural members and the overall reserve load strength ratios of the existing building can be calculated. For these, a reserve strength ratio database can be then established for the main body of the existing building, which enables determination of appropriate reserve load strength ratios for given monitored data, reasonable inductive safety risk analysis of the entire structure and timely issuance of early warnings.

In the method for assessing a safety risk in construction engineering of an existing building according to embodiments of the present invention, the reserve load strength ratio of the main body of the existing building is used to assess whether the existing building is associated with a safety risk, and early warning is provided against such a structural safety risk in construction engineering of the existing building. As such, process management and control of the construction engineering of the existing building is made possible, ensuring smooth progress of the construction engineering of the existing building.

According to embodiments of the present invention, a structural safety risk associated with renovation or expansion of the existing building such as a historic building under protection is comprehensively assessed, and by the combined use of real-time monitored data and structural reanalysis, the main body of the existing building is

refined and modeled, and risk weights are effectively assigned to the main body of the existing building. In this way, comprehensive and scientific assessment on safety risk of the main body is achieved, and timely early warning can be provided against a safety risk of any structural member that may significantly affect the existing building. This is helpful in reasonable risk management and control in renovation and expansion of the existing building and ensures smooth progress of the construction engineering of the existing building.

The present invention is not limited to the foregoing particular embodiments. Any and all changes and modifications made within the spirit and scope of the present invention fall within the protection scope of the invention.

CLAIMS

1. A method for assessing a safety risk in construction engineering of an existing building, comprising:

creating a finite element model representing a structure of the existing building;

defining a main body of the existing building according to the finite element model, the main body comprising columns, beams and truss rods; and

assessing a safety risk of the existing building using a reserve load strength ratio of the main body,

wherein the reserve load strength ratio of the main body is calculated according to a formula:

$$\varphi = \frac{1}{3} \times (\sum_{i=1}^{N_{\text{column}}} \varphi_i^{\text{column}} w_i^{\text{column}} + \sum_{i=1}^{N_{\text{beam}}} \varphi_i^{\text{beam}} w_i^{\text{beam}} + \sum_{i=1}^{N_{\text{rod}}} \varphi_i^{\text{rod}} w_i^{\text{rod}}),$$

where:

φ is the reserve load strength ratio of the main body of the existing building;

$\varphi_i^{\text{column}}$ represents reserve load strength ratios of the columns;

w_i^{column} represents safety risk weight factors of the columns in the main body of the existing building;

φ_i^{beam} represents reserve load strength ratios of the beams;

w_i^{beam} represents safety risk weight factors of the beams in the main body of the existing building;

φ_i^{rod} represents reserve load strength ratios of the truss rods;

w_i^{rod} represents safety risk weight factors of the truss rods in the main body of the existing building;

i represents the i -th structural member of the columns, the beams and the truss rods in the main body of the existing building and is a natural number greater than 0;

and

N is the total number of the columns, the beams and the truss rods in the main body of the existing building and is a natural number greater than 0,

wherein the reserve load strength ratio of each of the columns, the beams and the truss rods is calculated according to the formula:

$$\varphi_i = \frac{\sigma_{pi}^r - \sigma_i^r}{\sigma_{pi}^r - [\sigma_i^r]}$$

where:

φ_i is the reserve load strength ratio;

σ_{pi}^r is an ultimate load strength;

σ_i^r is an actual load strength;

$\sigma_{pi}^r - \sigma_i^r$ is an ultimate reserve load strength;

$[\sigma_i^r]$ is a nominal allowable load strength;

$\sigma_{pi}^r - [\sigma_i^r]$ is a nominal allowable reserve load strength;

r denotes a real structural member;

p denotes an ultimate limit of load strength; and

when $\sigma_i^r < [\sigma_i^r]$, φ_i is equal to 1,

wherein the safety risk weight factor of each of the columns, the beams and the truss rods in the main body of the existing building is calculated according to a formulae:

$$w_i^{\text{column}} = \frac{|\sigma_i^{\text{column}}|}{\sum_{i=1}^N |\sigma_i^{\text{column}}|},$$

where σ_i^{column} is a load strength of an i -th column against an axial force;

$$w_i^{\text{beam}} = \frac{|\sigma_i^{\text{beam}}|}{\sum_{i=1}^N |\sigma_i^{\text{beam}}|},$$

where σ_i^{beam} is a load strength of an i -th beam against a bending moment; and

$$w_i^{\text{rod}} = \frac{|\sigma_i^{\text{rod}}|}{\sum_{i=1}^N |\sigma_i^{\text{rod}}|},$$

where σ_i^{rod} is a load strength of an i -th truss rod against an axial force,

wherein if the reserve load strength ratio of the main body is less than 1, then the existing building is determined to be associated with a safety risk,

which is classified into one of the following classes:

Class I: when $X \leq \varphi < 1$;

Class II: when $Y \leq \varphi < X$; and

Class III: $\varphi < Y$,

where X is a boundary value between Classes I and II, and Y is a boundary value between Classes II and III.

2. The method for assessing a safety risk in construction engineering of an existing building according to claim 1, wherein if $X=0.85$ and $Y=0.6$, then the safety risk is classified

into Class I when $0.85 \leq \varphi < 1$, or

into Class II when $0.6 \leq \varphi < 0.86$, or

into Class III when $\varphi < 0.6$.

3. The method for assessing a safety risk in construction engineering of an existing building according to claim 1, wherein if $X=0.8$ and $Y=0.7$, then the safety risk is classified

into Class I when $0.8 \leq \varphi < 1.0$, or

into Class II when $0.7 \leq \varphi < 0.8$, or

into Class III when $\varphi < 0.7$.

4. The method for assessing a safety risk in construction engineering of an existing building according to claim 1, wherein a loading condition and a corresponding load strength of the columns, beams and truss rods in the main body of the existing building

are determined through monitoring structural deformation of the existing building in real time, the load strength being reflected in the finite element model, and a structural reanalysis is performed on the existing building using the finite element model to determine a real-time reserve load strength ratio of the main body of the existing building.

5. The method for assessing a safety risk in construction engineering of an existing building according to claim 4, wherein monitoring structural deformation of the existing building comprises monitoring angles of inclinations of walls with respect to a roof truss, displacement of walls relative to the roof truss and foundation settlement.