(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 414 514 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
14.08.2024 Bulletin 2024/33

(21) Application number: **24155575.4**

(22) Date of filing: **02.02.2024**

(51) International Patent Classification (IPC):
E04C 3/36 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
E04C 3/36

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
GE KH MA MD TN

(30) Priority: **07.02.2023 IT 202300001974**

(71) Applicant: **Info.Mtr. S.r.l.**
70126 Bari (IT)

(72) Inventors:
- **VITONE, GIOVANNI**
  BARI (IT)
- **RIZZI, ANDREA**
  BARI (IT)
- **RIZZI, VITO**
  BARI (IT)

(74) Representative: **Conversano, Gabriele**
Laforgia, Bruni & Partners srl
Via Michele Garruba, 3
70122 Bari (IT)

(54) COLUMN WITH CONNECTION SYSTEM FOR TRANSFERRING STRESSES BETWEEN CONCRETE AND STEEL

(57) Column (1) for the realization of mixed concrete and steel structures, comprising: a tube (10) with hollow section, configured to be filled with concrete through an opening (14) at its higher end or through openings (14) arranged on its own side surface, a plurality of connection systems (11, 12, 13) configured to transfer stresses between the hollow section in steel and filling concrete, each connection system (11, 12, 13) comprising at least two profiles in steel arranged in a plane orthogonal to the axis of said metal tube and configured to occupy partially the hollow portion of the section of the tube, characterized in that said tube column (10) is realized by means of a unique metal tube, it is subdivided in a plurality of lengths (110, 120, 130, 140) corresponding to sections comprised between two floors slab of the structure and at each length (110, 120, 130, 140) it is provided a group of foot connection systems (111, 121, 131, 141) and a group of head connection systems (112, 122, 132, 142) positioned at the head and foot of each length, respectively, in that said steel profiles are introduced in elongated holes with suitable dimensions for introducing from outside a respective profile and in the following welded, as fillet welds with full filling, to the outer tube (100), in that said elongated holes have height equal to thickness (Sp) of the relative profile and width equal to width (L) of the side of the tube (100) reduced by a suitable portion, so to guarantee the integrity of the tube (100) also during the cutting and welding steps.

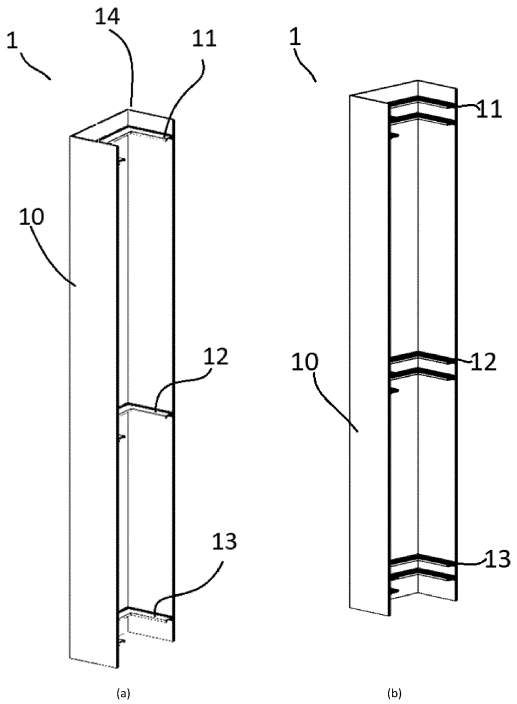

Fig. 2

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Description

[0001] The present invention relates to a column in steel with hollow section, for realizing steel-concrete mixed structures.

[0002] More specifically, the present invention relates to a connection node for transferring stresses between steel and concrete and a method for realizing the same, as well as the hollow column realized with the method according to the invention.

Technical field

[0003] Steel-concrete composite structures are constituted by portions realized in steel for metal carpentry and by portions realized in ordinary reinforced concrete, made interacting with each other by means of a suitably dimensioned connection system. Appreciated features of such structural system are those connected to the use of portions in metal carpentry which guarantee the advantages of the prefabrication and use of steel.

[0004] This ensures speed of building yard operations, auto-supporting of some elements also in absence of finishing casting (step 1), compactness of sections of resistant elements. To these advantages it is added the simplification generally guaranteed by the technology of reinforced concrete in comparison to the one of traditional metal carpentry works. The use of reinforced concrete allows in fact great assembly tolerances, the use of not so skilled workers, simplicity of realization of structural nodes, remarkable adaptability to even complex geometries, reduced elastic deformations.

[0005] The European norm "Eurocode 4: Design of composite steel and concrete structures, part 1-1: general rules and rules for buildings" for hollow columns in steel filled with concrete recommends the use of shear connections apt to distribute, among the portions of steel and concrete, the stresses transmitted by the elements connected to the end of the column and transmitted by the loads applied along the column, when the project resistance to shear exceeds the contact section between steel and concrete.

[0006] In seismic area the use of shear connections is a mandatory and essential condition to be able to react properly to the stresses the element is subjected to, and so the choice of the geometrical and dimensional features and the distribution along the development of the column but above all the embodiment of the connection system are very relevant.

[0007] Before the following description, it is to be said that steel-concrete mixed structures life is divided, as it is well known, in two steps.

[0008] In step 1 (or step of structure realization), the loads relating to the dead weight of the structure, of the other elements of the floor and of the concrete casting are provided. During this step, it is not possible to rely on the resistance properties of concrete, which is not solidified, or however, it has not reached its final resistance characteristics yet.

[0009] To evaluate the structural safety during this step, only the sections of the portions in steel, stressed by loads really provided in such step (structural components weight and working loads of the building yard) are considered as resistant sections.

[0010] The step 2 is instead the step during which the building, after concrete curing, assumes its final configuration of steel-concrete mixed structure. In this step, the resistance to be considered is both the one of steel and concrete, while the actions to be considered for structural tests are all the project actions, including possible seismic actions.

[0011] At the state of the art, the technical field of the realization of steel-concrete mixed structures comprises many solutions both relating to vertical structures (i.e. pillars or columns) and horizontal structures (i.e. beams). In particular, the present invention relates to a column in steel with hollow section, filled with concrete and able to resist to deviated tensile, compressive and bending stresses, having a hollow metal profile of square, rectangular or circular shape as crossing section, and connected to the filling concrete by means of a specific connection system apt to transfer stresses between steel section and filling concrete.

[0012] It is to be specified that, even if many realization embodiments of steel-concrete mixed columns are known at the state of the art - as for example those described in documents KR100620860, CN106638985A, KR20150046913, CN106759865, CN106522419 - all the embodiments known at the state of the art have some limits.

[0013] The embodiments known at the state of the art in fact do not allow to realize connection elements arranged arbitrarily along the longitudinal development of the column, nor describe specific embodiments and geometrical characteristics of the connection nodes which maximize the efficacy in distributing stresses, and so, the structural performance of the composite column.

Aim of the invention

[0014] Aim of the present invention is to provide a hollow column in steel for the realization of steel-concrete mixed structures, which overcomes the limits linked to the embodiments known at the state of the art, with particular reference to the embodiments of the connection node.

[0015] More specifically, the present invention provides a hollow column in steel for the realization of steel-concrete mixed structures in which the connection nodes for transferring stresses between steel and concrete have geometrical features so to maximize the efficacy, and can be arranged, along the development of the column, in any position, according to what results from structural calculations.

[0016] The present invention provides a method for the realization of a steel-concrete composite column consti-

tuted by a metal tube filled with concrete cast in place, with two materials interacting according to the deformation congruence principle and which allow performance in elastic/plastic field with a response capacity in terms of ductility and resistance very much above what it is possible with the ordinary reinforced concrete columns of equal dimensions.

[0017] Before the following detailed description, it is to be said that what described and claimed by the present inventors has been found out by laboratory test on prototypes realized in scale 1:1, subjected to pseudo-static cyclic test with increasing drifts displacement control.

Brief description of the invention

[0018] The present invention reaches the prefixed aims since it is a column (1) for the realization of mixed concrete and steel structures, comprising: a tube (10) with hollow section, configured to be filled with concrete through an opening (14) at its higher end or through openings (14) arranged on its own side surface, a plurality of connection systems (11, 12, 13) configured to transfer stresses between the hollow section in steel and filling concrete, each connection system (11, 12, 13) comprising at least two profiles in steel arranged in a plane orthogonal to the axis of said metal tube and configured to occupy partially the hollow portion of the section of the tube, characterized in that said tube column (10) is realized by means of a unique metal tube, it is subdivided in a plurality of lengths (110, 120, 130, 140) corresponding to sections comprised between two floors slab of the structure and at each length (110, 120, 130, 140) it is provided a group of foot connection systems (111, 121, 131, 141) and a group of head connection systems (112, 122, 132, 142) positioned at the head and foot of each length, respectively, in that said steel profiles are introduced in elongated holes with suitable dimensions for introducing from outside a respective profile and in the following welded, as fillet welds with full filling, to the outer tube (100), and in that said elongated holes have height equal to thickness (Sp) of the relative profile and width equal to width (L) of the side of the tube (100) reduced by a suitable portion, so to guarantee the integrity of the tube (100) also during the cutting and welding steps.

Detailed description of the invention

[0019] With reference to the appended drawings, the column (1) according to the present invention comprises a tube (10) with hollow section, configured to be filled with concrete through an opening (14) at its own higher end or through openings (141) arranged on its own side surface. As it will be explained better in the following, preferably said openings (141) are arranged at the fastening sections of floors slab.

[0020] It is to be specified that with hollow section it is intended an innerly hollow section, preferably of circular (101), square (102) or rectangular shape (103).

[0021] From a structural point of view, the tube (10) having such a section can be realized, without departing from the aims of the invention, both by using welded metal tubes and by using welding free metal tubes.

[0022] The column (1) comprises also a plurality of connection systems (11, 12, 13) configured to transfer stresses between the hollow section in steel and the filling concrete.

[0023] Each connection system (11, 12, 13) comprises at least a profile in steel, arranged in an orthogonal plane to the axis of said metal tube and configured to occupy partially the hollow portion of the section of the tube. In figure 2-a it is shown an embodiment in which each system comprises a unique steel profile.

[0024] Furthermore, preferably, as it is shown in figure 2-b as a whole and in figure 6 in detail, each connection system (11, 12, 13) comprises a plurality of steel profiles (111, 112), arranged each on a plane orthogonal to the axis of said metal tube and configured to occupy partially the hollow portion of the section of the tube. Preferably, the hollow column (1) comprises a plurality of connectors.

[0025] For example, in figure 5, it is shown a column (1), realized with a unique tube (10) and subdivided in 4 lengths (110, 120, 130, 140). With "length" it is intended the section of a column comprised between two floors slab, or between foundation and floor of the first floor.

[0026] At the first length starting from the top (110) it is provided a group of foot connectors (111) and a group of head connectors (112). Each group of connectors comprises at least two stresses distribution elements (11) of the type described in the following. Similarly, respective head and foot connector groups (121, 122, 131, 132, 141, 142) are associated to each of the following lengths (120, 130, 140).

[0027] The maximum tubes marketable lengths are about 13.5 m. This maximum length is to be intended as indicative and not limiting the aims of the invention. Anyway, it is clear that, for lenghts of many meters of the column, all the connector groups (111, 121, 122, 131, 132, 142) distant from the ends of the tube cannot be realized, from a structural point of view, by working inside the tube.

[0028] For this reason, in the following it is described the realization embodiment of the connection nodes according to the present invention, and the working method needed to realize them.

[0029] The realization method according to the invention comprises the steps of:

(1000) realization of a plurality of connection elements (11), by cutting steel plates with suitable thickness;
(2000) at the perimeter of each section of the tube (10) in which a connection node is desired, realization of elongated holes with suitable dimensions to introduce from outside the connection element (11);
(3000) calking of the portion of the outer edge of the connection element (11) which will have to be welded

to the tube (100), so to realize a "v" profile (113);
(4000) introduction of each connection element (11) in a respective elongated hole obtained along the perimeter of the tube (100);
(5000) welding, as fillet welds with full filling, of the calked outer edge (113) of the connection element (11) to the outer tube (100) with following restoration of the tube resistant section. As it is observed, the whole just described realization allows to operate from outside for the realization of the connection system, and so it does not require that the connection element is arranged at the ends of the column. It is to be specified that, according to what found out by the present inventors, the structural resistance better features are obtained with the following preferred realization embodiment of the mixed column according to the invention, in which:

- the depth of the "v" calking is equal to the thickness (T) of the tube (100) of the column reduced by 2 mm, with the calking "v" vertex at the center of the thickness (Sp) of the connection element (11);
- the dimensions of the calking (113) have to be added to the depth (Bc) the connection element (11) has to project of inside the tube (100), since the calking is wholly contained in the thickness of the column (100);
- the outer whole length of the connection elements (11) which is welded to the tube (100) is equal to the length of the whole perimeter of the tube

(100), reduced by a portion suitable to guarantee the integrity of the tube (100) also during the cutting and welding steps.

[0030] In particular, as it is shown in figure 6, in case of tubes with square or rectangular sections, the elongated holes realized for each section of the tube at step (1000)

- are four in number, one for each side of the tube (100),
- are centred with respect to the side of the tube and have height equal to the thickness (Sp) of the connection element (11) and width equal to width (L) of the side of the tube (100) reduced by six times the thickness (T) of the same tube (100).

[0031] In case of square or rectangular sections, and as it is shown in particular in figure 6-b, each connection element (11) has a shape in plant composed of:

- a rectangle of width equal to the width of the elongated hole obtained in the tube and height equal to the difference half between width of hole and width (L) of tube (100) with
- a isosceles trapezoid with sides at 45°, major base coincident with the width of the rectangle and height such that the whole depth of the connection element is equal to the calculation length (Bc) of the connection element increased by the thickness (T) of the tube.

[0032] In case of tubes (100) with circular section, as it is shown in figure 7, the elongated holes realized in step (1000) are two in number, are symmetrical with respect to a diameter of the section and have the ends of each opening spacing to each other four times the thickness (T) of the tube.

[0033] Also in this case, the height of the openings is equal to the thickness of the connector, so to allow its introduction.

[0034] The shape of each connection element (11) in this case is a segment of circular crown, with outer radius equal to the radius of the tube element (100) reduced by 2 mm, inner radius equal to the inner radius of the column (100) reduced by the calculation width (Bc) of connector and height of the segment of circular crown equal to the outer radius of the column (100) reduced by two times the thickness of the tube of the column and further reduced by 2 mm.

[0035] From a positioning point of view of the connectors along the section, as it is shown in figure 5 and figure 8-a, in a preferred embodiment the connectors positions along the longitudinal development of the column are concentrated at the head and foot of each length.

[0036] More in particular, in order to optimize the structural resistance performance, the first connector (11) at the foot of each length (110, 120, 130, 140) is positioned at a distance equal to 2 times the calculation width (Bc) of the connector from the beginning of the length, which is measured starting from the foundation for the first bottom length (104), and is measured extrados of the section in concrete of the floor beam for the other lengths (110, 120, 130).

[0037] The first connector (11) at the head of each length, starting from the top to bottom, has to be positioned as well at a distance equal to 2 times the calculation width (Bc) of the connector starting from intrados of the section in concrete of the floor beam.

[0038] The connectors next to the first one are spaced to each other two times the calculation width (Bc) of the connector.

[0039] The multi-floor column with composed section provided with connectors according to what just described can be progressively filled with concrete through the side openings (141) arranged at heights immediately higher to those of each floor slab, so to support, at the height of the general deck, the discharge of step 1 of auto-supporting beams with mixed steel-concrete section which converge on the same, thus contributing to the whole realization of the prefabrication in workshop with dry assembly on the building yard of the structural system of the building.

[0040] It is to be précised in fact that, to such aim, as it is shown in figure 9, at the height of each floor beam, the column (100) comprises a window (141) configured to allow the introduction of the head of a tube for concrete, thus allowing the filling of the portion of the underlying column. From the just described disclosure, it is clear that the device for transferring stresses for the hollow column (1) according to the invention can be realized simply in workshop in the steel structure prefabrication step, and does not need any operation to be carried out in building yard, with the exception of the execution of the concrete positioning and casting.

[0041] As yet said, each column comprises a system for transferring stresses at or near each end section of each single length of the pillaring, and more specifically at the head and foot of each single length, i.e. in the two end sections of each single column of the pillaring. This allows to obtain the result that, when a structure with frame is realized, which comprises a plurality of pillars realized by means of columns of the just described type, each pillar is provided with connections which allow the load transfer between steel and concrete at all the sections in which the load applied can be subjected to variations, which coincide with the head and the foot of the pillar. Thanks to this structural measure, it can be considered valid the hypothesis of deformation congruence for the crossing section of the column, constituted both by the steel hollow section and by the filling concrete. This hypothesis consists in considering the deformation of the hollow section equal to the average deformation of the surrounding concrete.

[0042] The just described connection system has to be dimensioned, as a function of the loads, to guarantee at the same time the project resistance both of the steel the metal connectors are made up of and of the concrete filling the hollow section. In other terms, the collapse of both the materials has to be prevented in order that the load can be transferred effectively. Resistances of all the fastening systems (by means of welding or screw coupling) between the metal connectors and steel hollow section of the composite column have to be tested as well.

Claims

1. Column (1) for the realization of mixed concrete and steel structures, comprising:

   - a tube (10) with hollow section, configured to be filled with concrete through an opening (14) at its higher end or through openings (14) arranged on its own side surface,
   - a plurality of connection systems (11, 12, 13) configured to transfer stresses between the hollow section in steel and filling concrete, each connection system (11, 12, 13) comprising at least two profiles in steel arranged in a plane orthogonal to the axis of said metal tube and configured to occupy partially the hollow portion of the section of the tube,

   characterized in that

   said tube column (10) is realized by means of a unique metal tube, it is subdivided in a plurality of lengths (110, 120, 130, 140) corresponding to sections comprised between two floors slab of the structure and at each length (110, 120, 130, 140) it is provided a group of foot connection systems (111, 121, 131, 141) and a group of head connection systems (112, 122, 132, 142) positioned at the head and foot of each length, respectively,
   in that
   said steel profiles are introduced in elongated holes with suitable dimensions for introducing from outside a respective profile and in the following welded to the outer tube (100),
   and **in that**
   said elongated holes have height equal to thickness (Sp) of the relative profile and width equal to width (L) of the side of the tube (100) reduced by a suitable portion, so to guarantee the integrity of the tube (100) also during the cutting and welding steps.

2. Column (1) for the realization of concrete and steel mixed structures according to claim 1, **characterized in that** said width suitable to guarantee the integrity of the tube (100) also during the cutting and welding steps is generally equal, for all the holes, to six times the thickness (T) of the same tube (100).

3. Column (1) for the realization of concrete and steel mixed structures according to claim 1 or 2, **characterized in that** said column (1) has rectangular section, said elongated holes are one in number for each side of said tube (100), are centred with respect to the side of the tube (100), and each of said steel profiles has a shape in plant made up of:

   - a rectangle of width equal to the width of the hole provided in the tube and height equal to the difference half between width of hole and width (L) of tube (100);
   - a isosceles trapezoid with sides at 45°, major base coincident with the width of the rectangle.

4. Column (1) for the realization of concrete and steel mixed structures according to claim 1 or 2, **characterized in that** said column (1) has circular section and said elongated holes are two in number, are symmetrical with respect to a diameter of the section and have the ends of each opening spacing to each other four times the thickness (T) of the tube.

5. Column (1) for the realization of concrete and steel mixed structures according to claim 4, **characterized in that** each of said profiles is a segment of circular crown, with outer radius equal to the radius of the tube element (100) reduced by 2 mm, inner radius equal to the inner radius of the column (100) reduced by the width (Bc) of connector (11) and height of the segment of circular crown equal to the outer radius of the column (100) reduced by two times the thickness of the tube of the column and further reduced by 2 mm.

6. Column (1) for the realization of concrete and steel mixed structures according to any one of the preceding claims, **characterized in that** the first connector (11) at the foot of each length (110, 120, 130, 140) is positioned at a distance from the beginning of each length (110, 120, 130, 140) equal to 2 times the width (Bc) of the connector.

7. Column (1) for the realization of concrete and steel mixed structures according to any one of the preceding claims, **characterized in that** the first connector (11) at the head of each length is positioned at a distance equal to 2 times the calculation width (Bc) of the connector starting from the intrados of the section in concrete of the floor beam, and the connectors next to the first one are spaced to each other 2 times the calculation width (Bc) of the connector.

8. Method for the realization of a hollow column, according to any one other preceding claims, comprising the steps of:

(1000) realization of a plurality of connection elements (11), by cutting steel plates;
(2000) at the perimeter of each section of the tube (10) in which a connection node is desired, realization of elongated holes with suitable dimensions to introduce from outside a respective connection element (11) obtained in step (1000);
(3000) calking of the portion of the outer edge of the connection element (11) in the portion which will have to be welded to the tube (100);
(4000) introduction of each connection element (11) in a respective elongated hole obtained along the perimeter of the tube (100);
(5000) welding, as fillet welds with full filling, of the calked outer edge (113) of the connection element (11) to the outer tube (100).

9. Method according to claim 8, **characterized in that**

- the depth of said calking is equal to the thickness (T) of the tube (100) of the column reduced by 2 mm, and said calking is symmetrical to the thickness (sp) of the connection element (11);
- after the introduction of step (4000) the calking is wholly contained in the thickness of the column (100) ;
- the outer whole length of the connection elements (11) which is welded to the tube (100) is equal to the length of the whole perimeter of the section of the tube (100), reduced by a portion suitable to guarantee the integrity of the tube (100) also during the cutting and welding steps.

10. Method according to claim 9, **characterized in that** said section is a square or rectangular section, and said elongated holes realized at step (1000) ;

- are four in number for each section, one for each side of the tube (100),
- are centred with respect to the side of the tube;
- have a height equal to the thickness (Sp) of the connection element (11) and width equal to width (L) of the side of the tube (100) reduced by six times the thickness (T) of the same tube (100).

11. Method according to claim 9 or 10, **characterized in that** said section is a rectangular section, and each connection element (11) has a shape in plant composed of:

- a rectangle of width equal to the width of the hole provided in the tube and height equal to the difference half between width of hole and width (L) of tube (100);
- a isosceles trapezoid with sides at 45°, major base coincident with the width of the rectangle.

12. Method according to claim 9, **characterized in that** said section is a circular section, said elongated holes realized in step (1000) are two in number, are symmetrical with respect to a diameter of the section and have the ends of each opening spacing to each other four times the thickness (T) of the tube.

13. Method according to claim 12, **characterized in that** the shape of each connection element (11) is a segment of circular crown, with outer radius equal to the radius of the tube element (100) reduced by 2 mm, inner radius equal to the inner radius of the column (100) reduced by the width (Bc) of connector and height of the segment of circular crown equal to the outer radius of the column (100) reduced by two times the thickness of the tube of the column and further reduced by 2 mm.

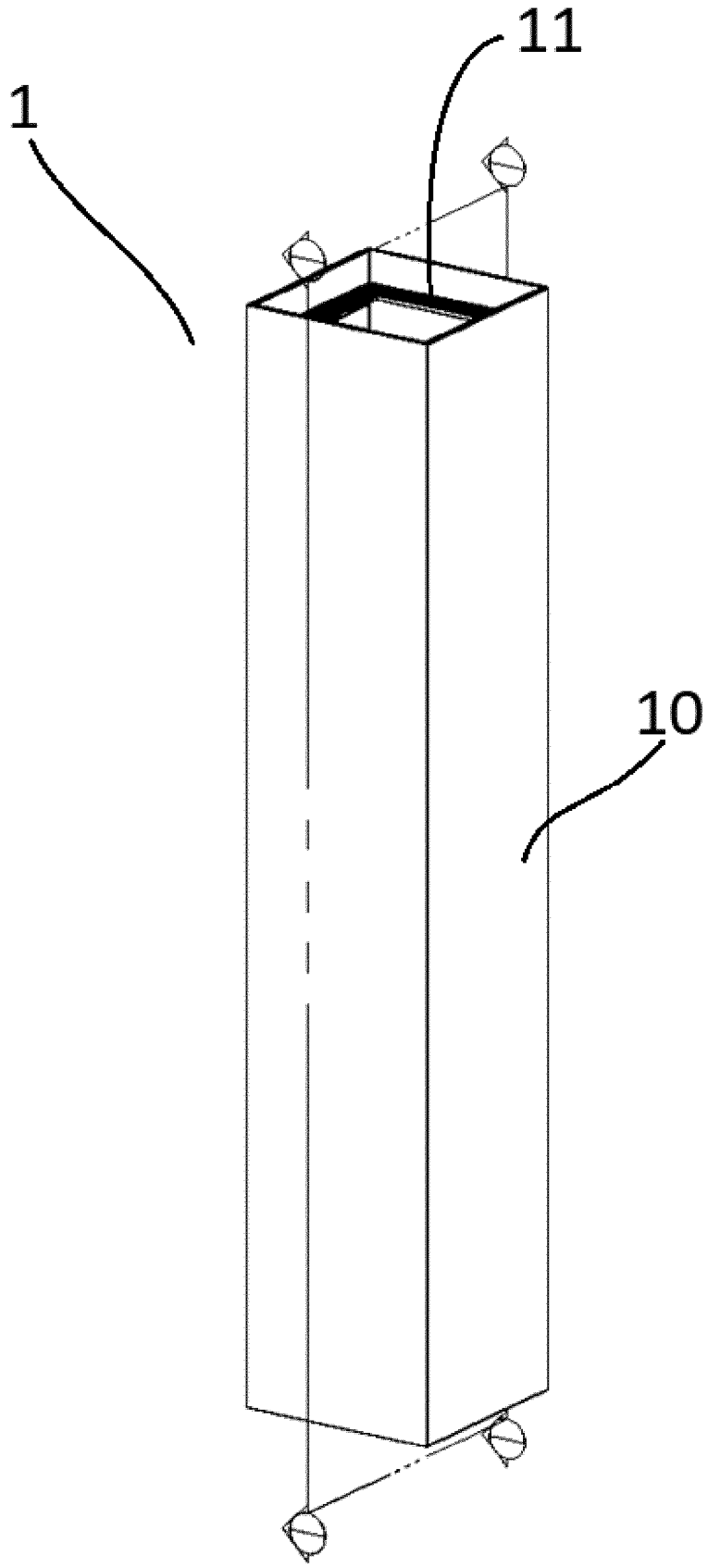
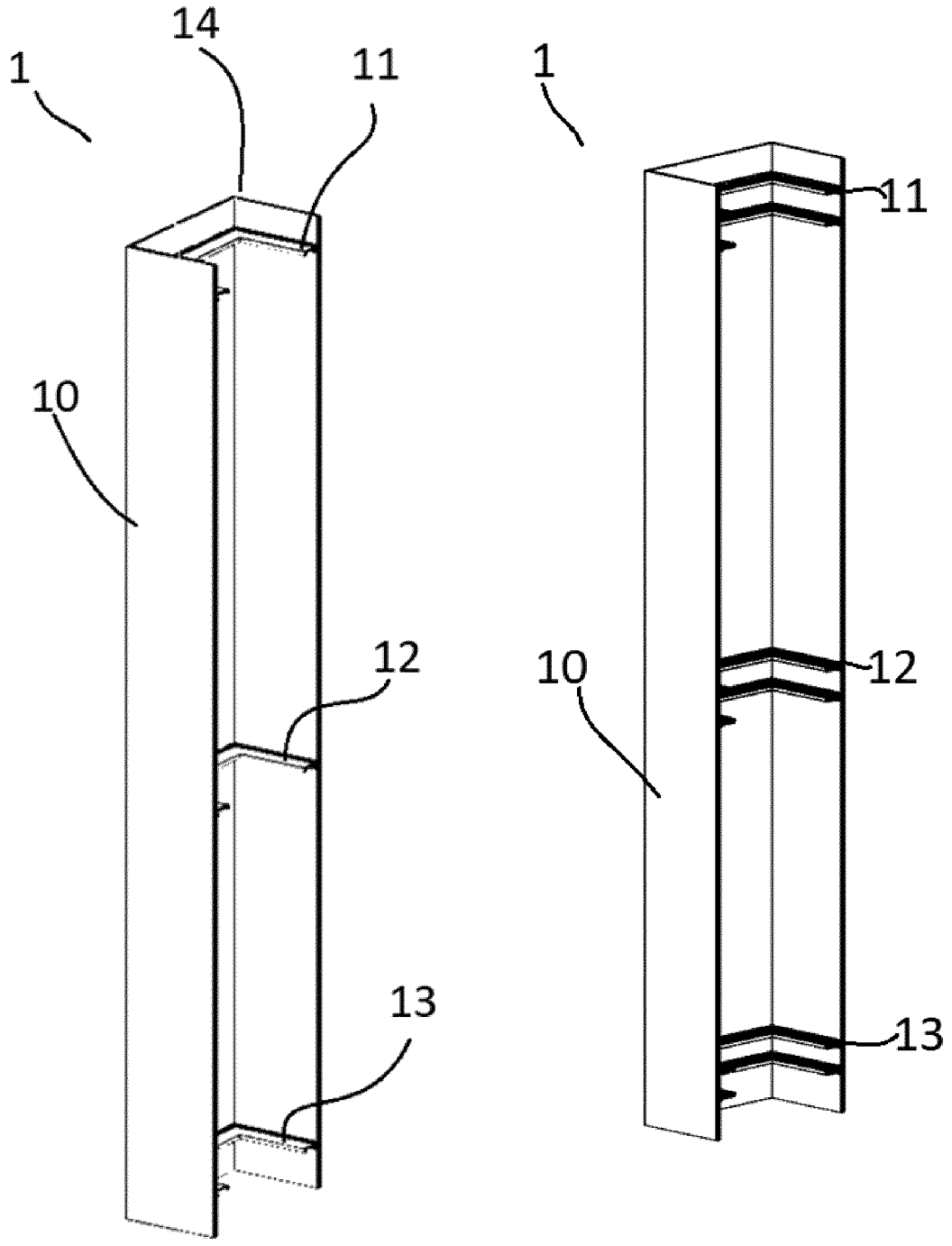
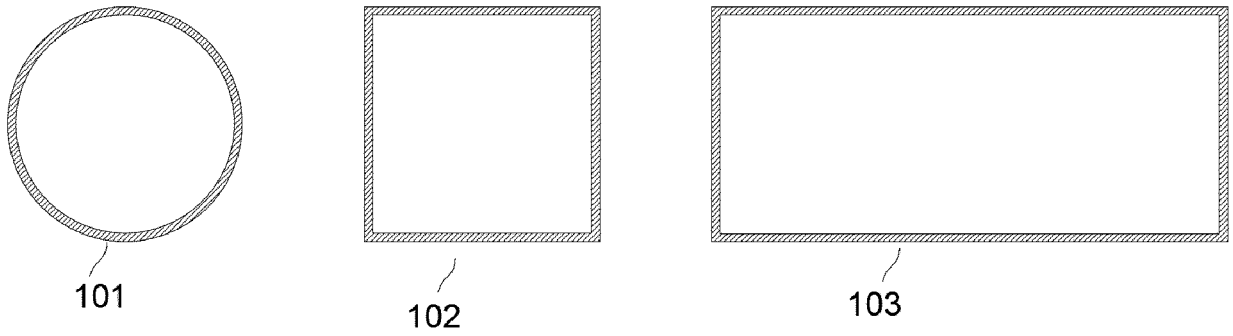


Fig. 1



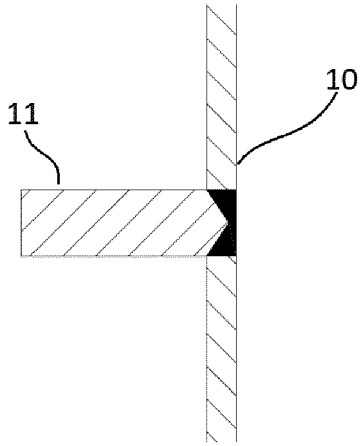
(a) (b)

Fig. 2



(a) (b) (c)

Fig. 3



(d)

Fig. 4

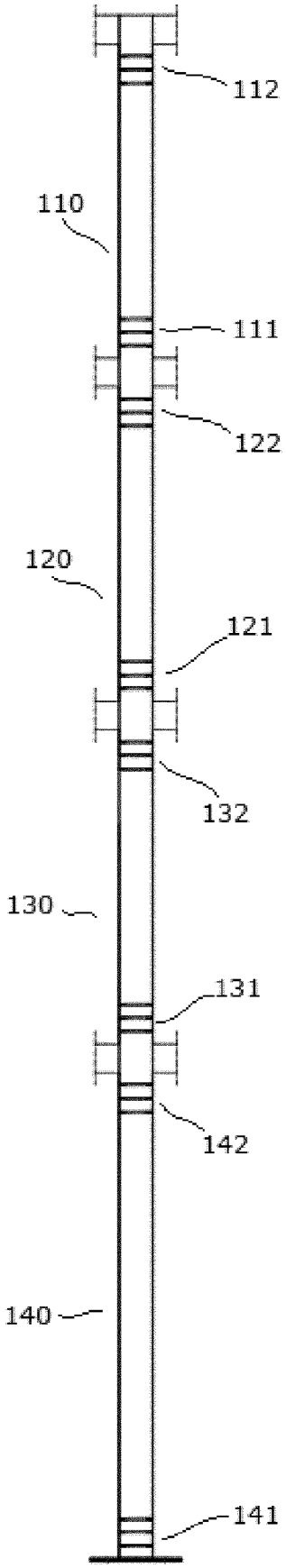


Fig. 5

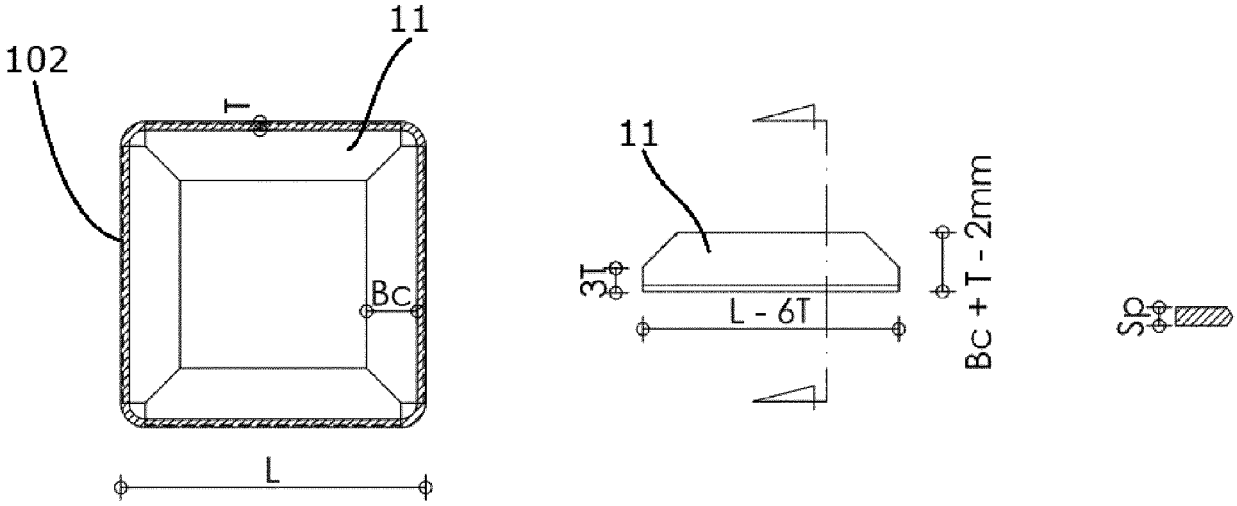

102
11
T
Bc
L
11
3T
L - 6T
Bc + T - 2mm
Sp

Fig. 6

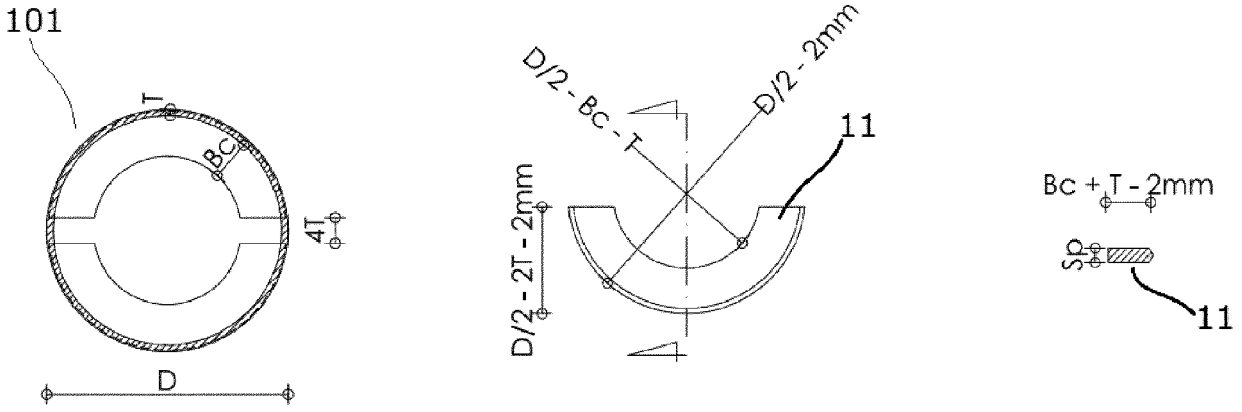
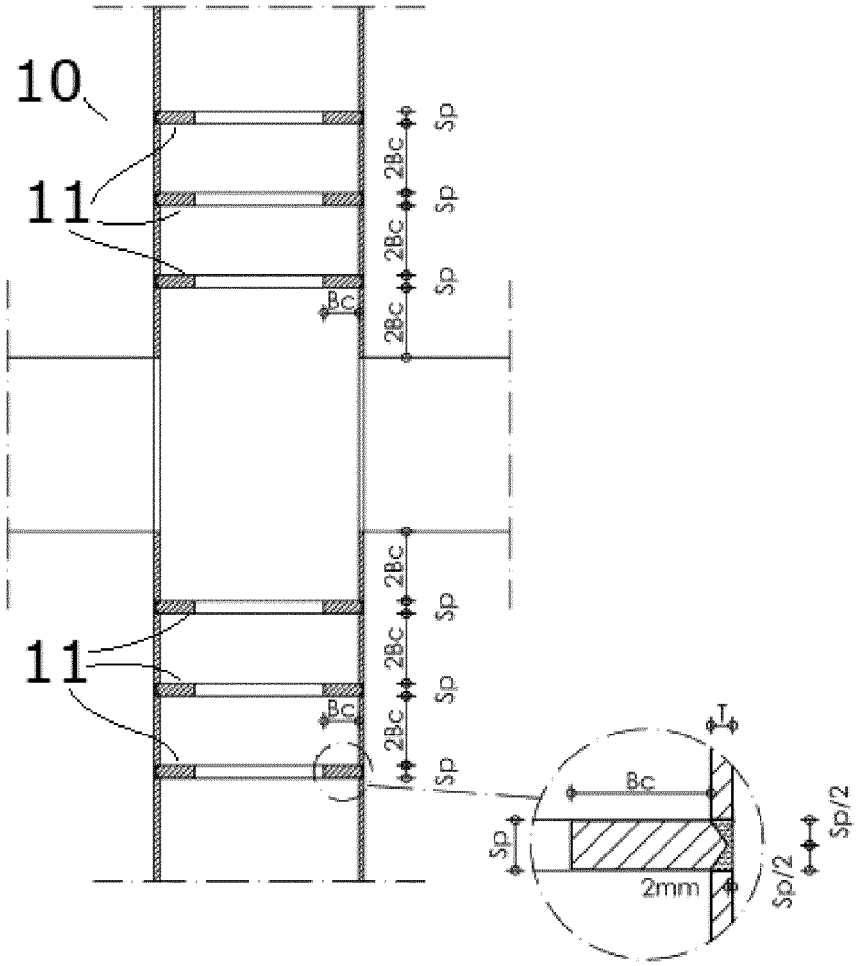

101
T
Bc
4T
D
D/2 - Bc - T
D/2 - 2mm
11
D/2 - 2T - 2mm
Bc + T - 2mm
Sp
11

Fig. 7



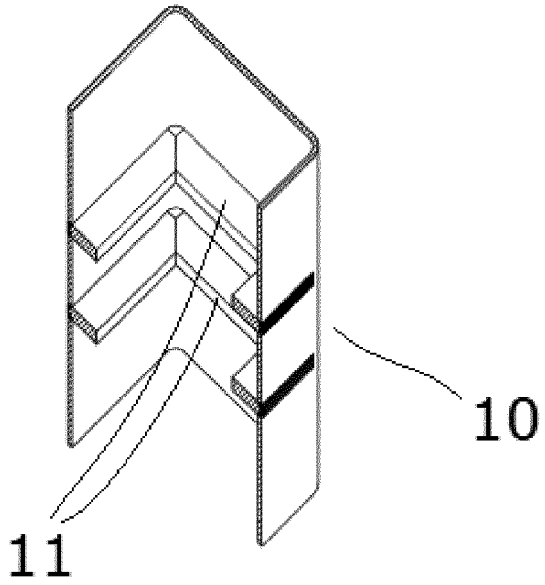


Fig. 8

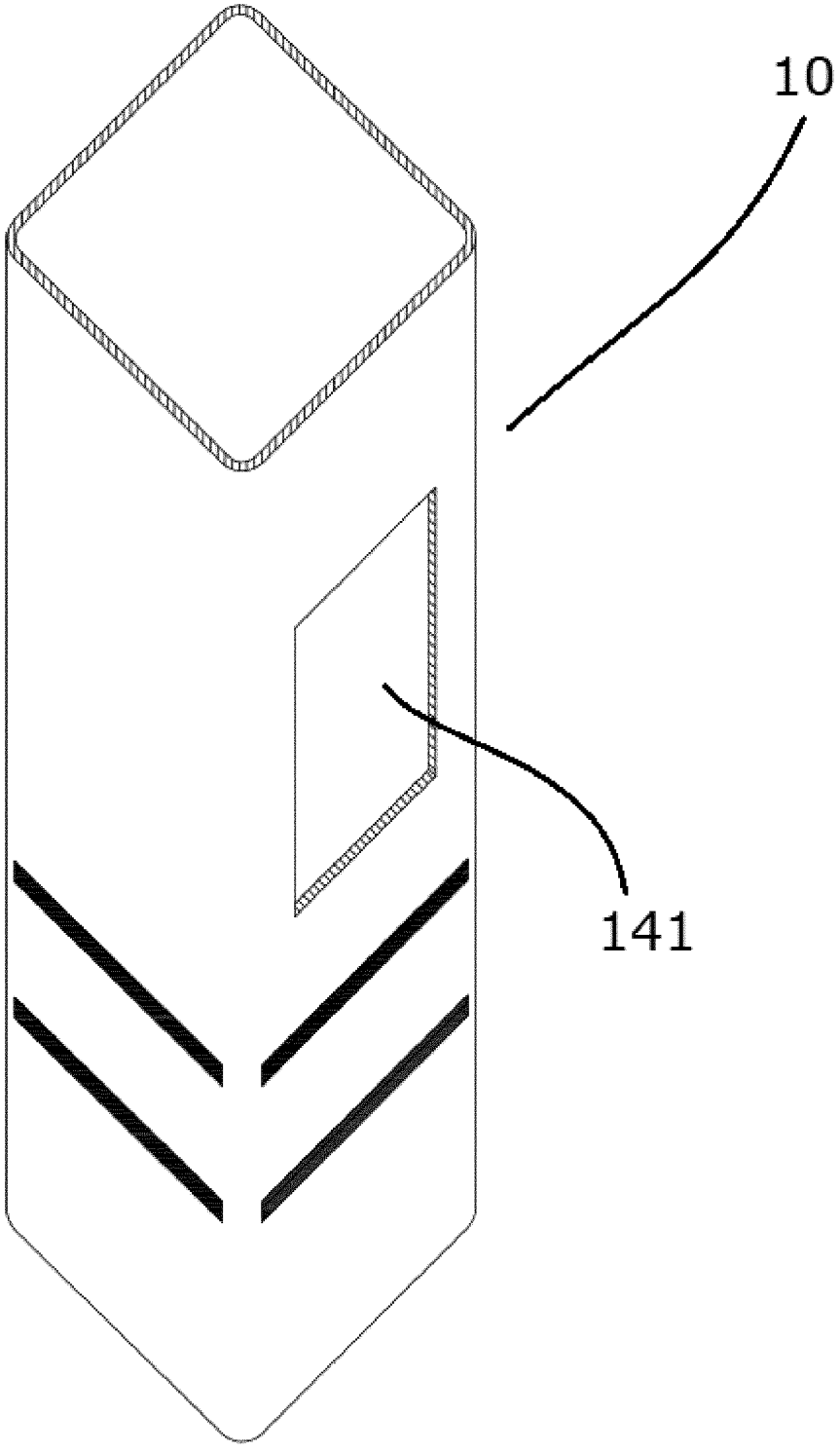


Fig. 9

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Application Number
EP 24 15 5575

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	US 2006/265992 A1 (HIRAGAKI MINORU [JP]) 30 November 2006 (2006-11-30) * figures 1-20 * * paragraph [0065] *	1,2,4, 6-10 3,5, 11-13	INV. E04C3/36
X	KR 101 518 622 B1 (POSCO [KR]; SHINSEGAE ENGINEERING & CONTRUCTION LTD [KR] ET AL.) 11 May 2015 (2015-05-11) * figures 1-13 *	1,9,10	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	6 June 2024	Petrinja, Etiel

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 24 15 5575

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06-06-2024

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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