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

(11) EP 4 063 580 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
28.09.2022 Bulletin 2022/39

(21) Application number: **21860326.4**

(22) Date of filing: **23.08.2021**

(51) International Patent Classification (IPC):
E04C 3/04 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
E04C 3/04; E04C 3/06; E04C 3/32

(86) International application number:
PCT/CN2021/114100

(87) International publication number:
WO 2022/042491 (03.03.2022 Gazette 2022/09)

(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 MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **25.08.2020 CN 202010866425**

(71) Applicant: **Lai, Cheng-Hsing**
Taichung City, Taiwan (TW)

(72) Inventor: **Lai, Cheng-Hsing**
Taichung City, Taiwan (TW)

(74) Representative: **Viering, Jentschura & Partner mbB**
Patent- und Rechtsanwälte
Am Brauhaus 8
01099 Dresden (DE)

(54) **METAL BEAM HAVING ASYMMETRICAL SECTION AND HAVING DAMAGE WARNING FUNCTION**

(57) A metal beam with asymmetric section and damage warning function includes a main body (10); the cross-sectional shape of the main body section defines a neutral axis (NA), and a pressure zone and a tension zone when subjected to a pure bending moment load. Each point of the main body (10) is arranged in a linear relationship with respect to the neutral axis (NA) within the elastic range. The cross-sectional shape of the main body section is on both sides of the neutral axis (NA) in an asymmetrical arrangement. The section modulus of the pressure zone of the main body section at the maximum bending moment is greater than the section modulus of the tension zone. Before the pressure zone bears a stress reaching the elastic limit to yield and enter plastic deformation, the tension zone has a stress exceeding the elastic limit and yield to enter plastic deformation first, so that the plastic deformation of the yielding tension zone provides a warning about a possibly occurring compressive shear damage of the pressure zone, forming the present invention.

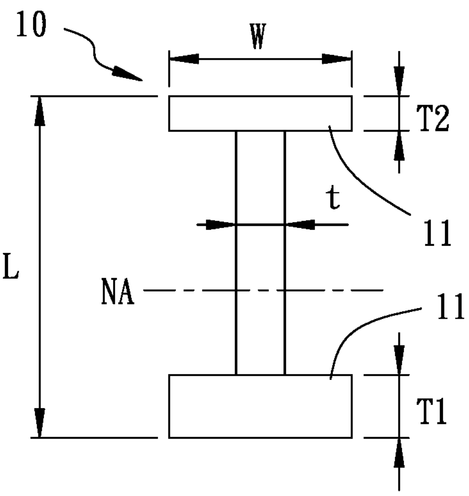

FIG. 4b

EP 4 063 580 A1

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention:

[0001] The present invention relates to beam structures, and more particularly, to a metal beam with asymmetrical section and damage warning function.

2. Description of the Related Art:

[0002] Current practice of selecting metal beams and columns in the industry has at least the following disadvantages:

1. Regarding the reinforced concrete deck (RC DECK), it has a considerable influence on the section modulus of the steel body. In terms of a symmetrical section, when the pressure zone and tension zone are subjected to the bending moment and axial pressure to reach the critical load, the pressure zone is the first to yield. However, the industry usually ignores the influence of reinforced concrete decks on the section modulus of the steel body. As a result, the section modulus of the tension zone at the end of the beam column is greater than that of the pressure zone and/or the pressure zone suffers a critical damage unexpectedly.
2. In addition, the industry also currently ignores the beam axial force (the pressure generated by the beam structure under a load). As for a steel beam with two fixed ends, a so-called axial pressure will be generated when it is loaded. As a result, the pressure zone would reach the elastic limit first unexpectedly.
3. Furthermore, regarding a cantilever steel beam with reinforced concrete deck, due to the combination of the deck and the beam, the section modulus of the tension zone would be greater than the section modulus of the pressure zone.

[0003] However, the current practice of selecting metal beams and columns in the industry, including ignoring the influence of reinforced concrete floor deck on the section modulus of the steel body, ignoring the beam axial force, and the situation of the section modulus of the tension zone being greater than the section modulus of the pressure zone due to the combination of the deck and the beam, possibly make the pressure zone of the beam reach the elastic limit and yield before the tension zone, causing a compressive shear damage to instantaneously occur, leading to serious consequences.

[0004] Therefore, the improvement by the present invention aims at solving and correcting the above-mentioned problems and disadvantages of conventional beam structure.

SUMMARY OF THE INVENTION

[0005] To improve the issues above, the present invention provides a metal beam with asymmetrical section and damage warning function. With an asymmetrical section arrangement for the section of the main body, the tension zone reaches the elastic limit and yield to enter a plastic deformation before the pressure zone, whereby the plastic deformation of the tension zone provides a warning about possibly occurring compressive shear damage of the pressure zone.

[0006] An embodiment of the present invention provides a metal beam with asymmetrical section and damage warning function, whose main body comprises a main body section. The cross-sectional shape of the main body section defines a neutral axis. The main body section defines a pressure zone and a tension zone when subjected to a pure bending moment load. Each point of the main body is arranged in a linear relationship with respect to the neutral axis within the elastic range, and the cross-sectional shape of the main body section is on both sides of the neutral axis in an asymmetrical arrangement. The pressure zone of the main body section at the maximum bending moment of the main body has a section modulus greater than the section modulus of the tension zone. Before the pressure zone bears a stress reaching the elastic limit to yield, the tension zone has a stress exceeding the elastic limit first and yield first, so that the plastic deformation of the yielding tension zone serves as a warning about the possibly occurring compressive shear damage of the pressure zone.

[0007] Therefore, because the shape of the main body section of the present invention is designed to be asymmetrically arrangement on both sides of the defined neutral axis, the section modulus of the pressure zone of the main body section at the maximum bending moment of the main body is greater than the section modulus of the tension zone. Thus, when the main body bears a load, the tension zone has reached the elastic limit to yield and begins to enter the plastic deformation, whereby the tension zone entering the plastic deformation stage provides a warning before the pressure zone undergoes a compressive shear damage, earning time for emergency treatments such as evacuation of personnel or structural reinforcement.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

Fig. 1 is a schematic view illustrating the support and uniformly distributed load of a metal beam in accordance with an embodiment of the present invention.

Fig. 2a is a schematic view of the H-shaped metal beam with asymmetric main body section in accordance with an embodiment of the present invention, wherein the main body section has identical widths and different thicknesses on two sides of the neutral axis.

Fig. 2b is a schematic view of the quadrangularly-shaped metal beam with asymmetric main body section in accordance with an embodiment of the present invention, wherein the main body section has identical widths and different thicknesses on two sides of the neutral axis.

Fig. 3a is another schematic view of the H-shaped metal beam with asymmetric main body section in accordance with an embodiment of the present invention, wherein the main body section has identical thicknesses and different widths on two sides of the neutral axis.

Fig. 3b is another schematic view of the quadrangularly-shaped metal beam with asymmetric main body section in accordance with an embodiment of the present invention, wherein the main body section has identical thicknesses and different widths on two sides of the neutral axis.

Fig. 4a is a sectional view of a conventional H-shaped metal beam with a symmetrical main body section, wherein the scale is not according to the actual specifications, but only for illustration.

Fig. 4b is a sectional view of an H-shaped metal beam with an asymmetrical main body section in accordance with an embodiment of the present invention, wherein the scale is not according to the actual specifications, but only for illustration.

Fig. 4c is another sectional view of an H-shaped metal beam with an asymmetrical main body section in accordance with an embodiment of the present invention, wherein the scale is not according to the actual specifications, but only for illustration.

Fig. 5 is a schematic view of a conventional H-shaped metal beam with a symmetrical section combined with a floor deck.

Fig. 6a is a schematic view illustrating the support and uniformly distributed load of another metal beam in accordance with an embodiment of the present invention.

Fig. 6b is a bending moment diagram of the metal beam of **Fig. 6a** bearing uniformly distributed load.

DETAILED DESCRIPTION OF THE INVENTION

[0009] The aforementioned and further advantages and features of the present invention will be understood by reference to the description of the preferred embodiment in conjunction with the accompanying drawings where the components are illustrated based on a proportion for explanation but not subject to the actual component proportion.

[0010] Referring to **Fig. 1** to **Fig. 6b,** the present invention provides a metal beam with asymmetrical section and damage warning function, as shown by **Fig. 1,** comprising a main body **10.** The main body **10** in the embodiment is a transverse beam, which has a plurality of supports **20** for bearing a load and generates a plurality of regions with positive and negative bending moments.

[0011] The main body **10** described in the present invention comprises a main body section, whose cross-sectional shape is asymmetrically arranged on two sides of a defined neutral axis **NA,** so as to for an asymmetrical section. This main body section defines a pressure zone and a tension zone when subjected to a pure bending moment load. Each point of the main body is arranged in a linear relationship with respect to the neutral axis **NA** within the elastic range. The pressure zone of the main body section at the maximum bending moment of the main body **10** has a section modulus greater than the section modulus of the tension zone. Before the pressure zone bears a stress reaching the elastic limit to yield, the tension zone has a stress exceeding the elastic limit first and yield first, so that the tension zone entering the plastic deformation stage provides a warning about a possible compressive shear damage of the pressure zone after the tension reaches the elastic limit and deforms. The elastic limit refers to the critical limit of the bearable stress (both tension and pressure) of the metal beams and columns before yielding. In other words, when the stress exceeds the elastic limit, the metal beams and columns begin to yield and enter a plastic deformation.

[0012] The main body **10** is preferably an H-shaped steel beam or a quadrangularly-shaped steel beam (as shown in **Fig. 2a** to **Fig. 3b),** and the cross-sectional shape of the main body section is asymmetrical one two sides of the neutral axis **NA.** In an embodiment, the widths of the main body section one the two sides are the same, but the thicknesses thereof are thicker on one side and thinner on the other side (as shown in **Fig. 2a** to **Fig. 2b),** wherein the thicker side is the pressure zone at the place of the maximum bending moment and has a larger section modulus; and the thinner side is the tension zone at the place of the maximum bending moment and has a smaller section modulus. The main body **10** of the present invention is not limited to having the aforementioned differences in thickness. For example, in another embodiment, the main body section thicknesses of the main body on two sides are same, but the widths thereof are wider on one side and narrower on the other side (as shown in **Fig. 3a** to **Fig. 3b).** In such case, the wider side is the pressure zone with a larger section modulus, and the narrower side is the tension zone with a smaller section modulus.

[0013] For example, an H-shaped metal steel beam is provided in a symmetrical arranged on two sides of the central axis NA, with the specification of the main body section being H400L*200W*7t* 11T (as shown by **Fig. 4a,** wherein **L** is height; **W** is width; t is web thickness; **T** is upper and lower flange thickness). Also, an H-shaped metal steel beam is provided in an asymmetrical arranged on two sides of the central axis **NA** (as shown by **Fig. 4b),** with the specification of the main body section being H400L*200W*7t*12T1/10T2 (**T1** is the pressure zone at the place of the maximum bending moment; **T2** is the tension zone at the place of the maximum bending moment). Also, still another H-shaped metal steel beam is provided in an asymmetrical arranged on two sides of the central axis **NA** (as shown by **Fig. 4c),** with the specification of the main body section being H400L*200W*7t*15T1/7T2. Regarding these three H-shaped metal steel beams, the sectional area, unit weight, moment of inertia Ix, section modulus Sx, and the ratio of section modulus Sx thereof are shown in Table 1 below:

Table 1

Model	Section steel type (mm)	Sectional Area(cm^2)	Unit Weight kgf/m	Moment of Inertia I_x (cm^4)	Section Modulus S_x (cm^3)	S_x Ratio
1	H400 L*200 W*7 t*11 T	70.46	56.1	19800	990	100%
2	H400 L *200 W *7 t *12T1/10T2			19710	1039/937	105%/ 95%
3	H400 L *200 W *7 t *15T1/7T2			18361	1158/761	117%/ 77%

[0014] As shown in Table 1, regarding models 1, 2, and 3, the cross-sectional area thereof are all 70.46 cm^2, and the unit weight are all 56.1 kgf/m. The section modulus (Sx) of model 1 is 990 cm^3, and the ratio is set as 100%. Comparing model 2, under the condition that the sectional area and unit weight remain unchanged, only the thickness of the upper and lower flanges 11 are modified according to the specifications of the main body section, so as to be asymmetrical on two sides of the neutral axis NA, wherein the upper and lower flanges thicknesses are modified into 10 mm and 12 mm, respectively. In the case, the section modulus of model 2 on the flange 11 side (pressure zone) having the thickness of 12 mm is increased to 1039 cm^3, which is 5% higher than that of model 1. Meanwhile, the section modulus on the flange 11 side (tension zone) having thickness of 10 mm is reduced to 937 cm^3, which is 5% less than that of the model 1. Comparing the model 3, the thicknesses of the upper and lower flanges 11 are modified according to the specifications of the main body, so as to be asymmetrical on two sides of the neutral axis NA. That is, the thicknesses of the upper and lower flanges 11 are changed to 7 mm and 15 mm, respectively. In such case, the section modulus of model 3 on the flange 11 side (pressure zone) having the thickness of 15 mm is increased to 1158 cm^3, which is 17% higher than that of model 1. Meanwhile, the section modulus on the flange 11 side (tension zone) having thickness of 7 mm is reduced to 761 cm^3, which is 23% less than that of the model 1. It can be seen that when such main body section is used for structures with fixed loading direction at critical points (such as construction beams and side columns), the load-bearing capacity on the side with a relatively large section modulus can be improved. Meanwhile, the other side with a relatively smaller section modulus, if in a tension status, will yield and undergoes deformation damage after exceeding the elastic limit, thereby providing a warning of compressive shear damage.

[0015] Regarding the main body **10** shown in **Fig. 1,** when a floor deck **D** is laid on the upper flange **11** and fixed with shear stud **30,** if the shear stud **30** has sufficient density and strength, the floor deck **D** is combined with the main body **10** through the shear stud **30** to form a T-shaped integral beam (as shown by **Fig. 5).** At this time, the span section between the main body **10** and the support **40** is presented as a positive bending moment, with the pressure zone on the upper side and the tension zone on the lower side. Because the upper flange **11** is constrained by the floor deck **D,** the section modulus of the pressure zone increases, thereby improving the carrying capacity thereof. According to the structural mode, the bending moment relationship can be expressed in accordance with mechanics of material (as shown in formula 1), and as shown in **Fig. 6a,** the supports **40** (also presented by end points A and B) on two sides and the middle point of the span are critical points (end points A and B are characteristic critical points). Also, as shown in **Fig. 6b,** both $\mathbf{M_A}$ and $\mathbf{M_B}$ are presented as negative bending moments, and $\mathbf{M_{max}}$ is presented as positive bending moment.

$$\text{Formula 1: } M_A = M_B = 2M_{max} = \frac{\omega l^2}{12}$$

[0016] However, the main body **10** is presented as a negative bending moment at the support **40,** with the tension zone on the upper side and the pressure zone on the lower side. The upper flange **11** is also constrained by the floor deck **D,** which in turn causes the section modulus of the tension zone to increase, thereby improving the bearing capacity thereof. As a result, the pressure zone at the support **40** first exceeds the elastic limit instead and breaks. Accordingly, it is known that when the main body **10** is combined with the floor deck **D,** the section modulus of the tension zone of the main body **10** is increased, thus improving the load bearing capacity thereof, causing the pressure zone to exceed the elastic limit first and may instantaneously undergo a compressive shear damage. This can greatly affect the design safety of the floor structure. However, according to the structural analysis and design method commonly used in the current construction industry, the combination of the floor with the main body **10** is regarded as non-contributing and therefore ignored. So, when used over limit, it may cause the risk of instantaneous damage of the pressure zone.

[0017] For example, a main body **10** has the aforementioned supports **40** at only two ends thereof, with the span between the two supports **40** being a span section, and the support **40** section being a support section. The main body section of the body **10** has the aforementioned specifications of H400L*200W*7t* 11T, and the uniformly distributed load of the main body **10** is 3000 kgf/m. Also, the upper flange **11** of the main body **10** is laid with a floor deck **D** which is fixed by shear stud **30.** In such case, if the uniformly distributed load is increased to 3300 kgf/m in an application over limit, as shown in Table 2, the section modulus of the tension zone of the support section increases, so that the load bearing capacity is improved, which results in that the stress ratio is prevented from exceeding the elastic limit. Instead, the stress ratio of the pressure zone of the support section exceeds the elastic limit to be broken. (In Table 2, σ represents the maximum stress of the section; fy represents the yield stress of the metal material, which is hypothetically 2500 kgf/cm^2; $S_{pressure}$ and $S_{tension}$ represent the section moduli of the pressure zone and tension zone, which are same in Tables 3, 4, and 5 below.)

Table 2

Section modulus and stress ratio σ/fy	Combination of main body and floor deck having original section	
	Support section	Span section
Section modulus $S_{pressure}$	1063	3222
Section modulus $S_{tension}$	1197	1533
Stress ratio of pressure zone	**-1.034**	0.171
Stress ratio of tension zone	-0.919	0.359

[0018] Still in an application over limit with the uniformly distributed load increased to 3300 kgf/m, the main body section of the main body **10** is replaced by the specifications of H400L*200W*7t* 14T1/8T2 in an asymmetrical section arrangement. In such case, as shown in **Fig. 3,** although the load bearing capacity of the tension zone of the support section is improved due to the increased section modulus, the cross-sectional shape of the main body section of the main body **10** is asymmetrical arranged on two sides of the neutral axis **NA.** Therefore, for the main body **10** combined with the floor deck **D,** the section modulus of the pressure zone is still greater than the section modulus of the tension zone, so that the stress ratio of the pressure zone of the support section is prevented from exceeding the elastic limit in an over limit application; instead, the stress ratio of the tension zone of the support section exceeds the elastic limit first and yields to under a plastic deformation damage, thereby still providing a warning about a possibly occurring unexpected instantaneous compressive shear damage of the pressure zone.

Table 3

Section modulus and stress ratio σ/fy	Combination of main body and floor deck having asymmetric section	
	Support section	Span section
Section modulus $S_{pressure}$	1224	2640
Section modulus $S_{tension}$	1021	1625

(continued)

Section modulus and stress ratio σ/fy	Combination of main body and floor deck having asymmetric section	
	Support section	Span section
Stress ratio of pressure zone	-0.899	0.208
Stress ratio of tension zone	**-1.078**	0.338

[0019] Alternatively, in an application without going over limit with the uniformly distributed load being 2750 kgf/m, while the upper flange **11** of the main body **10** is also laid with a floor deck **D** which is fixed by the shear stud **30,** according to commonly applied structural analysis in the current industry (contribution of floor deck D ignored), the specifications above RH400L*200W*7t* 11T would be used, with the stress ratio shown in Table 4:

Table 4

Section modulus and stress ratio σ/fy	Main body having original section with floor deck contribution ignored	
	Support section	Span section
Stress ratio of pressure zone	-0.921	0.460
Stress ratio of tension zone	-0.921	0.460

[0020] Accordingly, under the same conditions, if the metal beam with asymmetrical section of the present invention is selected instead, plus the contribution of floor deck D in accordance with the actual situation, the specifications of the main body section of the main body **10** can be reduced to the specifications of H380L*190W*7t*14T1/8T2 asymmetrical section arrangement. As shown in Table 5, the stress ratio of the pressure zone and the tension zone are both within the elastic range (stress ratio ≤ 1). Also, when there is a floor deck **D,** the section modulus of the pressure zone is greater than that of the tension zone, which still provides a higher load bearing capacity. Even in the case of application over limit, the stress ratio of the tension zone of the support section would exceed the elastic limit first and yield to undergo a plastic deformation damage. It can not only provide a warning about possibly occurring instantaneous compressive damage, but also reduce the unit weight due to the reduction of specifications (the unit weight being reduced by 6.4% compared to the specifications of H400L*200W*7t* 11T). Also, as long as the structural safety prerequisite is met, the material cost of the main body **10** can be reduced.

Table **5**

Section modulus and stress ratio σ/fy	Combination of main body and floor deck having asymmetric section	
	Support section	Span section
Section modulus $S_{pressure}$	1109	2567
Section modulus $S_{tension}$	935	1507
Stress ratio of pressure zone	-0.830	0.179
Stress ratio of tension zone	**-0.984**	0.305

[0021] From the above description, the characteristics of the present invention are clear as follows:

1. When the main body **10** of the present invention bears a critical loading, because the shape of the main body section of the present invention is designed to be asymmetrically arrangement on both sides of the defined neutral axis, the section modulus of the pressure zone of the main body section at the maximum bending moment of the main body **10** is greater than the section modulus of the tension zone. Thus, when the main body **10** bears a load, the tension zone has reached the elastic limit to yield and begins to enter the plastic deformation, thereby providing a warning before the pressure zone undergoes a compressive shear damage, thus beneficial for earning time for emergency treatments such as evacuation of personnel or structural reinforcement.
2. The current industry usually neglects the effects of reinforced concrete floor deck on the modules of the steel body or ignores the beam axial force (the pressure generated by the beam structure under a load), which causes the issues of the section modulus of the tension zone of the main beam column end being greater than that of the

pressure zone and/or the pressure zone undergoing critical damage first unexpectedly, or the issue of a cantilever steel beam of a floor deck D, due to the combination of the deck and the beam, having a section modulus of the tension zone greater than the section modulus of the pressure zone. Such issues can be resolved by use of the main body section of the main body **10** of the present invention, which is designed in an asymmetrical arrangement, so as to correct abovementioned improper construction practice.

3.The main body section of the main body **10** of the present invention has an asymmetrical section design, wherein the tension zone, after reaching the elastic limit, yields and begins to enter the plastic deformation, thereby not only providing a warning before the pressure zone undergoes a compressive shear damage, but also lowering the unit weight with the reduction of main body section specifications. Thus, as long as the structural safety prerequisite is met, the material cost of the main body **10** can be reduced.

Claims

1. A metal beam with asymmetric section and damage warning function, comprising a main body (10) and a floor deck (D); a flange (11) on the main body (10) being fixed with the floor deck (D) through a shear stud (30), so as to form an integral beam; the main body (10) comprising a main body section; the main body section having a cross-sectional shape which defines a neutral axis (NA), and the main body section defining a pressure zone and a tension zone when subjected to a pure bending moment load; each point of the main body (10) being arranged in a linear relationship with respect to the neutral axis (NA) within an elastic range; the cross-sectional shape of the main body section being asymmetrically arranged on both sides of the neutral axis (NA); the pressure zone of the main body section at the maximum bending moment of the main body (10) having a section modulus greater than a section modulus of the tension zone; before the pressure zone bears a stress reaching the elastic limit to yield, the tension zone bears a stress exceeding the elastic limit to yield first and enters a plastic deformation, such that the plastic deformation of the tension zone provides a warning about a possibly occurring compressive shear damage of the pressure zone.

2. The metal beam with asymmetric section and damage warning function of claim 1, wherein the two sides of the main body section asymmetrically arranged on two sides of the neutral axis (NA) have a same width (W), but the thicknesses (T) thereof are thicker on one side and thinner on the other side.

3. The metal beam with asymmetric section and damage warning function of claim 1, wherein the two sides of the main body section asymmetrically arranged on two sides of the neutral axis (NA) have a same thickness (T), but the widths (W) thereof are wider on one side and narrower on the other side.

4. The metal beam with asymmetric section and damage warning function of claim 1, wherein the main body (10) is a transverse beam which is supported by a plurality of supports (20) for bearing a load.

5. The metal beam with asymmetric section and damage warning function of claim 1, wherein the main body (10) section is formed in an H shape or a quadrangular shape.

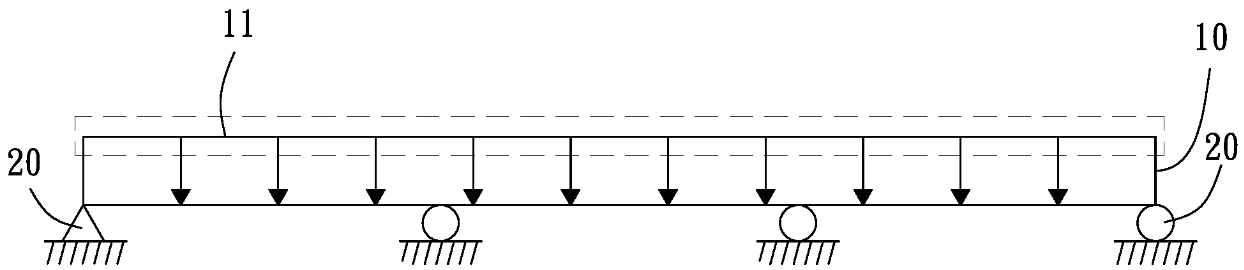

FIG. 1

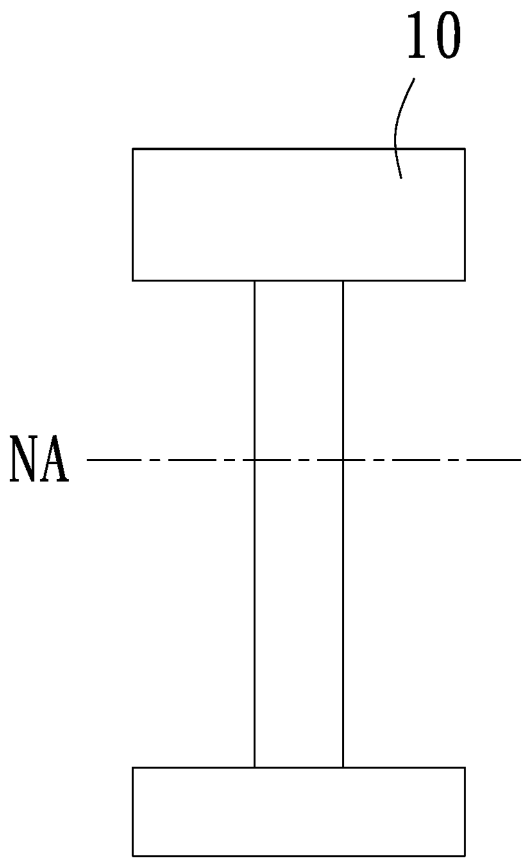

FIG. 2a

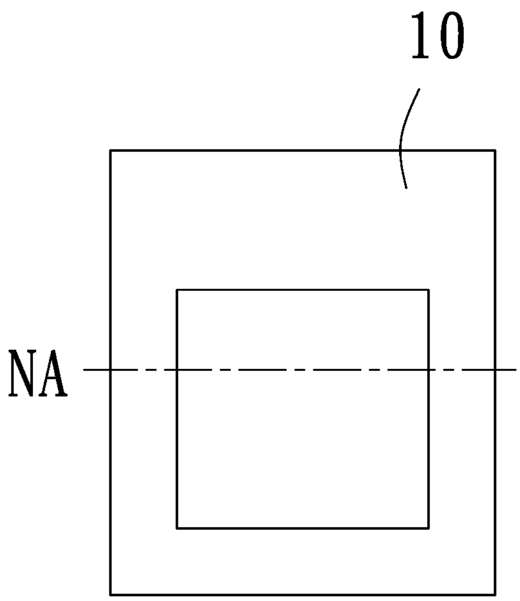

FIG. 2b

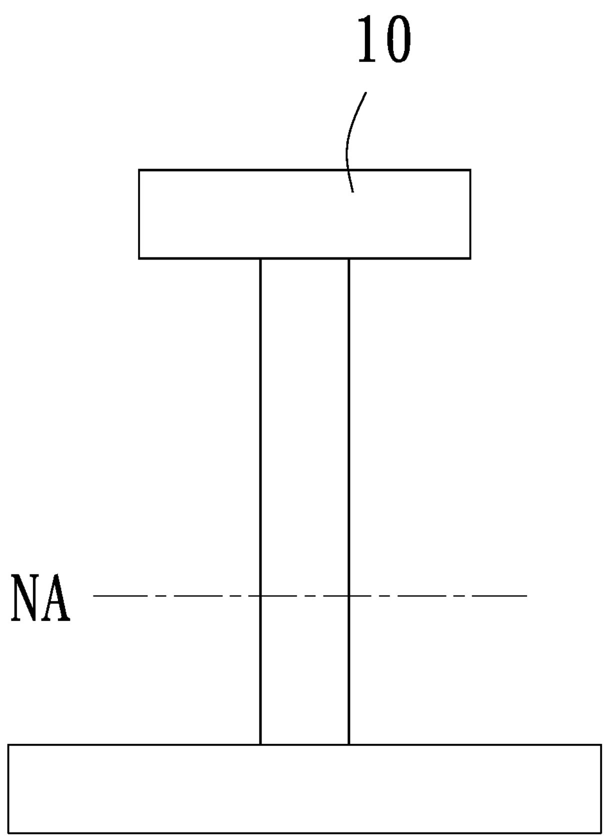

FIG. 3a

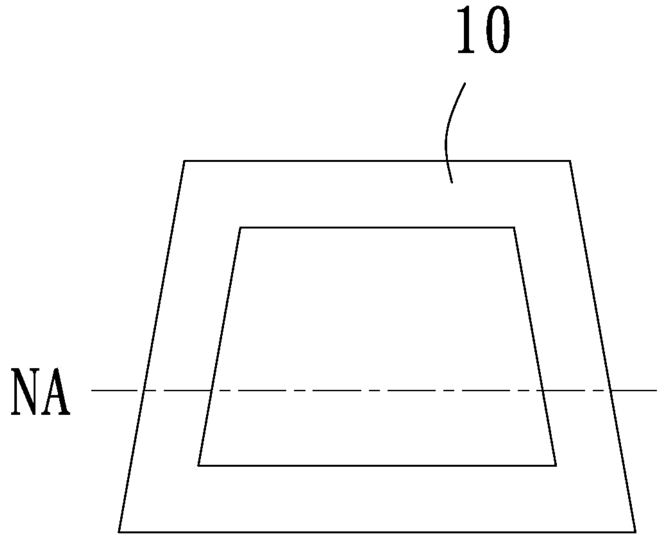

FIG. 3b

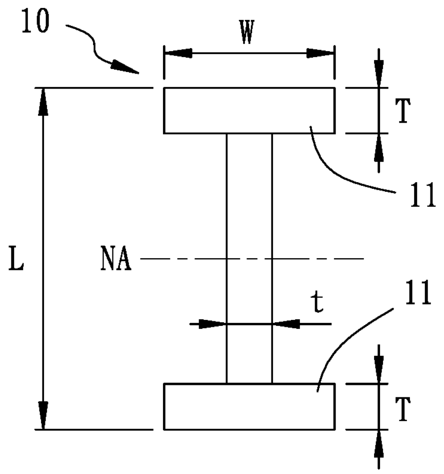

FIG. 4a

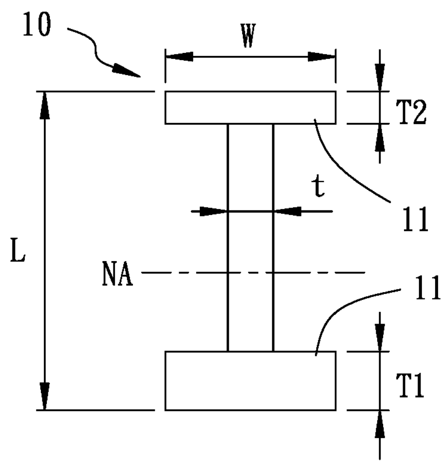

FIG. 4b

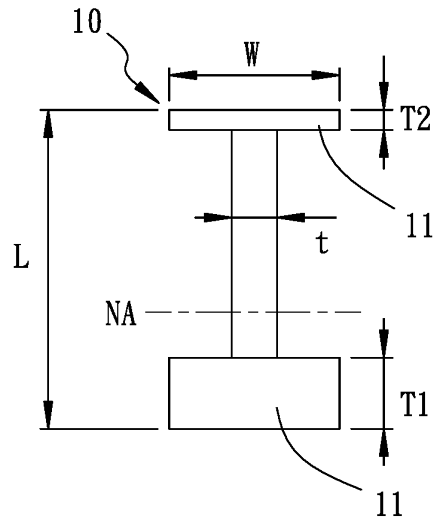

FIG. 4c

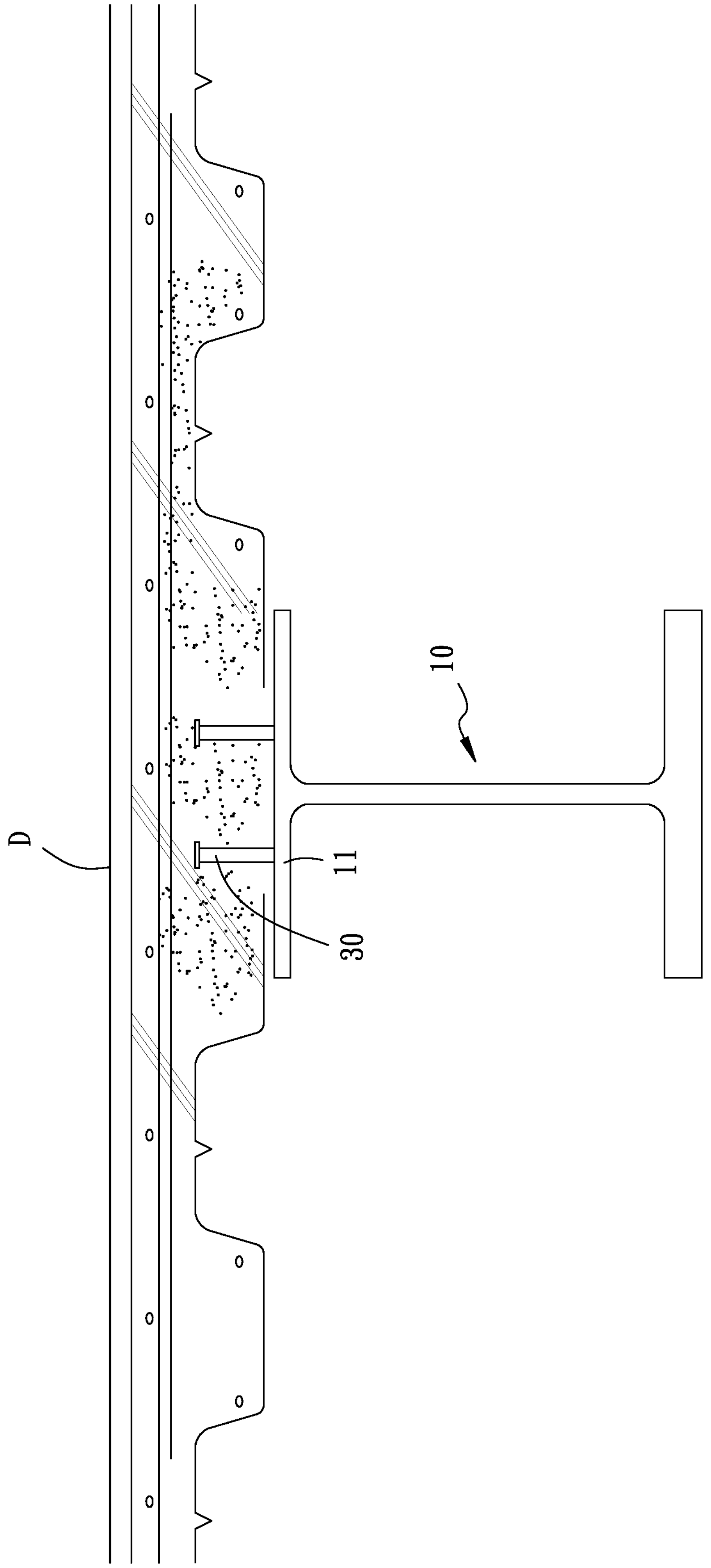

FIG. 5

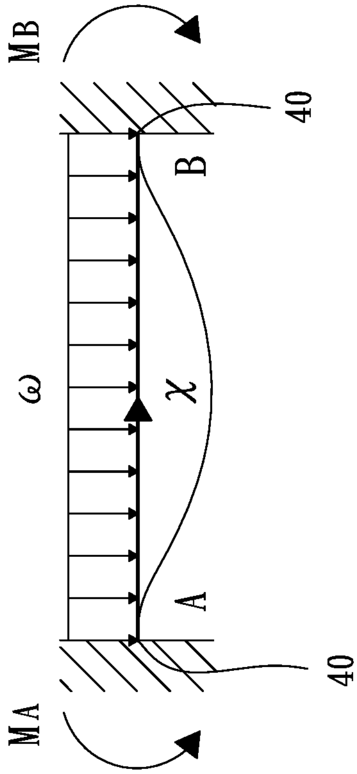

FIG. 6a

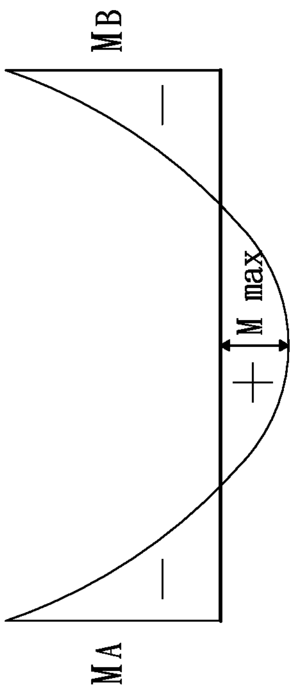

FIG. 6b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2021/114100

A. CLASSIFICATION OF SUBJECT MATTER

E04C 3/04(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS, CNKI, 超星读秀, VEN: 梁, 钢梁, 金属梁, 中和轴, 中性轴, 中性面, 中性层, 非对称, 不对称, 偏心, 偏移, 拉力区, 压力区, 脆性破坏, 延性破坏, 提醒, 提示, 醒目, 报警, 预警, 警示, 断面, 截面, 剖面, beam?, steel, metal, neutral w axis, section, offset, eccentric+, bias, partiality, asymmetr+, dissymmetric, brittle, +ductile, pull+, tension, tensile, pressure, stress, warn+, failure, fracture, rupture, damage, destruction

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	曹平周 等 (CAO, Pingzhou et al.). "梁的整体稳定 (non-official translation: Overall Beam Stability)" *钢结构 (Steel Construction),* 31 October 1999 (1999-10-31), p. 105	1-5
Y	CN 106703184 A (BEIJING UNIVERSITY OF TECHNOLOGY) 24 May 2017 (2017-05-24) description paragraph 0032, abstract	1-5
A	CN 101122158 A (JIANGSU MEIKAILONG STEEL CO., LTD.) 13 February 2008 (2008-02-13) entire document	1-5
A	CN 102176990 A (AMONIX INC.) 07 September 2011 (2011-09-07) entire document	1-5
A	CN 102209821 A (KOREA INST CONSTRUCTION TECH) 05 October 2011 (2011-10-05) entire document	1-5
A	CN 203097040 U (ZHU, Chongzhao) 31 July 2013 (2013-07-31) entire document	1-5

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 October 2021	**02 November 2021**

Name and mailing address of the ISA/CN	Authorized officer
China National Intellectual Property Administration (ISA/CN) **No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088** **China**	
Facsimile No. **(86-10)62019451**	Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2021/114100

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1888857 B1 (ASD WESTOK LTD.) 13 April 2011 (2011-04-13) entire document	1-5
A	JP 2000248685 A (TOMOE CORP.) 12 September 2000 (2000-09-12) entire document	1-5
A	KR 20100076578 A (RESEARCH INSTITUTE OF INDUSTRIAL SCIENCE AND TECHNOLOGY) 06 July 2010 (2010-07-06) entire document	1-5

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2021/114100

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	106703184	A	24 May 2017	None			
CN	101122158	A	13 February 2008	CN	101122158	B	29 June 2011
CN	102176990	A	07 September 2011	US	2010050569	A1	04 March 2010
				WO	2010027869	A1	11 March 2010
				US	7877937	B2	01 February 2011
				EP	2331277	A1	15 June 2011
				ZA	201101563	B	26 October 2011
				EP	2331277	A4	16 November 2011
CN	102209821	A	05 October 2011	US	2011247297	A1	13 October 2011
				JP	5143956	B2	13 February 2013
				US	8281534	B2	09 October 2012
				CN	102209821	B	09 July 2014
				JP	2012508333	A	05 April 2012
				WO	2010053220	A1	14 May 2010
CN	203097040	U	31 July 2013	None			
EP	1888857	B1	13 April 2011	ES	2362367	T3	04 July 2011
				GB	0510975	D0	06 July 2005
				AU	2006254011	B2	08 September 2011
				CY	1111685	T1	07 October 2015
				US	8028493	B2	04 October 2011
				CA	2631625	C	22 October 2013
				DE	602006021298	D1	26 May 2011
				AT	505604	T	15 April 2011
				EP	1888857	A1	20 February 2008
				NZ	563784	A	26 November 2010
				AU	2006254011	A1	07 December 2006
				ZA	200710134	A	25 September 2008
				US	2009100794	A1	23 April 2009
				WO	2006129057	A1	07 December 2006
				ZA	200710134	B	25 September 2008
				CA	2631625	A1	07 December 2006
JP	2000248685	A	12 September 2000	None			
KR	20100076578	A	06 July 2010	None			

Form PCT/ISA/210 (patent family annex) (January 2015)