[Document Type] CLAIMS

1. A method of evaluating a continuous beam including n, which is a natural number equal to or larger than two, beams which are disposed side by side in a longitudinal direction and of which end portions adjacent to each other in the longitudinal direction are semi-rigidly jointed to each other to be intermediate fulcrums, both ends of the entire continuous beam being a pair of end fulcrums, the method comprising:

a solution determination step of obtaining a plurality of bending moments at the intermediate fulcrums and the pair of end fulcrums and a plurality of rotation angles at the pair of end fulcrums based on given conditions,

wherein the given conditions include

a length and a bending stiffness of each of the n beams,

a plurality of rotational rigidities at the intermediate fulcrums and the pair of end fulcrums,

vertical loads acting on the n beams, and

a plurality of vertical displacements at the intermediate fulcrums and the pair of end fulcrums, and

wherein, in a case where the plurality of bending moments and the plurality of rotation angles are defined as a plurality of unknown quantities and a relational expression between the plurality of rotational rigidities, the plurality of bending moments, and the plurality of rotation angles and a relational expression between the plurality of vertical displacements are defined as a plurality of first boundary conditions having the same number as the number of the plurality of unknown quantities, in the solution determination step, the bending moments and a deflection distribution of the continuous beam are evaluated by solving the plurality of unknown quantities such that

the plurality of unknown quantities satisfy the plurality of first boundary conditions.

2. The method of evaluating a continuous beam according to claim 1,

wherein the solution determination step includes

a first design step of giving design values including the plurality of vertical displacements,

a second design step of giving second boundary conditions to the pair of end fulcrums according to joint states at the pair of end fulcrums,

a temporary design step of giving temporary design values including the bending moments acting on the pair of end fulcrums and the intermediate fulcrums according to the joint state at the pair of end fulcrums,

a solution calculation step of calculating, based on the temporary design values, calculation values including calculation results of the vertical displacements at the intermediate fulcrums so as to satisfy the plurality of first boundary conditions and the plurality of second boundary conditions,

a residual calculation step of obtaining a displacement residual which is a residual between the design value and the calculation value, and

a determination step of determining whether or not the displacement residual is smaller than a predetermined threshold value.

3. The method of evaluating a continuous beam according to claim 2,

wherein the solution determination step further includes a storage step of storing the temporary design values after the temporary design step,

wherein, in the determination step, in a case where the displacement residual is equal to or larger than the threshold value, giving other new temporary design values in the temporary design step instead of the temporary design values stored in the storage step and performing the solution calculation step, the residual calculation step, and the

determination step based on the new temporary design values are performed as a set, and the set is repeatedly performed until it is determined in the determination step that the displacement residual is smaller than the threshold value, and

wherein the bending moments of the temporary design values in a case where it is determined in the determination step that the displacement residual is smaller than the threshold value are defined as the bending moments acting on the intermediate fulcrums, and the plurality of rotation angles are obtained based on the bending moments.

4. The method of evaluating a continuous beam according to claim 2 or 3,

wherein, in the solution calculation step, for a natural number i equal to or larger than one and equal to or smaller than n, among the n beams, for an i-th beam from a first end fulcrum which is one of the end fulcrums of the continuous beam toward a second end fulcrum which is the other of the end fulcrums of the continuous beam,

the vertical displacements δ_{0i} (m) of the i-th beam at the intermediate fulcrums or the end fulcrums on a first end fulcrum side are defined as the given conditions, and

calculation results $\delta_{i,\,calc}$ (m) of the vertical displacements of the i-th beam at the intermediate fulcrums or the end fulcrums on a second end fulcrum side are calculated by Expression (9) obtained based on Expression (1) to Expression (8), the calculation results being included in the calculation values, and

wherein, in the residual calculation step, for a natural number i equal to or larger than one and equal to or smaller than (n-1), in a case where a residual between the vertical displacements $\delta_{0(i+1)}$ of the (i+1)-th beam at the intermediate fulcrums on the first end fulcrum side and the calculation results $\delta_{i,\,calc}$ of the vertical displacements of the i-th beam at the intermediate fulcrums on the second end fulcrum side is defined as

an i-th residual,

an intermediate residual which is a sum from the first residual to the (n-1)-th residual is calculated,

a residual at the second end fulcrum is calculated, the residual at the second end fulcrum being a residual between the vertical displacements δ_n at the second end fulcrum which are the given conditions and the calculation results $\delta_{n,\,calc}$ of the vertical displacements of an n-th beam at the second end fulcrum, and

the displacement residual is calculated, the displacement residual being a sum of the intermediate residual and the residual at the second end fulcrum,

$$V_{jl,i} = \frac{M_{j,i-1} - M_{j,i}}{L_i} + \frac{w_i \cdot L_i}{2} \quad \cdots (1)$$

$$V_{jr,i} = w_i \cdot L_i - V_{jl,i} = \frac{w_i \cdot L_i}{2} - \frac{M_{j,i-1} - M_{j,i}}{L_i} \quad \cdots (2)$$

$$x_{h,i} = \frac{1}{w_i}\left\{V_{jl,i} - \sqrt{{V_{jl,i}}^2 - 2w_i \cdot M_{j,i-1}}\right\} \quad \cdots (3)$$

$$x_{s,i} = \frac{1}{w_i}\left\{V_{jl,i} + \sqrt{{V_{jl,i}}^2 - 2w_i \cdot M_{j,i-1}}\right\} \quad \cdots (4)$$

$$f_{(x_i)} = \left(\frac{M_{j,i-1} - M_{j,i}}{L_i} + \frac{w_i \cdot L_i}{2}\right) \cdot \frac{{x_i}^2}{2} - \frac{w_i \cdot {x_i}^3}{6} - M_{j,i-1} \cdot x_i \quad \cdots (5)$$

$$F_{(x_i)} = \left(\frac{M_{j,i-1} - M_{j,i}}{L_i} + \frac{w_i \cdot L_i}{2}\right) \cdot \frac{{x_i}^3}{6} - \frac{w_i \cdot {x_i}^4}{24} - \frac{M_{j,i-1}}{2} \cdot {x_i}^2 \quad \cdots (6)$$

$$\varphi_{c(x_i)}\big|_{x_i=L_i} = -\left(\frac{1}{EI_{h,i}} - \frac{1}{EI_{s,i}}\right)\left(f_{(x_i)}\big|_{x_i=x_{h,i}} - f_{(x_i)}\big|_{x_i=x_{s,i}}\right) - \frac{1}{EI_{h,i}} f_{(x_i)}\big|_{x_i=L_i} + \varphi_{0i} \quad \cdots (7)$$

$$\varphi_{0i} = \left(\frac{1}{S_{jr,i-1}} + \frac{1}{S_{jl,i}}\right) M_{j,i-1} + \varphi_{c(x_{i-1})}\big|_{x_{i-1}=L_{i-1}} \quad \cdots (8)$$

$$\delta_{i,calc} = -\left(\frac{1}{EI_{h,i}} - \frac{1}{EI_{s,i}}\right)\left\{F_{(x_i)}\big|_{x_i=x_{h,i}} - F_{(x_i)}\big|_{x_i=x_{s,i}} + f_{(x_i)}\big|_{x_i=x_{h,i}}\left(L_i - x_{h,i}\right) - f_{(x_i)}\big|_{x_i=x_{s,i}}\left(L_i - x_{s,i}\right)\right\} - \frac{1}{EI_{h,i}} F_{(x_i)}\big|_{x_i=L_i} + \varphi_{0i} \cdot L_i + \delta_{0i} \quad \cdots (9)$$

here, for a natural number i equal to or larger than one and equal to or smaller than n, a length of the i-th beam is defined as L_i (m), a coordinate of the i-th beam is defined as x_i (m) in a case where an end of the i-th beam on the first end fulcrum side is

set as an origin and a direction from the first end fulcrum toward the second end fulcrum is set as positive, a vertical load acting on the i-th beam is defined as w_i (N/m), a rotational rigidity of the end of the i-th beam on the first end fulcrum side is defined as $S_{jl,\,i}$ (Nm/rad), a rotational rigidity of an end of the i-th beam on the second end fulcrum side is defined as $S_{jr,\,i}$ (Nm/rad), a bending stiffness of sagging bending of the i-th beam is defined as $EI_{s,\,i}$ (Nm^2), a bending stiffness of hogging bending of the i-th beam is defined as $EI_{h,\,i}$ (Nm^2), and a bending moment of the i-th beam at the intermediate fulcrums or the end fulcrums on the second end fulcrum side is defined as $M_{j,\,i}$ (Nm), and a bending moment $M_{j,\,0}$ (Nm) of a first beam at the first end fulcrum is 0 in a case where the first end fulcrum is pin-jointed and is an unknown quantity in a case where the first end fulcrum is rigidly jointed or semi-rigidly jointed, and a rotation angle φ_{01} (rad) of the first beam at the first end fulcrum is 0 in a case where the first end fulcrum is rigidly jointed and is an unknown quantity in a case where the first end fulcrum is pin-jointed or semi-rigidly jointed, the bending moment $M_{j,\,0}$ (Nm) and the rotation angle φ_{01} (rad) of the first beam being included in the second boundary conditions.

5. A program for an evaluation apparatus that evaluates a continuous beam including n, which is a natural number equal to or larger than two, beams which are disposed side by side in a longitudinal direction and of which end portions adjacent to each other in the longitudinal direction are semi-rigidly jointed to each other to be intermediate fulcrums, both ends of the entire continuous beam being a pair of end fulcrums, the program causing the evaluation apparatus to function as:

a solution determination unit that obtains a plurality of bending moments at the intermediate fulcrums and the pair of end fulcrums and a plurality of rotation angles at the pair of end fulcrums based on given conditions,

wherein the given conditions include

a length and a bending stiffness of each of the n beams,

a plurality of rotational rigidities at the intermediate fulcrums and the pair of end fulcrums,

vertical loads acting on the n beams, and

a plurality of vertical displacements at the intermediate fulcrums and the pair of end fulcrums, and

wherein, in a case where the plurality of bending moments and the plurality of rotation angles are defined as a plurality of unknown quantities and a relational expression between the plurality of rotational rigidities, the plurality of bending moments, and the plurality of rotation angles and a relational expression between the plurality of vertical displacements are defined as a plurality of first boundary conditions having the same number as the number of the plurality of unknown quantities,

the solution determination unit evaluates the bending moments and a deflection distribution of the continuous beam by solving the plurality of unknown quantities such that the plurality of unknown quantities satisfy the plurality of first boundary conditions.