[Document Type] CLAIMS

1. A beam joining structure comprising:

a first support member and a second support member forming a pair;

a beam which includes a first joint portion and a second joint portion respectively joined to the first support member and the second support member at both end portions, and is spanned between the first support member and the second support member by being joined via the first joint portion and the second joint portion in a semi-rigid manner in a state where flexural stiffness against sagging bending and the flexural stiffness against hogging bending are different from each other; and

a reinforcing member which is disposed to protrude in a direction from the first support member toward the second support member and reinforces the beam by withstanding at least a part of tensile stress generated in the beam by the hogging bending of the beam,

wherein a protruding length x of the reinforcing member from a virtual plane which is perpendicular to a member axis direction of the beam and includes the first joint portion is equal to or more than a first distance and equal to or less than a second distance,

the first distance is a distance from the first joint portion to an inflection point at which a bending moment distribution of the beam changes from the hogging bending to the sagging bending in a case where a two-point concentrated load acts on the beam, and

the second distance is, on an assumption that a reference beam in which both end portions are joined to the first support member and the second support member in a rigid manner and the flexural stiffness against the hogging bending and the flexural stiffness against the sagging bending are the same is used as the beam, a distance from the first joint portion to an inflection point at which a bending moment distribution of the reference beam changes from the hogging bending to the sagging bending in a case where a two-point concentrated load acts on the reference beam, and

the protruding length x of the reinforcing member satisfies Formula (1) in the unit of m,

$$x_h \leq x \leq \frac{2l}{9} \quad \cdots \quad (1)$$

here, $x_h$ is obtained by Formula (2A),

$$x_h = \frac{1}{\frac{1}{EI_h} - \frac{1}{EI_s}} \left\{ -\left( \frac{l}{2EI_s} + \frac{1}{K} \right) + \sqrt{\left( \frac{l}{2EI_s} + \frac{1}{K} \right)^2 + \frac{2l^2}{9EI_s} \left( \frac{1}{EI_h} - \frac{1}{EI_s} \right)} \right\} \quad \cdots \quad (2A)$$

here, each of variables is as follows,

$EI_h$: the flexural stiffness against the hogging bending of the beam ($kNm^2$)

$EI_s$: the flexural stiffness against the sagging bending of the beam ($kNm^2$)

l: a length of the beam (m)

K: a rotational stiffness of the first joint portion of the end portion of the beam (kNm/rad).

2. A beam joining structure comprising:

a first support member and a second support member forming a pair;

a beam which includes a first joint portion and a second joint portion respectively joined to the first support member and the second support member at both end portions, and is spanned between the first support member and the second support member by being joined via the first joint portion and the second joint portion in a semi-rigid manner in a state where flexural stiffness against sagging bending and the flexural stiffness against hogging bending are the same; and

a reinforcing member which is disposed to protrude in a direction from the first support member toward the second support member and reinforces the beam by withstanding at least a part of tensile stress generated in the beam by the hogging bending of the beam,

wherein a protruding length x of the reinforcing member from a virtual plane which is perpendicular to a member axis direction of the beam and includes the first joint portion is equal to or more than a first distance and equal to or less than a second distance,

the first distance is a distance from the first joint portion to an inflection point at which a bending moment distribution of the beam changes from the hogging bending to the sagging bending in a case where a two-point concentrated load acts on the beam, and

the second distance is, on an assumption that a reference beam in which both end portions are joined to the first support member and the second support member in a rigid manner and the flexural stiffness against the hogging bending and the flexural stiffness against the sagging bending are the same is used as the beam, a distance from the first joint portion to an inflection point at which a bending moment distribution of the reference beam changes from the hogging bending to the sagging bending in a case

where a two-point concentrated load acts on the reference beam, and

the protruding length x of the reinforcing member satisfies Formula (1) in the unit of m,

$$x_h \leq x \leq \frac{2l}{9} \quad \cdots \quad (1)$$

here, $x_h$ is obtained by Formula (2B),

$$x_h = \frac{2l}{9\left(1+\frac{2EI}{Kl}\right)} \quad \cdots \quad (2B)$$

here, each of variables is as follows,

EI: the flexural stiffness against the hogging bending or the sagging bending of the beam ($kNm^2$)

l: a length of the beam (m)

K: a rotational stiffness of the first joint portion of the end portion of the beam (kNm/rad).

3. A beam joining structure comprising:

a first support member and a second support member forming a pair;

a beam which includes a first joint portion and a second joint portion respectively joined to the first support member and the second support member at both end portions, and is spanned between the first support member and the second support member by being joined via the first joint portion and the second joint portion in a rigid manner in a state where flexural stiffness against sagging bending and the flexural stiffness against hogging bending are different from each other; and

a reinforcing member which is disposed to protrude in a direction from the first support member toward the second support member and reinforces the beam by withstanding at least a part of tensile stress generated in the beam by the hogging bending of the beam,

wherein a protruding length x of the reinforcing member from a virtual plane which is perpendicular to a member axis direction of the beam and includes the first joint portion is equal to or more than a first distance and equal to or less than a second distance,

the first distance is a distance from the first joint portion to an inflection point at which a bending moment distribution of the beam changes from the hogging bending to the sagging bending in a case where a two-point concentrated load acts on the beam, and

the second distance is, on an assumption that a reference beam in which both

end portions are joined to the first support member and the second support member in a rigid manner and the flexural stiffness against the hogging bending and the flexural stiffness against the sagging bending are the same is used as the beam, a distance from the first joint portion to an inflection point at which a bending moment distribution of the reference beam changes from the hogging bending to the sagging bending in a case where a two-point concentrated load acts on the reference beam,

wherein the protruding length x of the reinforcing member satisfies Formula (1) in the unit of m,

$$x_h \leq x \leq \frac{2l}{9} \quad \cdots \quad (1)$$

here, $x_h$ is obtained by Formula (2A'),

$$x_h = \frac{1}{\frac{1}{EI_h} - \frac{1}{EI_s}} \left\{ -\frac{l}{2EI_s} + \sqrt{\left(\frac{l}{2EI_s}\right)^2 + \frac{2l^2}{9EI_s}\left(\frac{1}{EI_h} - \frac{1}{EI_s}\right)} \right\} \quad \cdots \quad (2A')$$

here, each of variables is as follows,

$EI_h$: the flexural stiffness against the hogging bending of the beam ($kNm^2$)

$EI_s$: the flexural stiffness against the sagging bending of the beam ($kNm^2$)

l: a length of the beam (m).

4. A designing method of a beam joining structure, the beam joining structure including

a first support member and a second support member forming a pair,

a beam which includes a first joint portion and a second joint portion respectively joined to the first support member and the second support member at both end portions, and is spanned between the first support member and the second support member by being joined via the first joint portion and the second joint portion in a semi-rigid manner in a state where flexural stiffness against sagging bending and the flexural stiffness against hogging bending are different from each other, and

a reinforcing member which is disposed to protrude in a direction from the first support member toward the second support member and reinforces the beam by withstanding at least a part of tensile stress generated in the beam by the hogging bending of the beam,

the designing method comprising:

calculating a first distance which is a distance from the first joint portion to an inflection point at which a bending moment distribution of the beam changes from the hogging bending to the sagging bending in a case where a two-point concentrated load

acts on the beam;

calculating, on an assumption that a reference beam in which both end portions are joined to the first support member and the second support member in a rigid manner and the flexural stiffness against the hogging bending and the flexural stiffness against the sagging bending are the same is used as the beam, a second distance which is the distance from the first joint portion to an inflection point at which a bending moment distribution of the reference beam changes from the hogging bending to the sagging bending in a case where a two-point concentrated load acts on the reference beam; and

setting a protruding length x of the reinforcing member from a virtual plane which is perpendicular to a member axis direction of the beam and includes the first joint portion to be equal to or more than the first distance and equal to or less than the second distance,

and

the protruding length x of the reinforcing member satisfies Formula (1) in the unit of m,

$$x_h \leq x \leq \frac{2l}{9} \quad \cdots \quad (1)$$

here, $x_h$ is obtained by Formula (2A),

$$x_h = \frac{1}{\frac{1}{EI_h} - \frac{1}{EI_s}} \left\{ -\left( \frac{l}{2EI_s} + \frac{1}{K} \right) + \sqrt{\left( \frac{l}{2EI_s} + \frac{1}{K} \right)^2 + \frac{2l^2}{9EI_s} \left( \frac{1}{EI_h} - \frac{1}{EI_s} \right)} \right\} \quad \cdots \quad (2A)$$

here, each of variables is as follows,

$EI_h$: the flexural stiffness against the hogging bending of the beam ($kNm^2$)

$EI_s$: the flexural stiffness against the sagging bending of the beam ($kNm^2$)

l: a length of the beam (m)

K: a rotational stiffness of the first joint portion of the end portion of the beam (kNm/rad).

5. A designing method of a beam joining structure, the beam joining structure including

a first support member and a second support member forming a pair,

a beam which includes a first joint portion and a second joint portion respectively joined to the first support member and the second support member at both end portions, and is spanned between the first support member and the second support member by being joined via the first joint portion and the second joint portion in a semi-rigid manner in a state where flexural stiffness against sagging bending and the flexural

stiffness against hogging bending are the same, and

a reinforcing member which is disposed to protrude in a direction from the first support member toward the second support member and reinforces the beam by withstanding at least a part of tensile stress generated in the beam by the hogging bending of the beam,

the designing method comprising:

calculating a first distance which is a distance from the first joint portion to an inflection point at which a bending moment distribution of the beam changes from the hogging bending to the sagging bending in a case where a two-point concentrated load acts on the beam;

calculating, on an assumption that a reference beam in which both end portions are joined to the first support member and the second support member in a rigid manner and the flexural stiffness against the hogging bending and the flexural stiffness against the sagging bending are the same is used as the beam, a second distance which is the distance from the first joint portion to an inflection point at which a bending moment distribution of the reference beam changes from the hogging bending to the sagging bending in a case where a two-point concentrated load acts on the reference beam; and

setting a protruding length x of the reinforcing member from a virtual plane which is perpendicular to a member axis direction of the beam and includes the first joint portion to be equal to or more than the first distance and equal to or less than the second distance,

and

the protruding length x of the reinforcing member satisfies Formula (1) in the unit of m,

$$x_h \leq x \leq \frac{2l}{9} \quad \cdots \quad (1)$$

here, $x_h$ is obtained by Formula (2B),

$$x_h = \frac{2l}{9\left(1+\frac{2EI}{Kl}\right)} \quad \cdots \quad (2B)$$

here, each of variables is as follows,

EI: the flexural stiffness against the hogging bending or the sagging bending of the beam ($kNm^2$)

l: a length of the beam (m)

K: a rotational stiffness of the first joint portion of the end portion of the beam (kNm/rad).

6. A designing method of a beam joining structure, the beam joining structure including

a first support member and a second support member forming a pair,

a beam which includes a first joint portion and a second joint portion respectively joined to the first support member and the second support member at both end portions, and is spanned between the first support member and the second support member by being joined via the first joint portion and the second joint portion in a rigid manner in a state where flexural stiffness against sagging bending and the flexural stiffness against hogging bending are different from each other, and

a reinforcing member which is disposed to protrude in a direction from the first support member toward the second support member and reinforces the beam by withstanding at least a part of tensile stress generated in the beam by the hogging bending of the beam,

the designing method comprising:

calculating a first distance which is a distance from the first joint portion to an inflection point at which a bending moment distribution of the beam changes from the hogging bending to the sagging bending in a case where a two-point concentrated load acts on the beam;

calculating, on an assumption that a reference beam in which both end portions are joined to the first support member and the second support member in a rigid manner and the flexural stiffness against the hogging bending and the flexural stiffness against the sagging bending are the same is used as the beam, a second distance which is the distance from the first joint portion to an inflection point at which a bending moment distribution of the reference beam changes from the hogging bending to the sagging bending in a case where a two-point concentrated load acts on the reference beam; and

setting a protruding length x of the reinforcing member from a virtual plane which is perpendicular to a member axis direction of the beam and includes the first joint portion to be equal to or more than the first distance and equal to or less than the second distance,

wherein the protruding length x of the reinforcing member satisfies Formula (1) in the unit of m,

$$x_h \leq x \leq \frac{2l}{9} \quad \cdots \quad (1)$$

here, $x_h$ is obtained by Formula (2A'),

$$x_h = \frac{1}{\frac{1}{EI_h} - \frac{1}{EI_s}} \left\{ -\frac{l}{2EI_s} + \sqrt{\left(\frac{l}{2EI_s}\right)^2 + \frac{2l^2}{9EI_s}\left(\frac{1}{EI_h} - \frac{1}{EI_s}\right)} \right\} \quad \cdots \quad (2A')$$

here, each of variables is as follows,

$EI_h$: the flexural stiffness against the hogging bending of the beam ($kNm^2$)

$EI_s$: the flexural stiffness against the sagging bending of the beam ($kNm^2$)

l: a length of the beam (m).

7. A manufacturing method of a beam joining structure designed based on the designing method of a beam joining structure according to any one of claims 4 to 6, the manufacturing method comprising:

joining the beam to the first support member and the second support member; and

arranging the reinforcing member to have the set protruding length x.