

[Document Type] Specification

[Title of the Invention] METHOD OF DESIGNING FIRE RESISTANT
STRUCTURE, METHOD OF CONSTRUCTING FIRE RESISTANT STRUCTURE,
AND FIRE RESISTANT STRUCTURE

[Technical Field of the Invention]

[0001]

The present invention relates to a method of designing a fire resistant structure,
a method of constructing a fire resistant structure, and a fire resistant structure.

Priority is claimed on Japanese Patent Application No. 2018-221046, filed
November 27, 2018, the content of which is incorporated herein by reference.

[Related Art]

[0002]

In the related art, steel framed structures are known (see, for example, Non-
Patent Document 1). Steel framed structures are configured by connecting columns
and beams to each other and supporting a floor (slab) on the beams. The floor is
formed in a rectangular shape having a plurality of corner portions in a plan view. The
columns support each of the plurality of corner portions of the floor from below.

In structures, there may be cases where columns and beams of a steel framed
structure are subjected to a fireproof coating in order to improve fire resistant
performance. A column subjected to a fireproof coating becomes a protected column
with fireproof coating. A beam subjected to a fireproof coating becomes a protected
beam with fireproof coating.

[0003]

When a fire occurs in a structure, the temperature of columns and beams rises.
However, protected columns with fireproof coating and protected beams with fireproof

coating maintain a certain degree of stiffness and strength even when their respective temperatures rise. Therefore, the protected columns with fireproof coating and the protected beams with fireproof coating can support a floor even if there is a fire. On the other hand, columns and beams that are not subjected to a fireproof coating and columns and beams with a reduced fireproof coating compared to the protected columns with fireproof coating and the protected beams with fireproof coating lose stiffness and strength if there is a fire. If there is a fire, there may be cases where such stiffness and strength are considered to be reduced. Fire resistant performance is reduced in structures with columns, beams, and the like that are not subjected to a fireproof coating.

Since it takes a lot of effort to subject the columns and beams to the fireproof coating, it is desired to omit the fireproof coating.

[0004]

In general, a structure is composed of columns, beams, slab, and the like. The slab includes a tensile force transmitting member. For example, the tensile force transmitting member is a reinforcing bar. The structure becomes a fire resistant structure by subjecting the column to a fireproof coating to obtain a protected column with fireproof coating or by subjecting the beam to a fireproof coating to obtain a protected beam with fireproof coating. The slab is partitioned by columns and beams into a rectangular floor portion having a plurality of corner portions in plan view.

[0005]

As illustrated in FIG. 31, in a method of designing a fire resistant structure for designing a fire resistant structure 300 disclosed in Patent Document 1, a beam member 303 is set to be connected between a protected column member with fireproof coating 301 and a protected column member with reduced fireproof coating 302. In FIG. 31

and below, columns and beams subjected to a fireproof coating without reducing the fireproof coating are hatched.

The protected column member with fireproof coating 301 is a column member subjected to a fireproof coating. The protected column member with reduced fireproof coating 302 is a column member having a reduced fireproof coating compared to the protected column member with fireproof coating 301.

In a plan view of the fire resistant structure 300, a plurality of protected column members with fireproof coating 301 and a plurality of protected column members with reduced fireproof coating 302 are disposed side by side at intervals in each of a width direction E1 and a depth direction E2. The plurality of protected column members with fireproof coating 301 and the plurality of protected column members with reduced fireproof coating 302 are disposed in a grid pattern as a whole. At this time, the column members adjacent to the protected column members with reduced fireproof coating 302 in the width direction E1 and the depth direction E2 are disposed so as to be the protected column members with fireproof coating 301. The beam members 303 connect the plurality of protected column members with fireproof coating 301 and the plurality of protected column members with reduced fireproof coating 302 disposed in a grid pattern.

[0006]

A composite slab 304 is placed on a plurality of the beam members 303. Although not illustrated, the composite slab 304 has a concrete, a deck plate, and a reinforcing bar (tensile force transmitting member). The deck plate is fixed to the upper surface of the beam member 303 by driving tack joints, bolt joints, or the like.

In the fire resistant structure 300 configured as described above, the protected column member with fireproof coating 301 can maintain stiffness and strength not only

when the outside air temperature is a normal temperature but also if there is a fire. On the other hand, the protected column member with reduced fireproof coating 302 can maintain stiffness and strength in normal times, but cannot maintain stiffness and strength if there is a fire. If there is a fire, the stiffness and strength of the protected column member with reduced fireproof coating 302 are considered to be lost.

[0007]

The fire resistant structure 300 if there is a fire is deformed as illustrated in FIGS. 32 and 33. In FIG. 32, the composite slab 304 is not illustrated. In FIG. 33, the protected column member with reduced fireproof coating 302 and the composite slab 304 after the deformation are shown by two-dot chain lines.

In FIG. 32, the composite slab 304 disposed on a centerline M1 connecting the adjacent protected column members with fireproof coating 301 is hereinafter referred to as a slab 304a on the line. The protected column members with fireproof coating 301, the protected column members with reduced fireproof coating 302, the beam members 303, and the composite slabs 304 are affected by gravity not only in normal times but also if there is a fire.

[0008]

Since the stiffness and strength of the protected column members with fireproof coating 301 can be maintained if there is a fire, as illustrated in FIGS. 32 and 33, the position of the slab 304a on the line in an up-down direction E3 is maintained even if there is a fire. Contrary to this, since the protected column member with reduced fireproof coating 302 loses its stiffness and strength if there is a fire, the protected column member with reduced fireproof coating 302 moves downward (bends) as shown by two-dot chain lines in FIG. 33.

Since the positions of portions other than the slab 304a on the line in the up-

down direction E3 are not held, each portion of the composite slab 304 moves downward by gravity acting on the composite slab 304 in a direction away from the slab 304a on the line. Therefore, if there is a fire, the composite slab 304 is curved so as to be convex upward with the slab 304a on the line as the center.

In the curved composite slab 304, the concrete receives a compressive force and the reinforcing bar receives a tensile force, so that the composite slab 304 withstands a bending moment B1. The composite slab 304 resists the gravity acting on the composite slab 304 by the bending moment B1.

[0009]

As described above, in the fire resistant structure 300, the fireproof coating of the protected column member with reduced fireproof coating 302 is reduced compared to that of the protected column member with fireproof coating 301. However, in the fire resistant structure 300, robustness (redundancy, margin) of the framework of the fire resistant structure 300 occurs. Due to this robustness, the composite slab 304 is supported by the protected column members with fireproof coating 301 if there is a fire, even if the fireproof coating of the protected column member with reduced fireproof coating 302 is reduced.

[0010]

In a method of calculating an explosion-proof and fireproof film thickness disclosed in Patent Document 2, a specimen including a concrete structure and an explosion-proof and fireproof coating layer provided on the surface of the concrete structure is produced. Then, the specimen is heated, a change in temperature with time is measured, and the relationship between the depth and the temperature of the specimen is derived. Based on this relationship, it is determined whether or not the temperature of the concrete structure is equal to or lower than a heat resistance allowable

temperature. Furthermore, the thickness of the explosion-proof and fireproof coating layer is calculated based on the result.

[0011]

A slab structure disclosed in Patent Document 3 includes a primary beam, a secondary steel beam, and a slab. The primary beam has fire resistant performance and is laid between columns. The entirety or a portion of the secondary steel beam is not subjected to a fireproof coating treatment. The secondary steel beam is connected to the primary beam. The slab is made of reinforced concrete. The slab is supported by the primary beam and the secondary steel beam.

[0012]

A fire resistant structure disclosed in Patent Document 4 includes a plurality of column members, a plurality of primary beams, a secondary beam, and a floor slab.

Each primary beam is placed on the column members. The plurality of primary beams have a pair of orthogonal primary beams provided substantially orthogonal to the secondary beam and a pair of parallel primary beams provided substantially parallel to the secondary beam. One (hereinafter, referred to as a first primary beam) of the orthogonal primary beams and the parallel primary beams are subjected to a fireproof coating. The fireproof coatings of the primary beams which are the other of the orthogonal primary beams and the parallel primary beams and the secondary beam are reduced compared to the fireproof coating to which the first primary beam is subjected. The secondary beam is provided inside surrounded by the plurality of primary beams. The floor slab is provided above the primary beams and the secondary beam.

[Prior Art Document]

[Patent Document]

[0013]

[Patent Document 1] Japanese Unexamined Patent Application, First
Publication No. 2017-031592

[Patent Document 2] Japanese Unexamined Patent Application, First
Publication No. 2008-303646

[Patent Document 3] Japanese Unexamined Patent Application, First
Publication No. 2017-190586

[Patent Document 4] Japanese Unexamined Patent Application, First
Publication No. 2018-003556

[Non-Patent Document]

[0014]

[Non-Patent Document 1] Olivier Vassart, Bin Zhao “MEMBRANE
ACTION OF COMPOSITE STRUCTURES IN CASE OF FIRE”, 2013 No.132, ECCS,
Technical Committee 3 Fire Safety.

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0015]

In the method of designing a fire resistant structure disclosed in Patent
Documents 1, 3 and 4, any corner portion of the floor portion is supported by the
column member (column). For this reason, the degree of freedom in design of the
corner portions of the floor portion is limited.

In addition, Patent Document 2 does not describe a support structure at the
corner portion of the floor portion.

[0016]

The present invention has been made in view of such problems, and an object

thereof is to provide a method of designing a fire resistant structure, a method of constructing a fire resistant structure, and a fire resistant structure capable of increasing the degree of freedom in design of corner portions of a floor portion and omitting the fireproof coating of at least one column supporting a plurality of the corner portions of the floor portion while maintaining fire resistant performance.

[Means for Solving the Problem]

[0017]

In order to solve the above problems, the present invention proposes the following means.

(1) According to a first aspect of the present invention, there is provided a method of designing a fire resistant structure, in which the fire resistant structure includes a floor portion partitioned into a polygonal shape having a plurality of corner portions in a plan view in a slab including a tensile force transmitting member, a ring-shaped protected beam with fireproof coating that is subjected to a fireproof coating and supports a periphery of the floor portion from below, an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the plurality of corner portions of the floor portion, and a protected column with fireproof coating that is subjected to a fireproof coating and supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner, and in a case where directions that intersect each other in a flat surface of the floor portion are defined as a first intersection direction and a second intersection direction, the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction, the method including: a structure determination step of determining a disposition of the

slab, a plurality of beams supporting the slab from below, and columns supporting the plurality of beams by performing a structural calculation; a fire resistant specification determination step of performing setting so that the periphery of the floor portion partitioned from the slab is supported from below by the protected beam with fireproof coating obtained by subjecting the beam to the fireproof coating; a first support specification determination step of performing setting so that the extended beam is connected to the connected corner so as to support the part of the extended beam different from the part of the extended beam connected to the connected corner by the protected column with fireproof coating; and a second support specification determination step of performing setting so that the connected corner is not directly supported by the column or is supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the protected column with fireproof coating.

[0018]

(2) In the method of designing a fire resistant structure according to (1), after the fire resistant specification determination step, the first support specification determination step, and the second support specification determination step, a determination step of determining whether or not the maximum value of a deflection of the floor portion at a desired heating time when the fire resistant structure is heated on the basis of a heating curve defined in ISO 834-11:2014 is less than a threshold K defined by Expression (1) may be performed.

$$K = (L + l) / 30 \quad (1)$$

Here, L is a length (m) of a first span along the flat surface of the floor portion, and l is a length (m) of a second span which is along the flat surface of the floor portion and intersects the first span.

[0019]

(3) In the method of designing a fire resistant structure according to (2), in which, in the determination step, when the maximum value of the deflection of the floor portion is not less than the threshold K, the fire resistant specification determination step may be performed by changing at least some of the plurality of beams to be subjected to the fireproof coating so that at least one of a shape and a size of the floor portion partitioned from the slab is changed, and the determination step may be further performed after the first support specification determination step and the second support specification determination step are performed.

[0020]

(4) According to a second aspect of the present invention, there is provided a method of designing a fire resistant structure, in which the fire resistant structure includes a floor portion partitioned into a polygonal shape having a plurality of corner portions in a plan view in a slab including a tensile force transmitting member, a protected beam with fireproof coating that is subjected to a fireproof coating and supports a periphery of the floor portion from below, a first protected column with fireproof coating that is subjected to a fireproof coating and supports the protected beam with fireproof coating, a portion of the first protected column with fireproof coating and the protected beam with fireproof coating being formed in a ring shape as a whole, an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the plurality of corner portions of the floor portion, and a second protected column with fireproof coating that is subjected to a fireproof coating and supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner, and in a case where directions that intersect each other in a flat surface of the floor portion are defined as a first intersection

direction and a second intersection direction, the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction, the method including: a structure determination step of determining a disposition of the slab, a plurality of beams supporting the slab from below, and a plurality of columns supporting the plurality of beams by performing a structural calculation; a fire resistant specification determination step of performing setting so that the periphery of the floor portion partitioned from the slab is supported from below by the protected beam with fireproof coating obtained by subjecting the beam to the fireproof coating and the portion of the first protected column with fireproof coating obtained by subjecting the column to the fireproof coating; a first support specification determination step of performing setting so that the extended beam is connected to the connected corner so as to support the part of the extended beam different from the part of the extended beam connected to the connected corner by the second protected column with fireproof coating; and a second support specification determination step of performing setting so that the connected corner is not directly supported by the column or is supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the first protected column with fireproof coating.

[0021]

(5) In the method of designing a fire resistant structure according to (4), after the fire resistant specification determination step, the first support specification determination step, and the second support specification determination step, a determination step of determining whether or not the maximum value of a deflection of the floor portion at a desired heating time when the fire resistant structure is heated on

the basis of a heating curve defined in ISO 834-11:2014 is less than a threshold K defined by Expression (2) may be performed.

$$K = (L + l) / 30 \quad (2)$$

Here, L is a length (m) of a first span along the flat surface of the floor portion, and l is a length (m) of a second span which is along the flat surface of the floor portion and intersects the first span.

[0022]

(6) In the method of designing a fire resistant structure according to (5), in the determination step, when the maximum value of the deflection of the floor portion is not less than the threshold K, the fire resistant specification determination step may be performed by changing at least some of the plurality of beams to be subjected to the fireproof coating and the plurality of columns to be subjected to the fireproof coating so that at least one of a shape and a size of the floor portion partitioned from the slab is changed, the first support specification determination step and the second support specification determination step may be further performed, and thereafter the determination step may be performed.

(7) According to a third aspect of the present invention, there is provided a fire resistant structure designed by the method of designing a fire resistant structure according to any one of (1) to (6).

[0023]

(8) According to a fourth aspect of the present invention, there is provided a method of constructing a fire resistant structure, in which the fire resistant structure includes a floor portion partitioned into a polygonal shape having a plurality of corner portions in a plan view in a slab including a tensile force transmitting member, a ring-shaped protected beam with fireproof coating that is subjected to a fireproof coating and

supports a periphery of the floor portion from below, an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the plurality of corner portions of the floor portion, and a protected column with fireproof coating that is subjected to a fireproof coating and supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner, and in a case where directions that intersect each other in a flat surface of the floor portion are defined as a first intersection direction and a second intersection direction, the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction, the method including: a column and beam construction step of constructing the slab, a plurality of beams supporting the slab from below, and columns supporting the plurality of beams; a coating construction step of subjecting the beam to a fireproof coating to obtain the protected beam with fireproof coating so that the periphery of the floor portion partitioned from the slab is supported from below by the protected beam with fireproof coating; a first support step of connecting the extended beam to the connected corner so as to support the part of the extended beam different from the part of the extended beam connected to the connected corner by the protected column with fireproof coating; and a second support step of causing the connected corner so as not to be directly supported by the column or to be supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the protected column with fireproof coating.

[0024]

(9) According to a fifth aspect of the present invention, there is provided a method of constructing a fire resistant structure, in which the fire resistant structure

includes a floor portion partitioned into a polygonal shape having a plurality of corner portions in a plan view in a slab including a tensile force transmitting member, a protected beam with fireproof coating that is subjected to a fireproof coating and supports a periphery of the floor portion from below, a first protected column with fireproof coating that is subjected to a fireproof coating and supports the protected beam with fireproof coating, a portion of the first protected column with fireproof coating and the protected beam with fireproof coating being formed in a ring shape as a whole, an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the plurality of corner portions of the floor portion, and a second protected column with fireproof coating that is subjected to a fireproof coating and supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner, and in a case where directions that intersect each other in a flat surface of the floor portion are defined as a first intersection direction and a second intersection direction, the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction, the method including: a column and beam construction step of constructing the slab, a plurality of beams supporting the slab from below, and a plurality of columns supporting the plurality of beams; a coating construction step of subjecting the beam to a fireproof coating to obtain the protected beam with fireproof coating and subjecting the column to a fireproof coating to obtain the first protected column with fireproof coating so that the periphery of the floor portion partitioned from the slab is supported from below by the protected beam with fireproof coating and the portion of the first protected column with fireproof coating; a first support step of connecting the extended beam to the connected corner so as to

support the part of the extended beam different from the part of the extended beam connected to the connected corner by the second protected column with fireproof coating; and a second support step of causing the connected corner so as not to be directly supported by the column or to be supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the first protected column with fireproof coating.

[0025]

(10) According to a sixth aspect of the present invention, there is provided a fire resistant structure including: a floor portion partitioned into a polygonal shape having a plurality of corner portions in a plan view in a slab including a tensile force transmitting member; a ring-shaped protected beam with fireproof coating that is subjected to a fireproof coating and supports a periphery of the floor portion from below; an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the plurality of corner portions of the floor portion; and a protected column with fireproof coating that is subjected to a fireproof coating and supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner, in which, in a case where directions that intersect each other in a flat surface of the floor portion are defined as a first intersection direction and a second intersection direction, the connected corner is not directly supported by a column or is supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the protected column with fireproof coating, and the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction.

[0026]

(11) The fire resistant structure according to (10) may further include: a protected beam with reduced fireproof coating that has a reduced fireproof coating compared to the protected beam with fireproof coating, is disposed in a region surrounded by the ring-shaped protected beam with fireproof coating, and has an end portion connected to the protected beam with fireproof coating to support the floor portion from below.

(12) In the fire resistant structure according to (10) or (11), the polygonal shape may be a rectangular shape.

[0027]

(13) In the fire resistant structure according to any one of (10) to (12), when the fire resistant structure is heated on the basis of a heating curve defined in ISO 834-11:2014, the maximum value of a deflection of the floor portion at a desired heating time may be less than a threshold K defined by Expression (3).

$$K = (L + l) / 30 \quad (3)$$

Here, L is a length (m) of a first span along the flat surface of the floor portion, and l is a length (m) of a second span which is along the flat surface of the floor portion and intersects the first span.

(14) In the fire resistant structure according to any one of (10) to (13), the tensile force transmitting member may include a first reinforcing bar that extends along the first intersection direction and is configured to transmit the tensile force between the end portions of the floor portion in the first intersection direction, and a second reinforcing bar that extends along the second intersection direction and is configured to transmit the tensile force between the end portions of the floor portion in the second intersection direction.

[0028]

(15) According to a seventh aspect of the present invention, there is provided a fire resistant structure including: a floor portion partitioned into a polygonal shape having a plurality of corner portions in a plan view in a slab including a tensile force transmitting member; a protected beam with fireproof coating that is subjected to a fireproof coating and supports a periphery of the floor portion from below; a first protected column with fireproof coating that is subjected to a fireproof coating and supports the protected beam with fireproof coating, a portion of the first protected column with fireproof coating and the protected beam with fireproof coating being formed in a ring shape as a whole; an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the plurality of corner portions of the floor portion; and a second protected column with fireproof coating that is subjected to a fireproof coating and supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner, in which, in a case where directions that intersect each other in a flat surface of the floor portion are defined as a first intersection direction and a second intersection direction, the connected corner is not directly supported by a column or is supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the first protected column with fireproof coating, and the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction.

[0029]

(16) According to an eighth aspect of the present invention, there is provided a fire resistant structure including: a plurality of protected columns with fireproof coating

that are subjected to a fireproof coating, are disposed side by side in a first intersection direction along a horizontal plane, and are disposed side by side at a first pitch in a second intersection direction intersecting the first intersection direction along the horizontal plane; a pair of first protected beams with fireproof coating that are subjected to a fireproof coating, extend along the first intersection direction, and are disposed at intervals in the second intersection direction; a pair of second protected beams with fireproof coating that are subjected to a fireproof coating, extend along the second intersection direction, are formed to have a length different from the first pitch, having both ends directly connected to the pair of first protected beams with fireproof coating, and are connected to each of the plurality of protected columns with fireproof coating; a floor portion that is partitioned into a quadrangular shape having four corner portions in a plan view in a slab including a tensile force transmitting member, and has a periphery supported from below by the pair of first protected beams with fireproof coating and the pair of second protected beams with fireproof coating; and an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the four corner portions of the floor portion, in which the connected corner is not directly supported by a column or is supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the protected columns with fireproof coating, the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction, and at least one of the plurality of protected columns with fireproof coating supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner.

[0030]

In the configuration described in (1), not supporting the connected corners directly by the columns means that the connected corner is not supported by the column without the intervention of the beam. However, not supporting the connected corners directly by the column does not exclude the meaning that the connected corner is supported by the column via the beam.

[0031]

According to the configuration described in (1), by performing the structure determination step and the fire resistant specification determination step, the periphery of the floor portion is set to be supported from below by the ring-shaped protected beam with fireproof coating capable of maintaining a certain stiffness and strength even if there is a fire. The tensile force transmitting member included in the floor portion is configured to transmit each of the tensile force between the end portions of the floor portion in the first intersection direction and the tensile force between the end portions of the floor portion in the second intersection direction. If there is a fire, the center portion of the floor portion in a plan view deflects so as to be convex downward due to gravity and the like acting on the floor portion. However, due to a so-called membrane effect, the periphery of the floor portion is supported by the protected beam with fireproof coating. Then, the tensile force transmitting member elongated by the deflection of the floor portion is configured to transmit the tensile forces in the first intersection direction and the second intersection direction, respectively, so that the center portion of the floor portion is supported. Therefore, the fire resistant performance of the fire resistant structure can be set to be maintained at the same level as in the related art. The fire resistant performance of the fire resistant structure mentioned here means suppressing the deflection of the floor portion if there is a fire or suppressing an increase in external forces compared to the bending strength.

In the first support specification determination step, the connected corner is set to be supported by the protected column with fireproof coating via the extended beam. Furthermore, in the second support specification determination step, the connected corner is set so as not to be directly supported by the column or to be supported from below by the protected column with reduced fireproof coating. Therefore, the degree of freedom in design of the connected corner of the floor portion can be increased, and the fireproof coating of the column supporting at least one corner portion can be omitted.

[0032]

According to the configuration described in (8), by performing the column and beam construction step and the coating construction step, the periphery of the floor portion is supported from below by the ring-shaped protected beam with fireproof coating capable of maintaining a certain stiffness and strength even if there is a fire. The tensile force transmitting member included in the floor portion is configured to transmit each of the tensile force between the end portions of the floor portion in the first intersection direction and the tensile force between the end portions of the floor portion in the second intersection direction. If there is a fire, the center portion of the floor portion in a plan view deflects so as to be convex downward due to gravity and the like acting on the floor portion. However, due to the membrane effect, the periphery of the floor portion is supported by the protected beam with fireproof coating. Then, the tensile force transmitting member elongated by the deflection of the floor portion is configured to transmit the tensile forces in the first intersection direction and the second intersection direction, respectively, so that the center portion of the floor portion is supported. Therefore, the fire resistant performance of the fire resistant structure can be maintained at the same level as in the related art.

When the first support step is performed, the connected corner is supported by the protected column with fireproof coating via the extended beam. Furthermore, when the second support step is performed, the connected corner is not directly supported by the column or is supported from below by the protected column with reduced fireproof coating. Therefore, the degree of freedom in design of the connected corner of the floor portion can be increased, and the fireproof coating of the column supporting at least one corner portion can be omitted.

[0033]

According to the configuration described in (10), the periphery of the floor portion is supported from below by the ring-shaped protected beam with fireproof coating capable of maintaining a certain stiffness and strength even if there is a fire. The tensile force transmitting member included in the floor portion is configured to transmit each of the tensile force between the end portions of the floor portion in the first intersection direction and the tensile force between the end portions of the floor portion in the second intersection direction. If there is a fire, the center portion of the floor portion in a plan view deflects so as to be convex downward due to gravity and the like acting on the floor portion. However, due to the membrane effect, the periphery of the floor portion is supported by the protected beam with fireproof coating. Then, the tensile force transmitting member elongated by the deflection of the floor portion is configured to transmit the tensile forces in the first intersection direction and the second intersection direction, respectively, so that the center portion of the floor portion is supported. Therefore, the fire resistant performance of the fire resistant structure can be maintained at the same level as in the related art.

In the fire resistant structure, the connected corner is supported by the protected column with fireproof coating via the extended beam. Furthermore, the

connected corner is not directly supported by the column or is supported from below by the protected column with reduced fireproof coating. Therefore, the degree of freedom in design of the connected corner of the floor portion can be increased, and the fireproof coating of the column supporting at least one corner portion can be omitted.

[0034]

According to the configuration described in (4), by performing the structure determination step and the fire resistant specification determination step, the periphery of the floor portion is set to be supported from below by the protected beam with fireproof coating and the first protected column with fireproof coating which can maintain a certain stiffness and strength even if there is a fire and are formed in a ring shape as a whole. The tensile force transmitting member included in the floor portion is configured to transmit each of the tensile force between the end portions of the floor portion in the first intersection direction and the tensile force between the end portions of the floor portion in the second intersection direction. If there is a fire, the center portion of the floor portion in a plan view deflects so as to be convex downward due to gravity and the like acting on the floor portion. However, due to the membrane effect, the periphery of the floor portion is supported by the protected beam with fireproof coating and the portion of the first protected column with fireproof coating. Then, the tensile force transmitting member elongated by the deflection of the floor portion is configured to transmit the tensile forces in the first intersection direction and the second intersection direction, respectively, so that the center portion of the floor portion is supported. Therefore, the fire resistant performance of the fire resistant structure can be set to be maintained at the same level as in the related art.

In the first support specification determination step, the connected corner is set to be supported by the second protected column with fireproof coating via the extended

beam. Furthermore, in the second support specification determination step, the connected corner is set so as not to be directly supported by the column or to be supported from below by the protected column with reduced fireproof coating. Therefore, the degree of freedom in design of the connected corner of the floor portion can be increased, and the fireproof coating of the column supporting at least one corner portion can be omitted.

[0035]

According to the configuration described in (9), by performing the column and beam construction step and the coating construction step, the periphery of the floor portion is supported from below by the protected beam with fireproof coating and the first protected column with fireproof coating which can maintain a certain stiffness and strength even if there is a fire and are formed in a ring shape as a whole. The tensile force transmitting member included in the floor portion is configured to transmit each of the tensile force between the end portions of the floor portion in the first intersection direction and the tensile force between the end portions of the floor portion in the second intersection direction. If there is a fire, the center portion of the floor portion in a plan view deflects so as to be convex downward due to gravity and the like acting on the floor portion. However, due to the membrane effect, the periphery of the floor portion is supported by the protected beam with fireproof coating and the portion of the first protected column with fireproof coating. Then, the tensile force transmitting member elongated by the deflection of the floor portion is configured to transmit the tensile forces in the first intersection direction and the second intersection direction, respectively, so that the center portion of the floor portion is supported. Therefore, the fire resistant performance of the fire resistant structure can be maintained at the same level as in the related art.

When the first support step is performed, the connected corner is supported by the second protected column with fireproof coating via the extended beam.

Furthermore, when the second support step is performed, the connected corner is not directly supported by the column or is supported from below by the protected column with reduced fireproof coating. Therefore, the degree of freedom in design of the connected corner of the floor portion can be increased, and the fireproof coating of the column supporting at least one corner portion can be omitted.

[0036]

According to the configuration described in (15), the periphery of the floor portion is supported from below by the protected beam with fireproof coating and the first protected column with fireproof coating which can maintain a certain stiffness and strength even if there is a fire and are formed in a ring shape as a whole. The tensile force transmitting member included in the floor portion is configured to transmit each of the tensile force between the end portions of the floor portion in the first intersection direction and the tensile force between the end portions of the floor portion in the second intersection direction. If there is a fire, the center portion of the floor portion in a plan view deflects so as to be convex downward due to gravity and the like acting on the floor portion. However, due to the membrane effect, the periphery of the floor portion is supported by the protected beam with fireproof coating and the portion of the first protected column with fireproof coating. Then, the tensile force transmitting member elongated by the deflection of the floor portion is configured to transmit the tensile forces in the first intersection direction and the second intersection direction, respectively, so that the center portion of the floor portion is supported. Therefore, the fire resistant performance of the fire resistant structure can be maintained at the same level as in the related art.

In the fire resistant structure, the connected corner is supported by the second protected column with fireproof coating via the extended beam. Furthermore, the connected corner is not directly supported by the column or is supported from below by the protected column with reduced fireproof coating. Therefore, the degree of freedom in design of the connected corner of the floor portion can be increased, and the fireproof coating of the column supporting at least one corner portion can be omitted.

[0037]

According to the configuration described in (16), the periphery of the floor portion is supported from below by the ring-shaped first protected beam with fireproof coating and the second protected beam with fireproof coating capable of maintaining a certain stiffness and strength even if there is a fire. The tensile force transmitting member included in the floor portion is configured to transmit each of the tensile force between the end portions of the floor portion in the first intersection direction and the tensile force between the end portions of the floor portion in the second intersection direction. If there is a fire, the center portion of the floor portion in a plan view deflects so as to be convex downward due to gravity and the like acting on the floor portion. However, due to the membrane effect, the periphery of the floor portion is supported by the protected beam with fireproof coating. Then, the tensile force transmitting member elongated by the deflection of the floor portion is configured to transmit the tensile forces in the first intersection direction and the second intersection direction, respectively, so that the center portion of the floor portion is supported. Therefore, the fire resistant performance of the fire resistant structure can be maintained at the same level as in the related art.

In the fire resistant structure, the connected corner is supported by the protected column with fireproof coating via the extended beam. Furthermore, the

connected corner is not directly supported by the column or is supported from below by the protected column with reduced fireproof coating. Therefore, the degree of freedom in design of the connected corner of the floor portion can be increased, and the fireproof coating of the column supporting at least one connected corner can be omitted.

[0038]

According to the configurations described in (2) and (5), in the determination step, it can be determined whether or not the maximum value of the deflection of the floor portion is less than the threshold.

According to the configuration described in (3), when the maximum value of the deflection of the floor portion is not less than the threshold K, in the fire resistant specification determination step, at least some of the plurality of beams to be subjected to the fireproof coating and the plurality of columns to be subjected to the fireproof coating are changed so that at least one of the shape and size of the floor portion partitioned from the slab is changed. Accordingly, in the determination step, it can be determined again whether or not the maximum value of the deflection of the floor portion is less than the threshold K.

[0039]

According to the configuration described in (6), when the maximum value of the deflection of the floor portion is not less than the threshold K, in the fire resistant specification determination step, at least some of the plurality of beams to be subjected to the fireproof coating are changed so that at least one of the shape and size of the floor portion partitioned from the slab and the plurality of columns to be subjected to the fireproof coating are changed. Accordingly, in the determination step, it can be determined again whether or not the maximum value of the deflection of the floor portion is less than the threshold K.

According to the configuration described in (7), a fire resistant structure can be designed by the method of designing a fire resistant structure of the present invention. The method of designing a fire resistant structure of the present invention is a method capable of increasing the degree of freedom in design of the corner portions of the floor portion while maintaining fire resistant performance. In addition, the method of designing a fire resistant structure of the present invention is a method capable of omitting the fireproof coating of at least one column supporting the plurality of corner portions of the floor portion from below.

[0040]

According to the configuration described in (11), deflection of the floor portion in a normal time when a fire does not occur can be suppressed.

According to the configuration described in (12), it is possible to facilitate a compact disposition of a plurality of floor portions.

[0041]

According to the configuration described in (13), the membrane effect of the floor portion is effectively exhibited, and the floor portion can be made less likely to deflect downward.

According to the configuration described in (14), with a simple configuration of the first reinforcing bar and the second reinforcing bar, the tensile force between the end portions of the floor portion in the first intersection direction and the tensile force between the end portions of the floor portion in the second intersection direction can be respectively transmitted.

[Effects of the Invention]

[0042]

According to the method of designing a fire resistant structure, the method of

constructing a fire resistant structure, and the fire resistant structure of the present invention, the degree of freedom in design of the corner portions of the floor portion can be increased and the fireproof coating of at least one column supporting the plurality of corner portions of the floor portion can be omitted while maintaining fire resistant performance.

[Brief Description of the Drawings]

[0043]

FIG. 1 is a perspective view illustrating a portion of a building in which a fire resistant structure of a first embodiment of the present invention is used.

FIG. 2 is a cross-sectional view taken along the cutting-plane line A1-A1 in FIG. 1.

FIG. 3 is a plan view illustrating a first modification example of a first reinforcing bar of the fire resistant structure.

FIG. 4 is a plan view illustrating a second modification example of the first reinforcing bar of the fire resistant structure.

FIG. 5 is a plan view illustrating a third modification example of the first reinforcing bar of the fire resistant structure.

FIG. 6 is a plan view illustrating a fourth modification example of the first reinforcing bar of the fire resistant structure.

FIG. 7 is a cross-sectional view taken along the cutting-plane line A2-A2 in FIG. 1.

FIG. 8 is a flowchart showing a method of designing a fire resistant structure according to the first embodiment of the present invention.

FIG. 9 is a perspective view illustrating a structure determination step in the method of designing a fire resistant structure.

FIG. 10 is a perspective view illustrating a fire resistant specification determination step in the method of designing a fire resistant structure.

FIG. 11 is a perspective view illustrating an example in which the disposition of protected beams with fireproof coating and protected beams with reduced fireproof coating is adjusted in the method of designing a fire resistant structure.

FIG. 12 is an exploded perspective view of the fire resistant structure for describing an external force that normally acts on the fire resistant structure.

FIG. 13 is an exploded perspective view of the fire resistant structure for describing an external force acting on the fire resistant structure if there is a fire.

FIG. 14 is a flowchart showing a method of constructing a fire resistant structure according to the first embodiment of the present invention.

FIG. 15 is a perspective view illustrating a portion of a building in which a fire resistant structure of a comparative example is used.

FIG. 16 is a longitudinal sectional view of a first floor portion of the fire resistant structure of the comparative example.

FIG. 17 is a diagram showing a change in the temperature of each part with respect to time in the fire resistant structure of the comparative example.

FIG. 18 is a diagram showing a change in the maximum value of the deflection of the first floor portion with respect to time in the fire resistant structure of the comparative example.

FIG. 19 is a diagram showing changes in bending strength and external force with respect to time in the fire resistant structure of the comparative example.

FIG. 20 is a diagram showing a change in the value of (external force / bending strength) with respect to time in the fire resistant structure of the comparative example.

FIG. 21 is a perspective view illustrating a portion of a building in which a fire

resistant structure of an example is used.

FIG. 22 is a diagram showing changes in the temperature of each part with respect to time in the fire resistant structure of the example.

FIG. 23 is a diagram showing a change in the maximum value of the deflection of a first floor portion with respect to time in the fire resistant structure of the example.

FIG. 24 is a diagram showing changes in bending strength and external force with respect to time in the fire resistant structure of the example.

FIG. 25 is a diagram showing a change in the value of (external force / bending strength) with respect to time in the fire resistant structure of the example.

FIG. 26 is a perspective view illustrating a portion of a building in which a fire resistant structure in a modification example of the first embodiment of the present invention is used.

FIG. 27 is a perspective view illustrating a portion of a building in which a fire resistant structure in a modification example of the first embodiment of the present invention is used.

FIG. 28 is a perspective view illustrating a portion of a building in which a fire resistant structure in a modification example of the first embodiment of the present invention is used.

FIG. 29 is a perspective view illustrating a portion of a building in which a fire resistant structure of a second embodiment of the present invention is used.

FIG. 30 is a transverse sectional view of a building in which the fire resistant structure of the third embodiment of the present invention is used.

FIG. 31 is a perspective view of a fire resistant structure in the related art.

FIG. 32 is a plan view schematically illustrating a main portion of the fire resistant structure if there is a fire.

FIG. 33 is a cross-sectional view taken along the cutting-plane line A11-A11 in FIG. 32.

[Embodiments of the Invention]

[0044]

(First Embodiment)

Hereinafter, a building in which a first embodiment of a fire resistant structure according to the present invention is used will be described with reference to FIGS. 1 to 28.

As illustrated in FIG. 1, a building 1 includes a fire resistant structure 11 of the present embodiment and a support structure 41.

The fire resistant structure 11 includes a first floor portion (floor portion) 12, first protected beams with fireproof coating (protected beam with fireproof coating) 13A and 13B, second protected beams with fireproof coating (protected beam with fireproof coating) 14A, 14B, protected beams with reduced fireproof coating 15A, 15B, and 15C, protected columns with fireproof coating 16A and 16B, extended beams 17A and 17B, and protected columns with fireproof coating 18A and 18B.

In FIG. 1 and below, the boundary between adjacent protected beams with fireproof coating is shown by a solid thick line. In FIG. 1, the first floor portion 12 and a second floor portion 42 of the support structure 41, which will be described later, are transparently shown.

[0045]

The first floor portion 12 is formed in a plate shape having an up-down direction Z as the thickness direction. The first floor portion 12 is formed in a rectangular shape (polygonal shape) having a plurality of (in the present embodiment, four) corner portions 12a, 12b, 12c, and 12d (hereinafter, sometimes abbreviated to

corner portions 12a to 12d) in a plan view seen in the up-down direction Z. The corner portions 12a to 12d mentioned here mean a region in the vicinity of a part of the first floor portion 12 in which adjacent outer edges of the first floor portion 12 are connected to each other in a plan view. The outer edge of a portion of the first floor portion 12 in a plan view extends along a first intersection direction X in a flat surface 12e of the first floor portion 12. The flat surface 12e is the outer surface (upper surface, principal surface) of the first floor portion 12 perpendicular to the thickness direction of the first floor portion 12 (see also FIG. 2). The outer edge of the remaining portion of the first floor portion 12 in a plan view extends along a second intersection direction Y within the flat surface 12e of the first floor portion 12. The first intersection direction X and the second intersection direction Y are directions along the flat surface 12e and are orthogonal to each other (intersect each other).

In the present embodiment, the first intersection direction X and the second intersection direction Y are directions along a horizontal plane, but the first intersection direction X and the second intersection direction Y may also be directions inclined with respect to the horizontal plane.

[0046]

As illustrated in FIG. 2, the first floor portion 12 is a so-called composite slab. The first floor portion 12 includes a first deck plate (tensile force transmitting member) 21, a first concrete (concrete) 22, and reinforcing bars (tensile force transmitting members) 23. The first floor portion 12 may not include the first deck plate 21 and the first concrete 22, and the first floor portion 12 may not include the reinforcing bars 23 and the first concrete 22. The tensile force transmitting members included in the first floor portion 12 are not limited to the first deck plate 21 and the reinforcing bars 23.

For example, the first deck plate 21 is formed by bending a steel plate. The

periphery of the first deck plate 21 is supported from below by the first protected beams with fireproof coating 13A and 13B and the second protected beams with fireproof coating 14A and 14B.

The first concrete 22 is formed in a plate shape having the same shape as the first floor portion 12 in a plan view. The first concrete 22 is disposed on the first deck plate 21.

[0047]

The reinforcing bars 23 are buried in the first concrete 22. The reinforcing bars 23 include a plurality of first reinforcing bars 25 and a plurality of second reinforcing bars 26. In FIG. 1, only two first reinforcing bars 25 and two second reinforcing bars 26 are shown by two-dot chain lines.

As illustrated in FIGS. 1 and 2, each first reinforcing bar 25 extends along the first intersection direction X. Each first reinforcing bar 25 transmits a tensile force between end portions of the first concrete 22 (first floor portion 12) in the first intersection direction X. In other words, each first reinforcing bar 25 extends between a first end portion of the first concrete 22 in the first intersection direction X and a second end portion of the first concrete 22 opposite to the first end portion in the first intersection direction X. Each first reinforcing bar 25 transmits a tensile force acting between the first end portion and the second end portion of the first concrete 22 between the first end portion and the second end portion of the first concrete 22. The plurality of first reinforcing bars 25 are disposed at intervals in the second intersection direction Y.

Similarly, each second reinforcing bar 26 extends along the second intersection direction Y. Each second reinforcing bar 26 transmits a tensile force between end portions of the first concrete 22 in the second intersection direction Y. The plurality of

second reinforcing bars 26 are disposed at intervals in the first intersection direction X.

In the following description, the details of the configurations of the first reinforcing bar 25 and the second reinforcing bar 26 will be described by taking the first reinforcing bar 25 as an example.

[0048]

The first reinforcing bar 25 is not particularly limited as long as it can transmit a tensile force between the end portions of the first concrete 22 in the first intersection direction X. The first reinforcing bar 25 may be formed of one reinforcing bar between the first end portion and the second end portion of the first concrete 22 in the first intersection direction X but may be configured as follows. Round steel bar, deformed steel bar, mesh, or the like is used for the first reinforcing bar 25.

As in a first modification example illustrated in FIG. 3, a first reinforcing bar 25A may include reinforcing bar pieces 27a and 27b and a connection reinforcing bar 27c that connects end portions of the reinforcing bar pieces 27a and 27b. The reinforcing bar pieces 27a and 27b and the connection reinforcing bar 27c are formed of the same material as the first reinforcing bar 25.

The end portion of the reinforcing bar piece 27a and a first end portion of the connection reinforcing bar 27c are connected by a weld 28 formed by welding. The end portion of the reinforcing bar piece 27b and a second end portion of the connection reinforcing bar 27c opposite to the first end portion are connected by a weld 28.

[0049]

As in a second modification example illustrated in FIG. 4, a first reinforcing bar 25B may include the reinforcing bar piece 27a and the reinforcing bar piece 27b. The end portion of the reinforcing bar piece 27a and the end portion of the reinforcing bar piece 27b are connected by the weld 28.

As in a third modification example illustrated in FIG. 5, a first reinforcing bar 25C may include the reinforcing bar pieces 27a and 27b and an annealing wire (wire) 29. The reinforcing bar piece 27a and the reinforcing bar piece 27b are tied by the annealing wire 29 in a state of being overlapped by a predetermined required length. The reinforcing bar piece 27a and the reinforcing bar piece 27b are connected to each other by bonding.

As in a fourth modification example illustrated in FIG. 6, a first reinforcing bar 25D may include the reinforcing bar pieces 27a and 27b and a mechanical joint 30. The mechanical joint 30 is a coupling or the like. The mechanical joint 30 connects the reinforcing bar piece 27a and the reinforcing bar piece 27b by sandwiching the end portions of the reinforcing bar pieces 27a and 27b.

The second reinforcing bar 26 is configured in the same manner as the first reinforcing bar 25.

[0050]

As illustrated in FIG. 7, a bent portion 25a that is bent downward may be formed at the end portion of the first reinforcing bar 25 in the first intersection direction X. The bent portion 25a extends downward from the outside of the second reinforcing bar 26 disposed on the outermost side in the first intersection direction X among the plurality of second reinforcing bars 26.

The number of the first reinforcing bars 25 included in the reinforcing bars 23 is not particularly limited, and may be one. The number of the second reinforcing bars 26 included in the reinforcing bars 23 is not particularly limited, and may be one.

[0051]

In this example, as illustrated in FIG. 2, the first protected beam with fireproof coating 13A is an H-section steel 34A subjected to a fireproof coating 33A. A heat

insulating material such as rock wool or glass wool is used for the fireproof coating 33A. The fireproof coating 33A is wound or sprayed on the outer surface of the H-section steel 34A. The fireproof coating 33A is formed by a spraying and painting method, a forming sheet method, a winding method, or the like.

As illustrated in FIG. 1, the first protected beam with fireproof coating 13A is disposed below the outer edge connecting the corner portions 12a and 12b of the first floor portion 12.

Reinforced concrete (RC) or steel reinforced concrete construction (SRC) may be used for the first protected beam with fireproof coating 13A.

[0052]

The first protected beam with fireproof coating 13B is configured in the same manner as the first protected beam with fireproof coating 13A. The first protected beams with fireproof coating 13A and 13B each extend along the first intersection direction X and are disposed at intervals in the second intersection direction Y. The first protected beam with fireproof coating 13B is disposed below the outer edge connecting the corner portions 12c and 12d of the first floor portion 12.

The second protected beams with fireproof coating 14A and 14B are configured in the same manner as the first protected beam with fireproof coating 13A. That is, the second protected beams with fireproof coating 14A and 14B are subjected to a fireproof coating. The second protected beams with fireproof coating 14A and 14B each extend along the second intersection direction Y and are disposed at intervals in the first intersection direction X.

As illustrated in FIG. 2, both ends of the first protected beams with fireproof coating 13A and 13B are connected to the second protected beams with fireproof coating 14A and 14B, respectively. In FIG. 2, only a part of the connected state of the

first protected beams with fireproof coating 13A and 13B and the second protected beams with fireproof coating 14A and 14B is illustrated.

[0053]

Hereinafter, the protected beams with fireproof coating 13A, 13B, 14A, and 14B are abbreviated to protected beams with fireproof coating 13 and 14 when there is no need to distinguish therebetween. As illustrated in FIG. 1, the protected beams with fireproof coating 13 and 14 are formed in a ring shape (angular ring shape) which is a rectangular frame in a plan view as a whole. The protected beam with fireproof coating may be formed in a ring shape, which is a polygonal frame, or a ring shape (circular ring shape), which is a circular frame, in a plan view as a whole.

The protected beams with fireproof coating 13 and 14 support the periphery of the first floor portion 12 from below over the whole circumference. The protected beams with fireproof coating 13 and 14 may support a portion of the periphery of the first floor portion 12 from below.

The first floor portion 12 is fixed to the protected beams with fireproof coating 13 and 14 by studs 35 and the like provided on the upper surface of the protected beams with fireproof coating 13 and 14 (see FIG. 2). Specifically, the studs 35 penetrates the first deck plate 21 and are embedded in the first concrete 22.

[0054]

Here, with reference to FIG. 7, the positional relationship between the end portions of the first concrete 22 and the first reinforcing bar 25 in the first intersection direction X and the second protected beam with fireproof coating 14A will be described. The second protected beam with fireproof coating 14A includes a fireproof coating 37A and an H-section steel 38A, which are configured in the same manner as the fireproof coating 33A and the H-section steel 34A of the first protected beam with fireproof

coating 13A. The H-section steel 38A is configured by connecting an upper flange 38Aa and a lower flange 38Ab to each other via a web 38Ac.

Here, the end edge of the upper flange 38Aa of the H-section steel 38A on the center portion side of the first floor portion 12 in a plan view is referred to as an end edge 38Aa1. The end edge of the upper flange 38Aa opposite to the end edge 38Aa1 is referred to as an end edge 38Aa2. The center of the web 38Ac in the first intersection direction X is referred to as a plate center 38Ac1.

For example, the end of the first concrete 22 in the first intersection direction X coincides with the end edge 38Aa2.

In the first intersection direction X, the end of the first reinforcing bar 25 in the first intersection direction X reaches the end edge 38Aa1 from the center portion side of the first floor portion 12 in a plan view. It is more preferable that the end portion of the first reinforcing bar 25 reaches the plate center 38Ac1 in the first intersection direction X.

The same applies to the end portion of the second reinforcing bar 26 in the second intersection direction Y.

[0055]

The protected beam with reduced fireproof coating 15A is a beam having a reduced fireproof coating compared to the protected beams with fireproof coating 13 and 14. The protected beam with reduced fireproof coating 15A may be an H-section steel that is not subjected to a fireproof coating. The protected beam with reduced fireproof coating 15A may be an H-section steel subjected to a slight fireproof coating, although the fireproof coating is reduced compared to the protected beams with fireproof coating 13 and 14.

For example, the thickness of the fireproof coating such as rock wool in the

protected beams with fireproof coating 13 and 14, the protected columns with fireproof coating 16A and 16B, and the like is set based on “Sprayed rock wool coated fire resistant structure, construction quality management guidelines (Rock Wool Association Japan, spraying subcommittee). In a case where the protected beams with fireproof coating 13 and 14 and the like are required to be fire resistant for one hour, the thickness of the fireproof coating is set to 25 mm. Similarly, in a case where the protected beams with fireproof coating 13 and 14 and the like are required to be fire resistant for two hours, the thickness of the fireproof coating is set to 45 mm. In a case where the protected beams with fireproof coating 13 and 14 and the like are required to be fire resistant for three hours, the thickness of the fireproof coating is set to 65 mm. In the present specification, a beam or column subjected to a fireproof coating means, for example, a beam or column subjected to a fireproof coating of this specification.

In this case, the thickness of the fireproof coating on the protected beam with reduced fireproof coating 15A is set to about 1/10 to 1/2 of the thickness of the fireproof coating on the protected beams with fireproof coating 13 and 14 according to the corresponding fire resistant performance.

[0056]

The protected beams with reduced fireproof coating 15B and 15C are configured in the same manner as the protected beam with reduced fireproof coating 15A. Hereinafter, when the protected beams with reduced fireproof coating 15A, 15B, and 15C are abbreviated to protected beams with reduced fireproof coating 15 when there is no need to distinguish therebetween. The same applies to the protected columns with fireproof coating 16A and 16B and the like.

As illustrated in FIG. 1, the protected beams with reduced fireproof coating 15 are disposed in a region R1 surrounded by the ring-shaped protected beams with

fireproof coating 13 and 14. The protected beams with reduced fireproof coating 15 each extend between the first protected beam with fireproof coating 13A and the first protected beam with fireproof coating 13B along the first intersection direction X. The protected beams with reduced fireproof coating 15 are disposed at intervals in the second intersection direction Y. Both ends of the protected beams with reduced fireproof coating 15 are connected to the second protected beams with fireproof coating 14A and 14B, respectively.

The protected beams with reduced fireproof coating 15 support the center portion of the first floor portion 12 and the like in a plan view from below.

[0057]

As the protected column with fireproof coating 16A, a steel column (H-section steel, cross steel frame, square steel pipe, circular steel pipe, or the like) subjected to a fireproof coating is used. RC, SRC, or concrete filled steel tube (CFT) may be used for the protected column with fireproof coating 16A.

The protected column with fireproof coating 16B is configured in the same manner as the protected column with fireproof coating 16A. Hereinafter, the protected columns with fireproof coating 16A and 16B are abbreviated to protected columns with fireproof coating 16 when there is no need to distinguish therebetween.

The protected columns with fireproof coating 16 each extend along the up-down direction Z. The upper end portion of the protected column with fireproof coating 16A is connected to each of the joint portion between the first protected beam with fireproof coating 13B and the second protected beam with fireproof coating 14A, and the corner portion 12c of the first floor portion 12. The upper end portion of the protected column with fireproof coating 16B is connected to each of the joint portion between the first protected beam with fireproof coating 13B and the second protected

beam with fireproof coating 14B, and the corner portion 12d of the first floor portion 12.

The corner portions 12a and 12b of the first floor portion 12 are not directly supported by columns (including protected columns with fireproof coating and protected columns with reduced fireproof coating). Here, not directly supporting the corner portion 12a by the column means that the corner portion 12a is not supported by the column without the intervention of the beam. Specifically, it means that the column is not disposed below the corner portion 12a so that the corner portion 12a and the column are not in contact with each other. However, not directly supporting the corner portion 12a by the column does not exclude the meaning that the corner portion 12a is supported by the column via the beam. The same applies to the corner portion 12b.

[0058]

Hereinafter, the corner portion 12a is also referred to as a connected corner 12a, and the corner portion 12b is also referred to as a connected corner 12b. The connected corners 12a and 12b are two of the plurality of corner portions 12a to 12d of the first floor portion 12.

The connected corners 12a and 12b may be supported from below by protected columns with reduced fireproof coating having a reduced fireproof coating compared to the protected column with fireproof coating. The corner portions of the first floor portion 12 that are not directly supported by the columns are the corner portions 12a and 12b, but may be one of the corner portions 12a to 12d, or three or four of the corner portions 12a to 12d.

[0059]

The extended beam 17A is configured in the same manner as the first protected

beam with fireproof coating 13A. Although not illustrated, for example, the extended beam 17A is an H-section steel subjected to a fireproof coating. The extended beam 17A extends along the second intersection direction Y. A first end portion of the extended beam 17A is connected (joined) to each of a portion where the first protected beam with fireproof coating 13A and the second protected beam with fireproof coating 14A are connected and the connected corner 12a of the first floor portion 12. The extended beam 17A extends from the connected corner 12a in a direction away from the second protected beam with fireproof coating 14A.

The extended beam 17A is integrated with the second protected beam with fireproof coating 14A to constitute a connected protected beam with fireproof coating 39A.

In the present embodiment, the extended beam 17A and the second protected beam with fireproof coating 14A are integrally formed as the connected protected beam with fireproof coating 39A which is one protected beam with fireproof coating. However, for ease of description, a portion that supports the first floor portion 12 is treated as the second protected beam with fireproof coating 14A, and a portion that does not support the first floor portion 12 is treated as the extended beam 17A.

[0060]

The extended beam 17B is configured in the same manner as the extended beam 17A. The extended beam 17B extends along the second intersection direction Y. A first end portion of the extended beam 17B is connected to each of a portion where the first protected beam with fireproof coating 13A and the second protected beam with fireproof coating 14B are connected, and the connected corner 12b of the first floor portion 12.

The extended beam 17B is integrated with the second protected beam with

fireproof coating 14B to constitute a connected protected beam with fireproof coating 39B.

[0061]

The protected column with fireproof coating 18A is configured in the same manner as the protected column with fireproof coating 16A. Although not illustrated, for example, the protected column with fireproof coating 18A is an H-section steel subjected to a fireproof coating. An upper end portion of the protected column with fireproof coating 18A is connected to a second end portion (a part different from the part connected to the connected corner 12a) of the extended beam 17A to support the second end portion.

The protected column with fireproof coating 18B is configured in the same manner as the protected column with fireproof coating 18A. The protected column with fireproof coating 18B is connected to a second end portion (a part different from the part connected to the connected corner 12b) of the extended beam 17B to support the second end portion.

The protected column with fireproof coating 18A may be connected to the center portion of the extended beam 17A in a longitudinal direction or the like. The same applies to the protected column with fireproof coating 18B.

[0062]

The support structure 41 includes a second floor portion 42 and a third protected beam with fireproof coating 43.

The second floor portion 42 is configured in the same manner as the first floor portion 12. The second floor portion 42 is formed in a plate shape having the up-down direction Z as the thickness direction. The second floor portion 42 is disposed next to the first floor portion 12 in the second intersection direction Y. The second floor

portion 42 is disposed on one side of the second intersection direction Y with respect to the first floor portion 12.

The second floor portion 42 is integrated with the first floor portion 12 to constitute a floor (slab) 44. That is, the first floor portion 12 of the fire resistant structure 11 is a part of the floor 44 that is partitioned in a rectangular shape. The floor portions 12 and 42 are parts of the floor 44, which are partitioned from the floor 44.

As illustrated in FIG. 2, the second floor portion 42 includes a second deck plate 46, a second concrete 47, and a plurality of reinforcing bars 48, which are configured in the same manner as the first deck plate 21, the first concrete 22, and the plurality of reinforcing bars 23 of the first floor portion 12.

The second deck plate 46 is integrated with the first deck plate 21.

The second concrete 47 is integrated with the first concrete 22.

The plurality of reinforcing bars 48 include a plurality of first reinforcing bars 50 and a plurality of second reinforcing bars 51, which are configured in the same manner as the plurality of first reinforcing bars 25 and the plurality of second reinforcing bars 26. The second reinforcing bar 51 is integrated with the second reinforcing bar 26.

[0063]

The third protected beam with fireproof coating 43 is configured in the same manner as the first protected beam with fireproof coating 13A. The third protected beam with fireproof coating 43 extends along the first intersection direction X. The third protected beam with fireproof coating 43 is connected to each of the second end portion of the extended beam 17A and the second end portion of the extended beam 17B.

[0064]

As will be described later, the fire resistant structure 11 configured as described above is configured so that when the fire resistant structure 11 is heated based on the heating curve (standard heating curve, standard heating temperature curve) defined in ISO 834-11:2014 (hereinafter, abbreviated to ISO 834), the maximum value of the deflection of the first floor portion 12 at a desired heating time is less than the threshold K (m) defined by Expression (6).

$$K = (L + l) / 30 \quad (6)$$

Here, L is the length (m) of the first floor portion 12 in the first intersection direction X (first span). l is the length (m) of the first floor portion 12 in the second intersection direction Y (second span). L and l are the lengths of the first floor portion 12 in directions along the flat surface 12e.

The threshold K is the deflection limit value of the floor described in Non-Patent Document 1 described above.

The first span is not limited to the length in the first intersection direction X, and may be the length of the first floor portion 12 in a direction within the flat surface 12e (direction along the flat surface 12e). The second span is not limited to the length in the second intersection direction Y, and may be the length of the first floor portion 12 in a direction within the flat surface 12e, which is orthogonal to (intersects) the first span. The maximum value of the deflection of the first floor portion 12 is preferably less than the threshold K obtained by Expression (6) regardless of the directions of the first and second spans.

[0065]

In a case where the first floor portion is not rectangular in a plan view, L is the length of the first span along the flat surface of the first floor portion, and l is the length of the second span which is along the flat surface of the floor portion and intersects the

first span. At this time, it is preferable to set the directions of the first and second spans so that the threshold K obtained by Expression (6) becomes smaller. By setting the threshold K as described above, damage to the first floor portion 12 can be evaluated on the safe side.

The threshold is not limited thereto.

[0066]

Next, a method of designing a fire resistant structure for designing the fire resistant structure 11 configured as described above (hereinafter, also abbreviated to a design method) will be described. FIG. 8 is a flowchart showing a design method S of the present embodiment. The design method S is preferably used for, for example, a newly constructed fire resistant structure 11 and an existing fire resistant structure 11.

First, in a structure determination step (step S1 shown in FIG. 8), by performing a known structural calculation, as illustrated in FIG. 9, the disposition of the floor 44, a plurality of beams 52 supporting the floor 44 from below, and columns 53 supporting the plurality of beams 52 is determined. The beam 52 is a beam from which the fireproof coating is removed from the protected beams with fireproof coating 13 and 14 and the protected beams with reduced fireproof coating 15. The column 53 is a column from which the fireproof coating is removed from the protected columns with fireproof coating 16A and 16B.

In the structure determination step S1, for example, the specifications and disposition of the plurality of beams 52 and the plurality of columns 53 are determined from the weight of the floor 44 and the load acting on the floor 44.

When the structure determination step S1 is ended, the step proceeds to step S3.

[0067]

Next, in a fire resistant specification determination step (step S3), when the first floor portion 12 is partitioned from the floor 44, setting is performed as follows. As illustrated in FIG. 10, the fire resistant structure 11 is designed by performing setting so that the periphery of the first floor portion 12 partitioned from the floor 44 is supported from below by the protected beams with fireproof coating 13 and 14 obtained by subjecting the beams 52 to a fireproof coating over the whole circumference. At this time, the fire resistant structure 11 is designed by subjecting at least some of the plurality of beams 52 to a fireproof coating so that a membrane effect of the first floor portion 12 is exhibited if there is a fire. The membrane effect mentioned here means an effect of holding a floor portion on which a load acts, in a shape in which the center portion of the floor portion deflects to be convex downward by protected beams with fireproof coating and tensile force transmitting members if there is a fire.

In this example, the fire resistant structure 11 is designed by subjecting the beams 52 corresponding to the protected beams with fireproof coating 13 and 14 and the columns 53 corresponding to the protected columns with fireproof coating 16A and 16B to a fireproof coating.

When the fire resistant specification determination step S3 is ended, the step proceeds to step S5.

[0068]

Next, in a first support specification determination step (step S5), as illustrated in FIG. 1, setting is performed so that the first end portions of the extended beams 17A and 17B are connected to the connected corners 12a and 12b and the second end portions of the extended beams 17A and 17B are supported by the protected columns with fireproof coating 18A and 18B.

When the first support specification determination step S5 is ended, the step

proceeds to step S7.

Next, in a second support specification determination step (step S7), setting is performed so that the connected corners 12a and 12b are not directly supported by the columns or are supported from below by the protected columns with reduced fireproof coating. In this example, setting is performed so that the connected corners 12a and 12b are not directly supported by the columns. By setting the fire resistant structure 11 as described above, the columns themselves that support the connected corners 12a and 12b from below are eliminated, so that the fireproof coating of the columns that support the connected corners 12a and 12b from below is omitted.

In the second support specification determination step S7, only the connected corners 12a and 12b are not directly supported by the columns, and the connected corners 12a and 12b may not be set to be supported from below by the protected columns with reduced fireproof coating.

When the second support specification determination step S7 is ended, the step proceeds to step S9.

[0069]

Next, in a determination step (step S9), when the fire resistant structure 11 is heated based on the heating curve defined in ISO 834, it is determined whether or not the maximum value of the deflection of the first floor portion 12 at a desired heating time is less than the threshold K (smaller than the threshold K) defined by Expression (6). The determination step S9 is a step performed after the fire resistant specification determination step S3, the first support specification determination step S5, and the second support specification determination step S7.

As the desired heating time, for example, one hour, two hours, or the like is used based on the fire resistant performance defined in the Building Standards Act. In

general, the deflection of the first floor portion 12 is maximized at the center portion of the first floor portion 12 in a plan view. Whether or not the maximum value of the deflection of the first floor portion 12 is less than the threshold K can be determined by a known simulation.

In general, when a building is heated by the heat of a fire, the stiffness and strength of the protected beam with reduced fireproof coating are considered to be zero. Therefore, if there is a fire, the first floor portion 12 is not supported by the protected beams with reduced fireproof coating 15, but is supported by the protected beams with fireproof coating 13 and 14.

[0070]

When it is determined in the determination step S9 that the maximum value of the deflection of the first floor portion 12 is not less than the threshold K (NO), the step proceeds to the fire resistant specification determination step S3.

On the other hand, when it is determined that the maximum value of the deflection of the first floor portion 12 is less than the threshold K (YES), all the steps of the design method S are ended. At this time, the fire resistant structure 11 is designed to the above specification.

The fire resistant structure 11 is a fire resistant structure designed by the design method S.

[0071]

In the fire resistant specification determination step S3 to which the determination step S9 proceeds, at least some of the plurality of beams 52 to be subjected to the fireproof coating are changed so that at least one of the shape and size of the first floor portion partitioned from the floor 44 is changed. For example, at least some of the plurality of beams 52 to be subjected to the fireproof coating are changed in

the fire resistant structure 11 and the support structure 41 illustrated in FIG. 1 to obtain a fire resistant structure 11A and a support structure 41A illustrated in FIG. 11. That is, the protected beam with reduced fireproof coating 15A of the fire resistant structure 11 illustrated in FIG. 1 is subjected to a sufficient fireproof coating to obtain the first protected beam with fireproof coating 13A of the fire resistant structure 11A illustrated in FIG. 11. The fireproof coating of the first protected beam with fireproof coating 13A of the fire resistant structure 11 illustrated in FIG. 1 is reduced to obtain a first protected beam with reduced fireproof coating 54 of the support structure 41A as illustrated in FIG. 11.

The length of a first floor portion 12A of the fire resistant structure 11A illustrated in FIG. 11 is shorter in the second intersection direction Y than that of the first floor portion 12 of the fire resistant structure 11 illustrated in FIG. 1. Similarly, the length of the protected beams with fireproof coating 14A and 14B in the second intersection direction Y is shortened. The shape of the first floor portion 12A is changed to a shape close to a square in a plan view compared to the first floor portion 12.

[0072]

Changing the size of the first floor portion means, for example, without changing the rectangular shape of the first floor portion in a plan view, while maintaining a similar shape to the original first floor portion, increasing or reducing the size of the first floor portion.

Furthermore, after the first support specification determination step S5 and the second support specification determination step S7 are performed, the determination step S9 is performed.

[0073]

In general, as the first floor portion 12A becomes smaller, the maximum value of the deflection of the first floor portion 12A also becomes smaller. Although the deflection limit value of the floor described in Non-Patent Document 1 also becomes smaller, the degree to which the deflection limit value of the floor becomes small is smaller than the degree to which the maximum value of the deflection of the first floor portion 12A is small. Therefore, the maximum value of the deflection of the first floor portion 12A tends to be less than the deflection limit value (threshold) of the floor.

As described above, until a determination of YES is made in the determination step S9, the fire resistant specification determination step S3, the first support specification determination step S5, and the second support specification determination step S7 are repeatedly performed as a set to adjust the plurality of beams 52 to be subjected to the fireproof coating.

[0074]

In the present design method S, after the structure determination step S1, the fire resistant specification determination step S3, the first support specification determination step S5, and the second support specification determination step S7 are performed in this order. However, the order in which the fire resistant specification determination step S3, the first support specification determination step S5, and the second support specification determination step S7 are performed after the structure determination step S1 is not particularly limited. For example, after the structure determination step S1, the second support specification determination step S7, the first support specification determination step S5, and the fire resistant specification determination step S3 may be performed in this order.

[0075]

Here, a form in which the first floor portion 12 and the like deflect before and

after a fire due to the membrane effect will be schematically described.

FIG. 12 illustrates an exploded perspective view of the fire resistant structure 11 in a normal time when no fire has occurred. In FIG. 12 and FIG. 13 described later, the fire resistant structure 11 is shown in a simplified manner. Specifically, the protected beams with reduced fireproof coating 15, the extended beams 17A and 17B, and the protected columns with fireproof coating 18A and 18B of the fire resistant structure 11 are not illustrated.

In the normal time illustrated in FIG. 12, a downward external force $F1$ acts on the first floor portion 12, the protected beam with reduced fireproof coating 15A, and the like due to gravity, static load, and the like acting on the first floor portion 12, the protected beam with reduced fireproof coating 15A, and the like.

On the other hand, if there is a fire, as illustrated in FIG. 13, the center portion of the first floor portion 12 in a plan view deflects so as to be convex downward. However, due to the so-called membrane effect, the periphery of the first floor portion 12 is supported by the ring-shaped protected beams with fireproof coating 13 and 14. The first reinforcing bar 25 elongated by the deflection of the first floor portion 12 transmits a tensile force $F2$ in the first intersection direction X. The second reinforcing bar 26 elongated by the deflection of the first floor portion 12 transmits a tensile force $F3$ in the second intersection direction Y. That is, the first floor portion 12 resists gravity and the like acting on the first floor portion 12 by the tensile forces $F2$ and $F3$.

Therefore, the center portion of the first floor portion 12 is supported by the protected beams with fireproof coating 13 and 14 and the reinforcing bars 25 and 26 in each of the first intersection direction X and the second intersection direction Y.

[0076]

At this time, a tensile region R5 and a compressive region R6 are formed in the

first floor portion 12. The compressive region R6 is hatched in FIG. 13. In the tensile region R5, the first floor portion 12 is pulled along the deflected flat surface 12e. In the compressive region R6, the first floor portion 12 is compressed along the deflected flat surface 12e.

The tensile region R5 is formed in the center portion of the first floor portion 12 in a plan view. The compressive region R6 is formed around the tensile region R5.

[0077]

The membrane effect that occurs in the fire resistant structure 11 if there is a fire is an effect that the reinforcing bars 23 resist the tensile forces F2 and F3. On the other hand, in Patent Document 1, the robustness generated in the fire resistant structure if there is a fire is an effect of resisting the bending moment B1 by concrete and reinforcing bars.

As described above, the fire resistant structure 11 of the present embodiment and the fire resistant structure of Patent Document 1 have different effects if there is a fire.

[0078]

Next, a method of constructing a fire resistant structure for constructing the fire resistant structure 11 (manufacturing method, hereinafter, also abbreviated to a construction method) will be described. FIG. 14 is a flowchart showing a construction method S20 of the present embodiment. While each step of the design method S is only set and not used for actual construction, each step of the construction method S20 is different in that it is used for actual construction. The construction method S20 is preferably used for, for example, a newly constructed fire resistant structure 11.

In the construction method S20, a column and beam construction step S21, a coating construction step S23, a first support step S25, and a second support step S27

are performed.

In the column and beam construction step S21, the floor 44, the plurality of beams 52 that support the floor 44 from below, and the columns 53 that support the plurality of beams 52 are constructed.

In the coating construction step S23, the beams 52 are subjected to the fireproof coating to obtain the protected beams with fireproof coating 13 and 14, so that the periphery of the first floor portion 12 partitioned from the floor 44 is supported from below by the protected beams with fireproof coating 13 and 14. In the coating construction step S23, the columns 53 are subjected to the fireproof coating to obtain the protected columns with fireproof coating 16A and 16B.

In the first support step S25, the first end portions of the extended beams 17A and 17B are connected to the connected corners 12a and 12b, and the second end portions of the extended beams 17A and 17B are supported by the protected columns with fireproof coating 18A and 18B.

In the second support step S27, the connected corners 12a and 12b are not directly supported by the columns. In the second support step S27, the connected corners 12a and 12b may be supported from below by the protected columns with reduced fireproof coating.

In the second support step S27, only the connected corners 12a and 12b are not directly supported by the columns, and the connected corners 12a and 12b may not be supported from below by the protected columns with reduced fireproof coating.

As described above, all the steps of the construction method S20 are ended, and the fire resistant structure 11 is constructed.

[0079]

In a method of designing a fire resistant structure disclosed in Non-Patent

Document 1, all of a plurality of corner portions of the floor portion are designed to be supported by protected columns with fireproof coating. Therefore, those skilled in the art who have seen Non-Patent Document 1 design that all of the plurality of corner portions of the floor portion are supported by the protected columns with fireproof coating.

Since all the corner portions are supported by the protected columns with fireproof coating, the degree of freedom in design of the corner portions is reduced.

[0080]

Contrary to this, according to the design method S of the present embodiment, by performing the structure determination step S1 and the fire resistant specification determination step S3, the periphery of the first floor portion 12 is set to be supported from below by the ring-shaped protected beams with fireproof coating 13 and 14 capable of maintaining a certain stiffness and strength even if there is a fire. The reinforcing bars 23 (first reinforcing bars 25 and second reinforcing bars 26) included in the first floor portion 12 transmit each of the tensile force F2 between the end portions of the first floor portion 12 in the first intersection direction X and the tensile force F3 between the end portions of the first floor portion 12 in the second intersection direction Y. If there is a fire, the center portion of the first floor portion 12 in a plan view deflects so as to be convex downward due to gravity and the like acting on the first floor portion 12. However, due to the so-called membrane effect, the periphery of the first floor portion 12 is supported by the protected beams with fireproof coating 13 and 14. Then, the reinforcing bars 23 elongated by the deflection of the first floor portion 12 transmit the tensile forces F2 and F3 in the first intersection direction X and the second intersection direction Y, respectively, so that the center portion of the first floor portion 12 is supported. Therefore, the fire resistant performance of the fire resistant structure

11 can be set to be maintained at the same level as in the related art. The fire resistant performance of the fire resistant structure 11 mentioned here means suppressing the deflection of the first floor portion 12 if there is a fire or suppressing an increase in external forces compared to the bending strength.

[0081]

In the first support specification determination step S5, setting is performed so that the connected corners 12a and 12b are supported by the protected columns with fireproof coating 18A and 18B via the extended beams 17A and 17B. Furthermore, in the second support specification determination step S7, setting is performed so that the connected corners 12a and 12b are not directly supported by the columns. Therefore, the degree of freedom in design of the connected corners 12a and 12b of the first floor portion 12 can be increased, and the fireproof coating of the columns supporting the connected corners 12a and 12b can be omitted.

Omitting the fireproof coating of the columns supporting the connected corners 12a and 12b means omitting the fireproof coating of the columns by not directly supporting the connected corners 12a and 12b by the columns, or omitting the fireproof coating of the columns by supporting the connected corners 12a and 12b by the protected columns with reduced fireproof coating.

[0082]

In addition, according to the construction method S20 of the present embodiment, by performing the column and beam construction step S21 and the coating construction step S23, the periphery of the first floor portion 12 is supported from below by the ring-shaped protected beams with fireproof coating 13 and 14 capable of maintaining a certain stiffness and strength even if there is a fire. The reinforcing bars 23 included in the first floor portion 12 transmit each of the tensile force F2 between the

end portions of the first floor portion 12 in the first intersection direction X and the tensile force F3 between the end portions of the first floor portion 12 in the second intersection direction Y. If there is a fire, the center portion of the first floor portion 12 in a plan view deflects so as to be convex downward due to gravity and the like acting on the first floor portion 12. However, due to the membrane effect, the periphery of the first floor portion 12 is supported by the protected beams with fireproof coating 13 and 14. Then, the reinforcing bars 23 elongated by the deflection of the first floor portion 12 transmit the tensile forces F2 and F3 in the first intersection direction X and the second intersection direction Y, respectively, so that the center portion of the first floor portion 12 is supported. Therefore, the fire resistant performance of the fire resistant structure 11 can be maintained at the same level as in the related art.

In the first support step S25, the connected corners 12a and 12b are supported by the protected columns with fireproof coating 18A and 18B via the extended beams 17A and 17B. Furthermore, in the second support step S27, the connected corners 12a and 12b are not directly supported by the columns. Therefore, the degree of freedom in design of the connected corners 12a and 12b of the first floor portion 12 can be increased, and the fireproof coating of the columns supporting the connected corners 12a and 12b can be omitted.

[0083]

In addition, according to the fire resistant structure 11 of the present embodiment, the periphery of the first floor portion 12 is supported from below by the ring-shaped protected beams with fireproof coating 13 and 14 capable of maintaining a certain stiffness and strength even if there is a fire. The reinforcing bars 23 included in the first floor portion 12 transmit each of the tensile force F2 between the end portions of the first floor portion 12 in the first intersection direction X and the tensile force F2

between the end portions of the first floor portion 12 in the second intersection direction Y. If there is a fire, the center portion of the first floor portion 12 in a plan view deflects so as to be convex downward due to gravity and the like acting on the first floor portion 12. However, due to the membrane effect, the periphery of the first floor portion 12 is supported by the protected beams with fireproof coating 13 and 14. Then, the reinforcing bars 23 elongated by the deflection of the first floor portion 12 transmit the tensile forces F2 and F3 in the first intersection direction X and the second intersection direction Y, respectively, so that the center portion of the first floor portion 12 is supported. Therefore, the fire resistant performance of the fire resistant structure 11 can be maintained at the same level as in the related art.

In the fire resistant structure 11, the connected corners 12a and 12b are supported by the protected columns with fireproof coating 18A and 18B via the extended beams 17A and 17B. Furthermore, the connected corners 12a and 12b are not directly supported by the columns. Therefore, the degree of freedom in design of the connected corners 12a and 12b of the first floor portion 12 can be increased, and the fireproof coating of the columns supporting the connected corners 12a and 12b can be omitted.

[0084]

In the design method S, the determination step S9 is performed. Therefore, in the determination step S9, it can be determined whether or not the maximum value of the deflection of the first floor portion 12 is less than the threshold K.

When a determination of YES is made in the determination step S9, the fire resistant specification determination step S3 is performed by changing at least some of the plurality of beams 52 to be subjected to the fireproof coating so that at least one of the shape and size of the first floor portion partitioned from the floor 44 is changed, and

thereafter the determination step S9 is performed. Accordingly, when the maximum value of the deflection of the first floor portion 12 is not less than the threshold K, at least one of the shape and size of the first floor portion 12 partitioned from the floor 44 is adjusted, and in the determination step S9, it can be determined again whether or not the maximum value of the deflection of the first floor portion 12 is less than the threshold K.

[0085]

The fire resistant structure 11 is designed by the design method S. Therefore, the fire resistant structure 11 can be designed by the design method S of the present embodiment. The design method S of the present embodiment is a method capable of increasing the degree of freedom in design of the corner portions 12a and 12b of the first floor portion 12 while maintaining the fire resistant performance. The design method S of the present embodiment is a method in which the fireproof coating of at least one column supporting the corner portions 12a and 12b of the first floor portion 12 from below can be omitted.

The fire resistant structure 11 includes the protected beams with reduced fireproof coating 15. Accordingly, deflection of the first floor portion 12 in a normal time when a fire does not occur can be suppressed.

Since the first floor portion 12 is formed in a rectangular shape in a plan view, it is possible to facilitate a compact disposition of a plurality of first floor portions 12.

[0086]

The maximum value of the deflection of the first floor portion 12 at a desired heating time is less than the threshold K. Therefore, the membrane effect of the first floor portion 12 is effectively exhibited, and the first floor portion 12 can be made less likely to deflect downward.

The reinforcing bars 23 includes the first reinforcing bars 25 and the second reinforcing bars 26. Therefore, with a simple configuration of the first reinforcing bars 25 and the second reinforcing bars 26, the tensile force F2 between the end portions of the first floor portion 12 in the first intersection direction X and the tensile force F3 between the end portions of the first floor portion 12 in the second intersection direction Y can be respectively transmitted.

[0087]

(Simulation Result)

Here, an example in which the fire resistant performance of a fire resistant structure of a comparative example is evaluated by a simulation and beams to be subjected to a fireproof coating are adjusted in the fire resistant structure of the comparative example to obtain a fire resistant structure of an example will be described.

FIG. 15 illustrates a building 1B in which a fire resistant structure 11B of the comparative example is used. The building 1B includes the fire resistant structure 11B and a support structure 41B.

The fire resistant structure 11B includes, in addition to each configuration of the fire resistant structure 11 of the first embodiment, a protected beam with reduced fireproof coating 15D and protected columns with fireproof coating 16C and 16D.

[0088]

FIG. 16 illustrates a longitudinal sectional view of the first floor portion 12 of the fire resistant structure 11B used in the simulation.

The distance from the upper end of the reinforcing bar 23 to the upper surface of the first concrete 22 (the cover thickness of the first concrete 22 with respect to the reinforcing bar 23) was set to 30 mm. The thickness of the first floor portion 12 was set to 200 mm.

A design standard strength F_c of the first concrete 22 was set to 40 N/mm^2 (Newton per square millimeter). As the reinforcing bars 23 (first reinforcing bar 25 and second reinforcing bar 26), reinforcing bars having a nominal diameter of D10 and a tensile strength of 500 MPa were disposed at a pitch of 100 mm.

[0089]

As illustrated in FIG. 15, the protected beam with reduced fireproof coating 15D is configured in the same manner as the protected beam with reduced fireproof coating 15A. The protected beam with reduced fireproof coating 15D extends along the first intersection direction X and is disposed between the first protected beam with fireproof coating 13B and the protected beam with reduced fireproof coating 15C. Both ends of the protected beam with reduced fireproof coating 15D are connected to the second protected beams with fireproof coating 14A and 14B, respectively.

The protected columns with fireproof coating 16C and 16D are configured in the same manner as the protected column with fireproof coating 16A. The upper end portion of the protected column with fireproof coating 16C is connected to each of the joint portion between the first protected beam with fireproof coating 13A and the second protected beam with fireproof coating 14A, and the corner portion 12a of the first floor portion 12. The upper end portion of the protected column with fireproof coating 16D is connected to each of the joint portion between the first protected beam with fireproof coating 13A and the second protected beam with fireproof coating 14B, and the corner portion 12b of the first floor portion 12.

In the fire resistant structure 11B of the comparative example, all the corner portions 12a, 12b, 12c, and 12d of the first floor portion 12 are supported from below by the protected columns with fireproof coating 16C, 16D, 16A, and 16B, respectively.

[0090]

The support structure 41B includes, in addition to each configuration of the support structure 41 of the first embodiment, first protected beam with reduced fireproof coating 54A, 54B, 54C, and 54D.

The first protected beams with reduced fireproof coating 54 are configured in the same manner as the protected beam with reduced fireproof coating 15A. The first protected beams with reduced fireproof coating 54 extend between the third protected beam with fireproof coating 43 and the first protected beam with fireproof coating 13A along the first intersection direction X, and are disposed at intervals in the second intersection direction Y. Both ends of the first protected beam with reduced fireproof coating 54 are connected to the extended beams 17A and 17B, respectively.

[0091]

As the protected beams with fireproof coating 14 and the extended beams 17, which are primary beams, H-section steel ($800 \times 250 \times 12 \times 22$, made of S355) subjected to a fireproof coating was used. As the protected beams with fireproof coating 13 and 43, which are secondary beams, H-section steel ($600 \times 200 \times 9 \times 12$, made of S355) subjected to a fireproof coating was used.

As the protected beams with reduced fireproof coating 15 and the first protected beams with reduced fireproof coating 54, which are secondary beams, H-section steel ($600 \times 200 \times 9 \times 12$, made of S355) was used. The protected beams with reduced fireproof coating 15 and the first protected beams with reduced fireproof coating 54 are subjected to a fireproof coating according to the fire resistant specification.

The length of the fire resistant structure 11B in the first intersection direction X and the length thereof in the second intersection direction Y were each set to 15,000 mm. The length of the support structure 41B in the first intersection direction X and

the length thereof in the second intersection direction Y were each set to 15,000 mm.

The load conditions were set to 1.5 kPa (kilopascal) for a dead load and 3.0 kPa for a live load.

[0092]

Simulation results of the temperature and stress of the building 1B when the building 1B was heated based on the heating curve defined in ISO 834 are shown in FIGS. 17 to 20.

In the simulation, the temperature of the building 1B rises when the building 1B supported under predetermined constraint conditions is heated by a fire or the like. The building 1B whose temperature has risen expands, and its stiffness and strength decrease. Stress is generated in the building 1B according to the constraint conditions. It is considered that if there is a fire, the protected columns with fireproof coating 16 and 18, the protected beams with fireproof coating 13, 14, and 43, the extended beams 17, and the reinforcing bars 23 produce predetermined stiffness and strength, while the protected beams with reduced fireproof coating 15 and 54 lose their stiffness and strength.

[0093]

FIG. 17 shows a change in the temperature of each part of the fire resistant structure 11B with respect to time in the fire resistant structure 11B of the comparative example. In FIG. 17, the horizontal axis represents the time (minutes) and the vertical axis represents the temperature (°C). The solid line L1 represents a simulation result of the protected beam with reduced fireproof coating 15A that has not been subjected to a fireproof coating. The dotted line L2 represents a simulation result of the lower surface of the first floor portion 12, the dot dashed line L3 represents a simulation result of the upper surface of the first floor portion 12, and the two-dot chain line L4

represents a simulation result of the reinforcing bar 23.

During 120 minutes after the start of heating, the temperatures of the protected beam with reduced fireproof coating 15A, the lower and upper surfaces of the first floor portion 12, and the reinforcing bar 23 rise with the elapse of time. The temperature of each part is highest in the protected beam with reduced fireproof coating 15A, and decreases in the order of the lower surface of the first floor portion 12, the reinforcing bar 23, and the upper surface of the first floor portion 12.

[0094]

FIG. 18 shows a change in the maximum value of the deflection of the first floor portion 12 with respect to time in the fire resistant structure 11B of the comparative example. In FIG. 18, the horizontal axis represents the time (minutes), and the vertical axis represents the maximum value(mm) of the deflection of the first floor portion 12. The solid line L7 represents a simulation result of the maximum value of the deflection of the first floor portion 12. The dotted line L8 represents the deflection limit value of the first floor portion 12 according to the expression $\{(L + l) / 30\}$ of Non-Patent Document 1 described above. At time t1 (after about 40 minutes) at which the maximum value of the deflection of the first floor portion 12 has reached the deflection limit value, the calculation of the deflection of the first floor portion 12 is stopped so that the maximum value of the deflection of the first floor portion 12 does not increase any more. If the calculation of the deflection of the first floor portion 12 is not stopped at time t1, the maximum value of the deflection of the first floor portion 12 increases as shown by the dot dashed line L9.

It could be seen that in the fire resistant structure 11B of the comparative example, since the maximum value of the deflection of the first floor portion 12 reached the deflection limit value at time t1, the first floor portion 12 is held without collapsing

until at least time t_1 .

[0095]

FIG. 19 shows a change in the bending strength with respect to time in the fire resistant structure 11B of the comparative example. In FIG. 19, the horizontal axis represents the time (minutes) and the vertical axis represents the bending strength (kN/m^2). The dotted line L13 represents a simulation result of the bending strength of the first protected beam with fireproof coating 13A. The dot dashed line L14 represents a simulation result of the bending strength of the first floor portion 12, and the solid line L12 represents a simulation result of the bending strength of the first protected beam with fireproof coating 13A and the first floor portion 12 as a whole. The dotted line L15 represents an external force acting by the above-mentioned loads.

With the elapse of time, the temperature of the first protected beam with fireproof coating 13A rises, and the bending strength of the first protected beam with fireproof coating 13A decreases. On the other hand, the bending strength of the first floor portion 12 increases as the temperature rises. The bending strength of the first protected beam with fireproof coating 13A and the first floor portion 12 as a whole becomes substantially smaller with the elapse of time.

If the bending strength represented by the line L12 is larger than the external force represented by the line L15, the first floor portion 12 can support the loads.

[0096]

FIG. 20 shows a change in the value of (external force / bending strength of (the first protected beam with fireproof coating 13A and the first floor portion 12 as a whole)) with respect to time in the fire resistant structure 11B of the comparative example. In FIG. 20, the horizontal axis represents the time (minutes), and the vertical axis represents the value of (external force / bending strength). FIG. 20 is for clearly

showing the magnitude relationship between the bending strength represented by the line L12 and the external force represented by the line L15 in FIG. 19. The solid line L18 represents the value of (external force / bending strength), and the dotted line L19 represents a line having a value of (external force / bending strength) of 1.0.

With the elapse of time, the value of (external force / bending strength) increases and approaches 1.0. However, since the value of (external force / bending strength) does not reach 1.0 even after 120 minutes have elapsed, it could be seen that the first floor portion 12 can support the loads even after 120 minutes have elapsed after the occurrence of a fire.

[0097]

As described above, in the fire resistant structure 11B of the comparative example, it could be seen that the first floor portion 12 does not collapse due to an external force larger than the bending strength, and the first floor portion 12 is held without collapsing at least until the maximum value of the deflection reaches the deflection limit value.

In the determination step S9 of the design method S described above, a determination of YES may be made when the maximum value of the deflection of the first floor portion 12 is less than the threshold and the external force acting on the fire resistant structure 11 is smaller than the bending strength. When a determination of YES is made in the determination step S9, all the steps of the design method S are ended.

[0098]

FIG. 21 illustrates a building 1C in which a fire resistant structure 11C of the example is used. The building 1C includes the fire resistant structure 11C and support structures 41C and 41D.

The fire resistant structure 11C includes extended beams 58A and 58B and protected columns with fireproof coating 59A and 59B in place of the protected beam with reduced fireproof coating 15D and the protected columns with fireproof coating 16C and 16D for the fire resistant structure 11B.

In the first floor portion 12 of the fire resistant structure 11C, in addition to the corner portions 12a and 12b among the corner portions 12a to 12d being the connected corners 12a and 12b, the corner portions 12c and 12d are also the connected corners 12c and 12d. That is, the protected columns with fireproof coating 16 are not connected to any of the connected corners 12a to 12d.

The extended beams 58A and 58B are configured in the same manner as the extended beam 17A. The extended beams 58A and 58B extend along the second intersection direction Y.

A first end portion of the extended beam 58A is connected to each of a portion where the first protected beam with fireproof coating 13B and the second protected beam with fireproof coating 14A are connected and the connected corner 12c of the first floor portion 12. The extended beam 58A extends from the connected corner 12c in a direction away from the second protected beam with fireproof coating 14A. A first end portion of the extended beam 58B is connected to each of a portion where the first protected beam with fireproof coating 13B and the second protected beam with fireproof coating 14B are connected and the connected corner 12d of the first floor portion 12. The extended beam 58B extends from the connected corner 12d in a direction away from the second protected beam with fireproof coating 14B.

The protected columns with fireproof coating 59A and 59B are configured in the same manner as the protected column with fireproof coating 18A. An upper end portion of the protected column with fireproof coating 59A is connected to a second end

portion of the extended beam 57A. An upper end portion of the protected column with fireproof coating 59B is connected to a second end portion of the extended beam 57B.

[0099]

The upper end portion of the protected column with fireproof coating 16A is connected to each of the center portion of the second protected beam with fireproof coating 14A in the second intersection direction Y and the center portion between the corner portion 12a and the corner portion 12c of the first floor portion 12. The upper end portion of the protected column with fireproof coating 16B is connected to each of the center portion of the second protected beam with fireproof coating 14B in the second intersection direction Y and the center portion between the corner portion 12b and the corner portion 12d of the first floor portion 12.

[0100]

The support structure 41C does not include the first protected beams with reduced fireproof coating 54C and 54D for the support structure 41B.

The support structure 41D includes a third floor portion 61, a fourth protected beam with fireproof coating 62, and second protected beams with reduced fireproof coating 63A and 63B. The third floor portion 61, the fourth protected beam with fireproof coating 62, and the second protected beams with reduced fireproof coating 63A and 63B are configured in the same manner as the second floor portion 42, the third protected beam with fireproof coating 43, the first protected beams with reduced fireproof coating 54A and 54B of the support structure 41C.

[0101]

In the building 1C, the second floor portion 42 and the third floor portion 61 of the support structures 41C and 41D are disposed on both sides of the first floor portion 12 of the fire resistant structure 11C in the second intersection direction Y.

The length of the building 1C in the first intersection direction X and the length of the building 1B in the first intersection direction X are equal to each other. The length of the building 1C in the second intersection direction Y and the length of the building 1B in the second intersection direction Y are equal to each other.

The building 1C is a building configured by reducing the fireproof coating of the first protected beam with fireproof coating 13A or subjecting the protected beam with reduced fireproof coating 15B and the first protected beam with reduced fireproof coating 54C in the building 1B to a fireproof coating.

[0102]

Simulation results of the temperature and stress of the building 1C when the building 1C was heated based on the heating curve defined in ISO 834 are shown in FIGS. 22 to 25.

FIG. 22 shows a change in the temperature of each part with respect to time in the fire resistant structure 11C of the example. In FIG. 22, the horizontal axis represents the time (minutes) and the vertical axis represents the temperature (°C). The solid line L21 represents a simulation result of the protected beam with reduced fireproof coating 15A that has not been subjected to a fireproof coating. The dotted line L22 represents a simulation result of the lower surface of the first floor portion 12, the dot dashed line L23 represents a simulation result of the upper surface of the first floor portion 12, and the two-dot chain line L24 represents a simulation result of the reinforcing bar 23.

The changes in the temperature of the first protected beam with fireproof coating 13A, the lower and upper surfaces of the first floor portion 12, and the reinforcing bar 23 in the fire resistant structure 11C of the example represented by the lines L21 to L24 are equal to the changes in the temperature of the first protected beam

with fireproof coating 13A, the lower and upper surfaces of the first floor portion 12, and the reinforcing bar 23 in the fire resistant structure 11B of the comparative example represented by the lines L1 to L4 in FIG. 17.

[0103]

FIG. 27 shows a change in the maximum value of the deflection of the first floor portion 12 with respect to time in the fire resistant structure 11C of the example. In FIG. 23, the horizontal axis represents the time (minutes), and the vertical axis represents the maximum value(mm) of the deflection of the first floor portion 12. The solid line L27 represents a simulation result of the maximum value of the deflection of the first floor portion 12. The dotted line L28 represents the deflection limit value of the first floor portion 12 according to the expression $\{(L + l) / 30\}$ of Non-Patent Document 1 described above. The length of the first floor portion 12 of the fire resistant structure 11C of the embodiment in the second intersection direction Y is shorter than the length of the first floor portion 12 of the fire resistant structure 11B of the comparative example in the second intersection direction Y. Therefore, the deflection limit value of the first floor portion 12 represented by the line L28 is smaller than the deflection limit value of the first floor portion 12 represented by the line L8 in FIG. 18. However, since the length of the first floor portion 12 of the fire resistant structure 11C of the example in the second intersection direction Y is shorter than the length of the first floor portion 12 of the fire resistant structure 11B of the comparative example in the second intersection direction Y, the maximum value of the deflection of the first floor portion 12 becomes smaller.

In the fire resistant structure 11C of the example, it could be seen that the maximum value of the deflection of the first floor portion 12 does not reach the deflection limit value even after 120 minutes have elapsed after the occurrence of a fire

due to the so-called membrane effect, and the first floor portion 12 can support the loads.

[0104]

FIG. 24 shows a change in the bending strength with respect to time in the fire resistant structure 11C of the example. In FIG. 24, the horizontal axis represents the time (minutes) and the vertical axis represents the bending strength (kN/m^2). The dotted line L33 represents a simulation result of the bending strength of the first protected beam with fireproof coating 13A. The dot dashed line L34 represents a simulation result of the bending strength of the first floor portion 12, and the solid line L32 represents a simulation result of the bending strength of the first protected beam with fireproof coating 13A and the first floor portion 12 as a whole. The dotted line L35 represents an external force acting by the above-mentioned loads.

[0105]

FIG. 25 shows a change in the value of (external force / bending strength) with respect to time in the fire resistant structure 11C of the example. In FIG. 25, the horizontal axis represents the time (minutes), and the vertical axis represents the value of (external force / bending strength). FIG. 25 is for clearly showing the magnitude relationship between the bending strength represented by the line L32 and the external force represented by the line L35 in FIG. 24. The solid line L38 represents the value of (external force / bending strength), and the dotted line L39 represents a line having a value of (external force / bending strength) of 1.0.

With the elapse of time, the value of (external force / bending strength) increases and approaches 1.0. However, since the value of (external force / bending strength) does not reach 1.0 even after 120 minutes have elapsed, it could be seen that the first floor portion 12 can support the loads even after 120 minutes have elapsed after

the occurrence of a fire.

Furthermore, it could be seen that the value of the gradually approaching (external force / bending strength) value in the fire resistant structure 11C of the example is smaller than the value of the gradually approaching (external force / bending strength) value in the fire resistant structure 11B of the comparative example, so that the fire resistant structure 11C of the example has a margin in bending strength.

[0106]

As described above, in the fire resistant structure 11C of the example, it could be seen that since the maximum value of the deflection of the first floor portion 12 does not reach the deflection limit value and the external force is smaller than the bending strength, the first floor portion 12 can support the loads.

In the building 1B including the fire resistant structure 11B of the comparative example, by subjecting the first protected beam with fireproof coating 13A, the protected beam with reduced fireproof coating 15, and the first protected beam with reduced fireproof coating 54 to a fireproof coating or reducing the fireproof coating thereof, the fire resistant structure 11C of the example included in the building 1C can be obtained.

[0107]

The configuration of the fire resistant structure of the present embodiment can be variously modified as described below.

A building 2 illustrated in FIG. 26 includes a fire resistant structure 71 of the present embodiment and support structures 81A and 81B.

The fire resistant structure 71 does not include the protected columns with fireproof coating 16A and 16B for the fire resistant structure 11C of the example.

The support structure 81A does not include the first protected beams with

reduced fireproof coating 54A and 54B for the support structure 41C of the embodiment. The support structure 81B does not include the second protected beams with reduced fireproof coating 63A and 63B for the support structure 41D of the embodiment.

[0108]

A building 2A illustrated in FIG. 27 includes the fire resistant structure 71A of the present embodiment and the support structures 81A and 81B.

The fire resistant structure 71A includes, in addition to each configuration of the fire resistant structure 71 of the modification example, the protected columns with fireproof coating 16A and 16B.

The upper end portion of the protected column with fireproof coating 16A is connected to each of the center portion of the second protected beam with fireproof coating 14A in the second intersection direction Y and the center portion between the corner portion 12a and the corner portion 12c of the first floor portion 12. The upper end portion of the protected column with fireproof coating 16B is connected to each of the center portion of the second protected beam with fireproof coating 14B in the second intersection direction Y and the center portion between the corner portion 12b and the corner portion 12d of the first floor portion 12.

[0109]

The building 2B illustrated in FIG. 28 includes a fire resistant structure 71B of the present embodiment and the support structures 81A and 81B.

The fire resistant structure 71B includes, in addition to each configuration of the fire resistant structure 71 of the modification example, protected columns with fireproof coating 16A, 16B, 16C, and 16D.

The upper end portion of the protected column with fireproof coating 16A is

connected to each of the joint portion between the second protected beam with fireproof coating 14A and the protected beam with reduced fireproof coating 15A and the outer edge between the corner portions 12a and 12c of the first floor portion 12 closer to the corner portion 12a. The upper end portion of the protected column with fireproof coating 16B is connected to each of the joint portion between the second protected beam with fireproof coating 14B and the protected beam with reduced fireproof coating 15A and the outer edge between the corner portions 12b and 12d of the first floor portion 12 closer to the corner portion 12b.

The protected columns with fireproof coating 16C and 16D are configured in the same manner as the protected column with fireproof coating 16A. The upper end portion of the protected column with fireproof coating 16C is connected to each of the joint portion between the second protected beam with fireproof coating 14A and the protected beam with reduced fireproof coating 15C and the outer edge between the corner portions 12a and 12c of the first floor portion 12 closer to the corner portion 12c. The upper end portion of the protected column with fireproof coating 16D is connected to each of the joint portion between the second protected beam with fireproof coating 14B and the protected beam with reduced fireproof coating 15C and the outer edge between the corner portions 12b and 12d of the first floor portion 12 closer to the corner portion 12d.

Both ends of the second protected beams with fireproof coating 14A and 14B are directly connected to the pair of first protected beams with fireproof coating 13A and 13B. The second protected beams with fireproof coating 14A and 14B are connected to the protected columns with fireproof coating 16.

The protected beams with fireproof coating 13 and 14 are formed in a ring shape as a whole.

[0110]

The protected columns with fireproof coating 16A, 16B, 16C, and 16D are disposed side by side in the first intersection direction X and disposed side by side in the second intersection direction Y at a first pitch P1. The second protected beams with fireproof coating 14A and 14B are formed to have a length P2 longer than that of the first pitch P1. In this case, at least one of the corner portions 12a and 12b and the corner portions 12c and 12d protrudes outward from the protected columns with fireproof coating 16A, 16B, 16C and 16D in the second intersection direction Y. In this modification example, all of the corner portions 12a and 12b and the corner portions 12c and 12d protrude outward from the protected columns with fireproof coating 16A, 16B, 16C and 16D in the second intersection direction Y.

The second protected beams with fireproof coating 14A and 14B may be formed shorter than the first pitch P1.

[0111]

According to the fire resistant structure 71B of the modification example, the periphery of the first floor portion 12 is supported from below by the ring-shaped protected beams with fireproof coating 13 and 14 capable of maintaining a certain stiffness and strength even if there is a fire. The reinforcing bars 23 included in the first floor portion 12 transmit each of the tensile force F2 between the end portions of the first floor portion 12 in the first intersection direction X and the tensile force F3 between the end portions of the first floor portion 12 in the second intersection direction Y. If there is a fire, the center portion of the first floor portion 12 in a plan view deflects so as to be convex downward due to gravity and the like acting on the first floor portion 12. However, due to the membrane effect, the periphery of the first floor portion 12 is supported by the protected beams with fireproof coating 13 and 14.

Then, the reinforcing bars 23 elongated by the deflection of the first floor portion 12 transmit the tensile forces F2 and F3 in the first intersection direction X and the second intersection direction Y, respectively, so that the center portion of the first floor portion 12 is supported. Therefore, the fire resistant performance of the fire resistant structure 11 can be maintained at the same level as in the related art.

In the fire resistant structure 71B, the connected corners 12a, 12b, 12c, and 12d are supported by the protected columns with fireproof coating 18A, 18B, 59A, 59B via the extended beams 17A, 17B, 58A, and 58B. Furthermore, the connected corners 12a to 12d are not directly supported by the columns. Therefore, the degree of freedom in design of the connected corners 12a to 12d of the first floor portion 12 can be increased, and the fireproof coating of the columns supporting the connected corners 12a to 12d can be omitted.

[0112]

Since the second protected beams with fireproof coating 14A and 14B are formed in the length P2 longer than the first pitch P1, the positions of the ends of the second protected beams with fireproof coating 14A and 14B are shifted from the positions of the protected columns with fireproof coating 16A, 16B, 16C, and 16D in the second intersection direction Y, and a space can be formed below the corner portions 12a, 12b, 12c, and 12d of the first floor portion 12 supported by the ends of the second protected beams with fireproof coating 14A and 14B.

The second intersection direction Y may be a direction that intersects the first intersection direction X. In this case, for example, the first floor portion 12 is formed in a parallelogram shape (quadrangular shape) in a plan view.

[0113]

As in the fire resistant structure 11 of the present embodiment and the fire

resistant structures 71, 71A, and 71B of the modification examples, the number of corner portions that are not connected to the extended beams among the corner portions 12a to 12d of the first floor portion 12 is not particularly limited, and may be one or two or more.

With the fire resistant structures 71, 71A, and 71B of the modification examples, while maintaining the fire resistant performance, the degree of freedom in design of the corner portions of the first floor portion 12 can be increased, and the fireproof coating of at least one column supporting the corner portions 12a to 12d of the first floor portion 12 can be omitted.

[0114]

(Second Embodiment)

Next, a second embodiment of the present invention will be described with reference to FIG. 29 and FIGS. 8 and 14 described above. Like elements the same as those of the embodiment are denoted by like reference numerals, a description thereof will be omitted, and only differences will be described.

As illustrated in FIG. 29, a building 4 includes a fire resistant structure 121 of the present embodiment and the support structure 41.

The fire resistant structure 121 includes, in place of the protected columns with fireproof coating 16A and 16B and the protected columns with fireproof coating 18A and 18B of the fire resistant structure 11 of the first embodiment, first protected columns with fireproof coating 122A and 122B and second protected columns with fireproof coating (protected columns with fireproof coating) 123A and 123B.

The first protected columns with fireproof coating 122A and 122B are configured in the same manner as the protected column with fireproof coating 16A, but differ from the protected column with fireproof coating 16A only in length. The first

protected columns with fireproof coating 122A and 122B are longer than the protected column with fireproof coating 16A.

Here, a part of (a portion of itself) the first protected column with fireproof coating 122A connected to the protected beams with fireproof coating 13 and 14 is referred to as a column piece 122A1. Similarly, a part of the first protected column with fireproof coating 122B connected to the protected beams with fireproof coating 13 and 14 in the up-down direction Z is referred to as a column piece 122B1.

[0115]

The first protected columns with fireproof coating 122A and 122B support the protected beams with fireproof coating 13 and 14. The protected beams with fireproof coating 13, 14 and the column pieces 122A1 and 122B1 are formed in a ring shape as a whole.

The second protected columns with fireproof coating 123A and 123B are configured in the same manner as the first protected column with fireproof coating 122A. The middle portion of the second protected column with fireproof coating 123A in the up-down direction Z is connected to the second end portion of the extended beam 17A and supports the second end portion. Similarly, the middle portion of the protected column with fireproof coating 123B in the up-down direction Z is connected to the second end portion of the extended beam 17B to support the second end portion.

The connected corners 12a and 12b of the first floor portion 12 are not directly supported by the columns. The connected corners 12a and 12b may be supported from below by the protected columns with reduced fireproof coating having a reduced fireproof coating compared to the first protected columns with fireproof coating 122A and 122B.

[0116]

In this example, the protected beams with fireproof coating 13 and 14 and the two column pieces 122A1 and 122B1 are formed in a ring shape as a whole. However, the number of protected beams with fireproof coating and the number of column pieces formed in a ring shape as a whole are not particularly limited.

[0117]

Next, a design method for designing the fire resistant structure 121 configured as described above will be described. FIG. 8 is a flowchart showing a design method S30 of the present embodiment. The difference between the design method S30 and the design method S of the first embodiment is that a fire resistant specification determination step S31, a second support specification determination step S33, and a determination step S35 are performed in place of the fire resistant specification determination step S3, the second support specification determination step S7, and the determination step S9.

In the fire resistant specification determination step S31, setting is performed so that the periphery of the first floor portion 12 partitioned from the floor 44 is supported from below by the protected beams with fireproof coating 13 and 14 and the column pieces 122A1 and 122B1.

In the second support specification determination step S33, setting is performed so that the connected corners 12a and 12b are not directly supported by the columns, or are supported from below by the protected columns with reduced fireproof coating having a reduced fireproof coating compared to the first protected columns with fireproof coating 122A and 122B.

In the determination step S35, at least one of the plurality of beams to be subjected to the fireproof coating and the plurality of columns to be subjected to the fireproof coating are changed so that at least one of the shape and size of the first floor

portion partitioned from the floor 44 is changed in the fire resistant specification determination step S31.

[0118]

Next, a construction method for constructing the fire resistant structure 121 will be described. FIG. 14 is a flowchart showing a construction method S40 of the present embodiment. The difference between the construction method S40 and the construction method S20 of the first embodiment is that a coating construction step S41, a first support step S43, and a second support step S45 are performed in place of the coating construction step S23, the first support step S25, and the second support step S27.

In the coating construction step S41, the beams 52 are subjected to a fireproof coating to obtain the protected beams with fireproof coating 13 and 14, and the columns 53 are subjected to a fireproof coating to obtain the first protected columns with fireproof coating 122A and 122B. Accordingly, the periphery of the first floor portion 12 partitioned from the floor 44 is supported from below by the protected beams with fireproof coating 13 and 14 and the column pieces 122A1 and 122B1.

In the first support step S43, the first end portions of the extended beams 17A and 17B are connected to the connected corners 12a and 12b. Then, the second end portions of the extended beams 17A and 17B are supported by the second protected columns with fireproof coating 123A and 123B.

In the second support step S45, the connected corners 12a and 12b are not directly supported by the columns. In the second support step S45, the connected corners 12a and 12b may be supported from below by the protected columns with reduced fireproof coating having a reduced fireproof coating compared to the first protected columns with fireproof coating 122A and 122B.

[0119]

As described above, according to the design method S30 of the present embodiment, by performing the structure determination step S1 and the fire resistant specification determination step S31, the periphery of the first floor portion 12 is set to be supported from below by the protected beams with fireproof coating 13 and 14 and the column pieces 122A1 and 122B1 which can maintain a certain stiffness and strength even if there is a fire and are formed in a ring shape as a whole. The reinforcing bars 23 included in the first floor portion 12 transmit each of the tensile force F2 between the end portions of the first floor portion 12 in the first intersection direction X and the tensile force F3 between the end portions of the first floor portion 12 in the second intersection direction Y. If there is a fire, the center portion of the first floor portion 12 in a plan view deflects so as to be convex downward due to gravity and the like acting on the first floor portion 12. However, due to the membrane effect, the periphery of the first floor portion 12 is supported by the protected beams with fireproof coating 13 and 14 and the column pieces 122A1 and 122B1. Then, the reinforcing bars 23 elongated by the deflection of the first floor portion 12 transmit the tensile forces F2 and F3 in the first intersection direction X and the second intersection direction Y, respectively, so that the center portion of the first floor portion 12 is supported. Therefore, the fire resistant performance of the fire resistant structure 121 can be set to be maintained at the same level as in the related art.

[0120]

In the first support specification determination step S5, setting is performed so that the connected corners 12a and 12b are supported by the second protected columns with fireproof coating 123A and 123B via the extended beams 17A and 17B. Furthermore, in the second support specification determination step S33, setting is

performed so that the connected corners 12a and 12b are not directly supported by the columns. Therefore, the degree of freedom in design of the connected corners 12a and 12b of the first floor portion 12 can be increased, and the fireproof coating of the columns supporting the connected corners 12a and 12b can be omitted.

[0121]

In addition, according to the construction method S40 of the present embodiment, by performing the column and beam construction step S21 and the coating construction step S41, the periphery of the first floor portion 12 is supported from below by the protected beams with fireproof coating 13 and 14 and the column pieces 122A1 and 122B1 which can maintain a certain stiffness and strength even if there is a fire and are formed in a ring shape as a whole. The reinforcing bars 23 included in the first floor portion 12 transmit each of the tensile force F2 between the end portions of the first floor portion 12 in the first intersection direction X and the tensile force F3 between the end portions of the first floor portion 12 in the second intersection direction Y. If there is a fire, the center portion of the first floor portion 12 in a plan view deflects so as to be convex downward due to gravity and the like acting on the first floor portion 12. However, due to the membrane effect, the periphery of the first floor portion 12 is supported by the protected beams with fireproof coating 13 and 14 and the column pieces 122A1 and 122B1. Then, the reinforcing bars 23 elongated by the deflection of the first floor portion 12 transmit the tensile forces F2 and F3 in the first intersection direction X and the second intersection direction Y, respectively, so that the center portion of the first floor portion 12 is supported. Therefore, the fire resistant performance of the fire resistant structure 121 can be maintained at the same level as in the related art.

When the first support step S43 is performed, the connected corners 12a and

12b are supported by the second protected columns with fireproof coating 123A and 123B via the extended beams 17A and 17B. Furthermore, when the second support step S45 is performed, the connected corners 12a and 12b are not directly supported by the columns. Therefore, the degree of freedom in design of the connected corners 12a and 12b of the first floor portion 12 can be increased, and the fireproof coating of the columns supporting the connected corners 12a and 12b can be omitted.

[0122]

In addition, according to the fire resistant structure 121 of the present embodiment, the periphery of the first floor portion 12 is supported from below by the protected beams with fireproof coating 13 and 14 and the column pieces 122A1 and 122B1 which can maintain a certain stiffness and strength even if there is a fire and are formed in a ring shape as a whole. The reinforcing bars 23 included in the first floor portion 12 transmit each of the tensile force F2 between the end portions of the first floor portion 12 in the first intersection direction X and the tensile force F2 between the end portions of the first floor portion 12 in the second intersection direction Y. If there is a fire, the center portion of the first floor portion 12 in a plan view deflects so as to be convex downward due to gravity and the like acting on the first floor portion 12.

However, due to the membrane effect, the periphery of the first floor portion 12 is supported by the protected beams with fireproof coating 13 and 14 and the column pieces 122A1 and 122B1. Then, the reinforcing bars 23 elongated by the deflection of the first floor portion 12 transmit the tensile forces F2 and F3 in the first intersection direction X and the second intersection direction Y, respectively, so that the center portion of the first floor portion 12 is supported. Therefore, the fire resistant performance of the fire resistant structure 121 can be maintained at the same level as in the related art.

In the fire resistant structure 121, the connected corners 12a and 12b are supported by the second protected columns with fireproof coating 123A and 123B via the extended beams 17A and 17B. Furthermore, the connected corners 12a and 12b are not directly supported by the columns. Therefore, the degree of freedom in design of the connected corners 12a and 12b of the first floor portion 12 can be increased, and the fireproof coating of the columns supporting the connected corners 12a and 12b can be omitted.

[0123]

In the design method S30, the determination step S35 is performed. Accordingly, in the determination step S35, it can be determined whether or not the maximum value of the deflection of the first floor portion 12 is less than the threshold K.

When a determination of YES is made in the determination step S35, the fire resistant specification determination step S31 is performed by changing at least some of the plurality of beams 52 to be subjected to the fireproof coating so that at least one of the shape and size of the first floor portion partitioned from the floor 44 is changed, and thereafter the determination step S35 is performed. Accordingly, when the maximum value of the deflection of the first floor portion 12 is not less than the threshold K, at least one of the shape and size of the first floor portion 12 partitioned from the floor 44 is adjusted, and in the determination step S35, it can be determined again whether or not the maximum value of the deflection of the first floor portion 12 is less than the threshold K.

[0124]

(Third Embodiment)

Next, a third embodiment of the present invention will be described with

reference to FIG. 30. Like elements the same as those of the embodiments are denoted by like reference numerals, the description thereof will be omitted, and only differences will be described.

As illustrated in FIG. 30, fire resistant structures 91A, 91B, and 91C of the present embodiment are used in a building 3. In FIG. 30, protected beams with fireproof coating 94 and protected beams with reduced fireproof coating 95, which will be described later, are shown to be transparent, and floor portions 96a, 96b, and 96c included in the fire resistant structures 91A, 91B, and 91C are hatched.

The building 3 includes a plurality of protected columns with fireproof coating 93 disposed in a grid pattern in a plan view. The plurality of protected columns with fireproof coating 93 are disposed side by side in each of the first intersection direction X and the second intersection direction Y.

A plurality of the protected beams with fireproof coating 94 are connected to the plurality of protected columns with fireproof coating 93, and the protected beams with reduced fireproof coating 95 are connected to the plurality of protected beams with fireproof coating 94.

[0125]

A floor 96 is supported on the plurality of protected beams with fireproof coating 94 and the protected beams with reduced fireproof coating 95.

A core wall 99 is disposed at the center of the building 3 in a plan view, and a staircase 100 is disposed at the outer edge of the building 3.

The fire resistant structure 91A includes the floor portion 96a that is a portion of the floor 96. The floor portion 96a is formed in a rectangular shape having a plurality of corner portions in a plan view. The protected column with fireproof coating 93 is not connected to any corner portion of the floor portion 96a.

Of the four corner portions of the floor portion 96b included in the fire resistant structure 91B, the protected columns with fireproof coating 93 are connected to two corner portions. Of the four corner portions of the floor portion 96c included in the fire resistant structure 91C, the protected columns with fireproof coating 93 are connected to two corner portions.

[0126]

According to the fire resistant structures 91A, 91B, and 91C of the present embodiment, while maintaining the fire resistant performance, the degree of freedom in design of the corner portions of the floor portions 96a, 96b, and 96c can be increased, and the fireproof coating of at least one column supporting the plurality of corner portions of the floor portions 96a, 96b, and 96c can be omitted. Furthermore the degree of freedom in disposing the fire resistant structures 91A, 91B, and 91C in the building 3 can be increased.

[0127]

While the first to third embodiments of the present invention have been described in detail with reference to the drawings, the specific configuration is not limited to these embodiments, and changes, combinations, deletions, and the like of configurations within a range that does not deviate from the gist of the present invention are also included. Furthermore, it is needless to say that the respective configurations described in the embodiments can be used in combination as appropriate.

For example, in the design methods S and S30 of the first and second embodiments, the determination step S9 may not be performed. The maximum value of the deflection of the first floor portion at a desired heating time of the fire resistant structure may be the threshold K or more.

[0128]

In the first to third embodiments, the protected beams with fireproof coating 13 and 14 may not include the studs 35. That is, the periphery of the first floor portion 12 may be supported from below by the protected beams with fireproof coating 13 and 14, or may be supported from below by the protected beams with fireproof coating 13 and 14 and the column pieces 122A1 and 122B1.

The first floor portion may have a polygonal shape such as a triangular shape or a pentagonal shape in a plan view. The protected beams with fireproof coating 13 and 14 may be formed in a circular ring shape or the like in a plan view as a whole. The fire resistant structure may not include the protected beams with reduced fireproof coating.

[Industrial Applicability]

[0129]

The method of designing a fire resistant structure, the method of constructing a fire resistant structure, and the fire resistant structure of the present disclosure can be suitably used as a fire resistant structure and a design method and a construction method thereof capable of increasing the degree of freedom in design of corner portions of a floor portion and omitting the fireproof coating of at least one column supporting a plurality of the corner portions of the floor portion while maintaining fire resistant performance.

[Brief Description of the Reference Symbols]

[0130]

11, 11A, 11C, 71, 71A, 71B, 91A, 91B, 91C, 121	Fire resistant structure
12, 12A	First floor portion (floor portion)
12a, 12b	Corner portion (connected corner)
12c, 12d	Corner portion

12e	Flat surface
13A, 13B	First protected beam with fireproof coating (protected beam with fireproof coating)
14A, 14B	Second protected beam with fireproof coating (protected beam with fireproof coating)
15A, 15B, 15C, 95	Protected beam with reduced fireproof coating
16A, 16B, 16C, 16D, 93	Protected column with fireproof coating
17A, 17B	Extended beam
18A, 18B	Protected column with fireproof coating
21	First deck plate (tensile force transmitting member)
23	Reinforcing bar (tensile force transmitting member)
44	Floor (slab)
45A, 45B	First protected column with fireproof coating (protected column with fireproof coating)
52	Beam
53	Column
59A, 59B	Second protected column with fireproof coating (protected column with fireproof coating)
94	Protected beam with fireproof coating
96a, 96b, 96c	Floor portion
122A, 122B	First protected column with fireproof coating
122A1, 122B1	Column piece (portion of itself)
123A, 123B	Second protected column with fireproof coating
F2, F3	Tensile force
S, S30	Design method (method of designing fire resistant structure)

S1	Structure determination step
S3, S31	Fire resistant specification determination step
S5	First support specification determination step
S7, S33	Second support specification determination step
S9, S35	Determination step
S20, S40	Construction method (method of constructing fire resistant structure)
S21	Column and beam construction step
S23, S41	Coating construction step
S25, S43	First support step
S27, S45	Second support step
X	First intersection direction
Y	Second intersection direction

1. A method of designing a fire resistant structure,

in which the fire resistant structure includes

a floor portion partitioned into a polygonal shape having a plurality of corner portions in a plan view in a slab including a tensile force transmitting member,

a ring-shaped protected beam with fireproof coating that is subjected to a fireproof coating and supports a periphery of the floor portion from below,

an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the plurality of corner portions of the floor portion, and

a protected column with fireproof coating that is subjected to a fireproof coating and supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner, and

in a case where directions that intersect each other in a flat surface of the floor portion are defined as a first intersection direction and a second intersection direction, the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction,

the method comprising:

a structure determination step of determining a disposition of the slab, a plurality of beams supporting the slab from below, and columns supporting the plurality of beams by performing a structural calculation;

a fire resistant specification determination step of performing setting so that the periphery of the floor portion partitioned from the slab is supported from

below by the protected beam with fireproof coating obtained by subjecting the beam to the fireproof coating;

a first support specification determination step of performing setting so that the extended beam is connected to the connected corner so as to support the part of the extended beam different from the part of the extended beam connected to the connected corner by the protected column with fireproof coating; and

a second support specification determination step of performing setting so that the connected corner is not directly supported by the column or is supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the protected column with fireproof coating.

2. The method of designing a fire resistant structure according to claim 1, wherein, after the fire resistant specification determination step, the first support specification determination step, and the second support specification determination step, a determination step of determining whether or not a maximum value of a deflection of the floor portion at a desired heating time when the fire resistant structure is heated on the basis of a heating curve defined in ISO 834-11:2014 is less than a threshold K defined by Expression (1) is performed,

$$K = (L + l) / 30 \quad (1)$$

where L is a length (m) of a first span along the flat surface of the floor portion, and l is a length (m) of a second span which is along the flat surface of the floor portion and intersects the first span.

3. The method of designing a fire resistant structure according to claim 2, wherein, in the determination step, when the maximum value of the deflection

of the floor portion is not less than the threshold K, the fire resistant specification determination step is performed by changing at least some of the plurality of beams to be subjected to the fireproof coating so that at least one of a shape and a size of the floor portion partitioned from the slab is changed, and the determination step is further performed after the first support specification determination step and the second support specification determination step are performed.

4. A method of designing a fire resistant structure,

in which the fire resistant structure includes

a floor portion partitioned into a polygonal shape having a plurality of corner portions in a plan view in a slab including a tensile force transmitting member,

a protected beam with fireproof coating that is subjected to a fireproof coating and supports a periphery of the floor portion from below,

a first protected column with fireproof coating that is subjected to a fireproof coating and supports the protected beam with fireproof coating, a portion of the first protected column with fireproof coating and the protected beam with fireproof coating being formed in a ring shape as a whole,

an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the plurality of corner portions of the floor portion, and

a second protected column with fireproof coating that is subjected to a fireproof coating and supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner, and

in a case where directions that intersect each other in a flat surface of the floor portion are defined as a first intersection direction and a second intersection direction,

the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction,

the method comprising:

a structure determination step of determining a disposition of the slab, a plurality of beams supporting the slab from below, and a plurality of columns supporting the plurality of beams by performing a structural calculation;

a fire resistant specification determination step of performing setting so that the periphery of the floor portion partitioned from the slab is supported from below by the protected beam with fireproof coating obtained by subjecting the beam to the fireproof coating and the portion of the first protected column with fireproof coating obtained by subjecting the column to the fireproof coating;

a first support specification determination step of performing setting so that the extended beam is connected to the connected corner so as to support the part of the extended beam different from the part of the extended beam connected to the connected corner by the second protected column with fireproof coating; and

a second support specification determination step of performing setting so that the connected corner is not directly supported by the column or is supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the first protected column with fireproof coating.

5. The method of designing a fire resistant structure according to claim 4, wherein, after the fire resistant specification determination step, the first support specification determination step, and the second support specification determination step, a determination step of determining whether or not a maximum

value of a deflection of the floor portion at a desired heating time when the fire resistant structure is heated on the basis of a heating curve defined in ISO 834-11:2014 is less than a threshold K defined by Expression (2) is performed,

$$K = (L + l) / 30 \quad (2)$$

where L is a length (m) of a first span along the flat surface of the floor portion, and l is a length (m) of a second span which is along the flat surface of the floor portion and intersects the first span.

6. The method of designing a fire resistant structure according to claim 5, wherein, in the determination step, when the maximum value of the deflection of the floor portion is not less than the threshold K, the fire resistant specification determination step is performed by changing at least some of the plurality of beams to be subjected to the fireproof coating and the plurality of columns to be subjected to the fireproof coating so that at least one of a shape and a size of the floor portion partitioned from the slab is changed, the first support specification determination step and the second support specification determination step are further performed, and thereafter the determination step is performed.

7. A fire resistant structure designed by the method of designing a fire resistant structure according to any one of claims 1 to 6.

8. A method of constructing a fire resistant structure,
in which the fire resistant structure includes

a floor portion partitioned into a polygonal shape having a plurality of corner portions in a plan view in a slab including a tensile force transmitting member,

a ring-shaped protected beam with fireproof coating that is subjected to a fireproof coating and supports a periphery of the floor portion from below,

an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the plurality of corner portions of the floor portion, and

a protected column with fireproof coating that is subjected to a fireproof coating and supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner, and

in a case where directions that intersect each other in a flat surface of the floor portion are defined as a first intersection direction and a second intersection direction, the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction,

the method comprising:

a column and beam construction step of constructing the slab, a plurality of beams supporting the slab from below, and columns supporting the plurality of beams;

a coating construction step of subjecting the beam to a fireproof coating to obtain the protected beam with fireproof coating so that the periphery of the floor portion partitioned from the slab is supported from below by the protected beam with fireproof coating;

a first support step of connecting the extended beam to the connected corner so as to support the part of the extended beam different from the part of the extended beam connected to the connected corner by the protected column with fireproof coating; and

a second support step of causing the connected corner so as not to be directly supported by the column or to be supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the protected column with fireproof coating.

9. A method of constructing a fire resistant structure,
in which the fire resistant structure includes

a floor portion partitioned into a polygonal shape having a plurality of corner portions in a plan view in a slab including a tensile force transmitting member,

a protected beam with fireproof coating that is subjected to a fireproof coating and supports a periphery of the floor portion from below,

a first protected column with fireproof coating that is subjected to a fireproof coating and supports the protected beam with fireproof coating, a portion of the first protected column with fireproof coating and the protected beam with fireproof coating being formed in a ring shape as a whole,

an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the plurality of corner portions of the floor portion, and

a second protected column with fireproof coating that is subjected to a fireproof coating and supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner, and

in a case where directions that intersect each other in a flat surface of the floor portion are defined as a first intersection direction and a second intersection direction, the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile

force between end portions of the floor portion in the second intersection direction,

the method comprising:

a column and beam construction step of constructing the slab, a plurality of beams supporting the slab from below, and a plurality of columns supporting the plurality of beams;

a coating construction step of subjecting the beam to a fireproof coating to obtain the protected beam with fireproof coating and subjecting the column to a fireproof coating to obtain the first protected column with fireproof coating so that the periphery of the floor portion partitioned from the slab is supported from below by the protected beam with fireproof coating and the portion of the first protected column with fireproof coating;

a first support step of connecting the extended beam to the connected corner so as to support the part of the extended beam different from the part of the extended beam connected to the connected corner by the second protected column with fireproof coating; and

a second support step of causing the connected corner so as not to be directly supported by the column or to be supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the first protected column with fireproof coating.

10. A fire resistant structure comprising:

a floor portion partitioned into a polygonal shape having a plurality of corner portions in a plan view in a slab including a tensile force transmitting member;

a ring-shaped protected beam with fireproof coating that is subjected to a fireproof coating and supports a periphery of the floor portion from below;

an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the plurality of corner portions of the floor portion; and

a protected column with fireproof coating that is subjected to a fireproof coating and supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner,

wherein, in a case where directions that intersect each other in a flat surface of the floor portion are defined as a first intersection direction and a second intersection direction, the connected corner is not directly supported by a column or is supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the protected column with fireproof coating, and

the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction.

11. The fire resistant structure according to claim 10, further comprising:

a protected beam with reduced fireproof coating that has a reduced fireproof coating compared to the protected beam with fireproof coating, is disposed in a region surrounded by the ring-shaped protected beam with fireproof coating, and has an end portion connected to the protected beam with fireproof coating to support the floor portion from below.

12. The fire resistant structure according to claim 10 or 11,

wherein the polygonal shape is a rectangular shape.

13. The fire resistant structure according to any one of claims 10 to 12, wherein, when the fire resistant structure is heated on the basis of a heating curve defined in ISO 834-11:2014, a maximum value of a deflection of the floor portion at a desired heating time is less than a threshold K defined by Expression (3),

$$K = (L + l) / 30 \quad (3)$$

where L is a length (m) of a first span along the flat surface of the floor portion, and l is a length (m) of a second span which is along the flat surface of the floor portion and intersects the first span.

14. The fire resistant structure according to any one of claims 10 to 13, wherein the tensile force transmitting member includes

a first reinforcing bar that extends along the first intersection direction and is configured to transmit the tensile force between the end portions of the floor portion in the first intersection direction, and

a second reinforcing bar that extends along the second intersection direction and is configured to transmit the tensile force between the end portions of the floor portion in the second intersection direction.

15. A fire resistant structure comprising:

a floor portion partitioned into a polygonal shape having a plurality of corner portions in a plan view in a slab including a tensile force transmitting member;

a protected beam with fireproof coating that is subjected to a fireproof coating and supports a periphery of the floor portion from below;

a first protected column with fireproof coating that is subjected to a fireproof

coating and supports the protected beam with fireproof coating, a portion of the first protected column with fireproof coating and the protected beam with fireproof coating being formed in a ring shape as a whole;

an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the plurality of corner portions of the floor portion; and

a second protected column with fireproof coating that is subjected to a fireproof coating and supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner,

wherein, in a case where directions that intersect each other in a flat surface of the floor portion are defined as a first intersection direction and a second intersection direction, the connected corner is not directly supported by a column or is supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the first protected column with fireproof coating, and

the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction.

16. A fire resistant structure comprising:

a plurality of protected columns with fireproof coating that are subjected to a fireproof coating, are disposed side by side in a first intersection direction along a horizontal plane, and are disposed side by side at a first pitch in a second intersection direction intersecting the first intersection direction along the horizontal plane;

a pair of first protected beams with fireproof coating that are subjected to a

fireproof coating, extend along the first intersection direction, and are disposed at intervals in the second intersection direction;

a pair of second protected beams with fireproof coating that are subjected to a fireproof coating, extend along the second intersection direction, are formed to have a length different from the first pitch, having both ends directly connected to the pair of first protected beams with fireproof coating, and are connected to each of the plurality of protected columns with fireproof coating;

a floor portion that is partitioned into a quadrangular shape having four corner portions in a plan view in a slab including a tensile force transmitting member, and has a periphery supported from below by the pair of first protected beams with fireproof coating and the pair of second protected beams with fireproof coating; and

an extended beam that is subjected to a fireproof coating and is connected to a connected corner which is at least one of the four corner portions of the floor portion,

wherein the connected corner is not directly supported by a column or is supported from below by a protected column with reduced fireproof coating having a reduced fireproof coating compared to the protected columns with fireproof coating,

the tensile force transmitting member is configured to transmit each of a tensile force between end portions of the floor portion in the first intersection direction and a tensile force between end portions of the floor portion in the second intersection direction, and

at least one of the plurality of protected columns with fireproof coating supports a part of the extended beam which is different from a part of the extended beam connected to the connected corner.