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(71) Applicant(s):
NET ZERO PROJECTS LIMITED
Mercury House, 19-21 Chapel Street, Marlow, SL7 3HN, United Kingdom

(72) Inventor(s):
Andrew Robert Coward

(74) Agent and/or Address for Service:
Forresters IP LLP
Port of Liverpool Building, Pier Head, LIVERPOOL, L3 1AF, United Kingdom

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(56) Documents Cited:
GB 0650030 A **WO 2009/001388 A1**
CA 002332751 A1 **CN 112982787 A**
CN 103883054 A **CN 101285329 A**
NL 001033619 A1

(58) Field of Search:
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Other: **WPI, EPODOC**

(54) Title of the Invention: **A structural slab and method of manufacture**
Abstract Title: **A structural concrete slab with reinforcing webs and cords and method of manufacture using 3D printing**

(57) A slab has a planar flange 1, e.g. a flat rectangular reinforced concrete slab, connected to and separated from chords 3 by webs 2, the flange and webs being in compression and the chords comprising tensions members, wherein the webs comprise an additive material. Also claimed is a method of manufacturing a slab having a flange and webs including 3D printing the webs and 3D printing a boundary frame for the flange before pouring material inside the boundary to form the flange. The webs may be solid or hollow, and may be triangular in cross section. The cords may be steel cables, steel ropes, chain, solid bars, carbon fibre rods or similar, and may have tension members, terminating in hooks or eyes for attaching to anchors located in the flange. The slab can be assembled/ constructed on site e.g. if too large to be prefabricated and transported by road, and may be used in place of a conventional double T slab. The 3D printing method allows bespoke shapes and sizes of slabs with a suitable arrangement of webs and cords to provide the required strength.

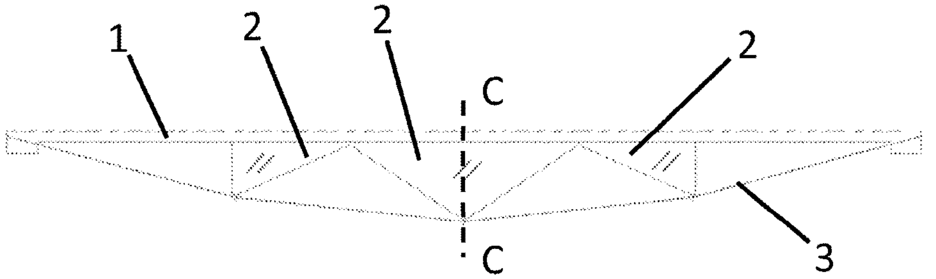

Fig. 1A

GB 2619012 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

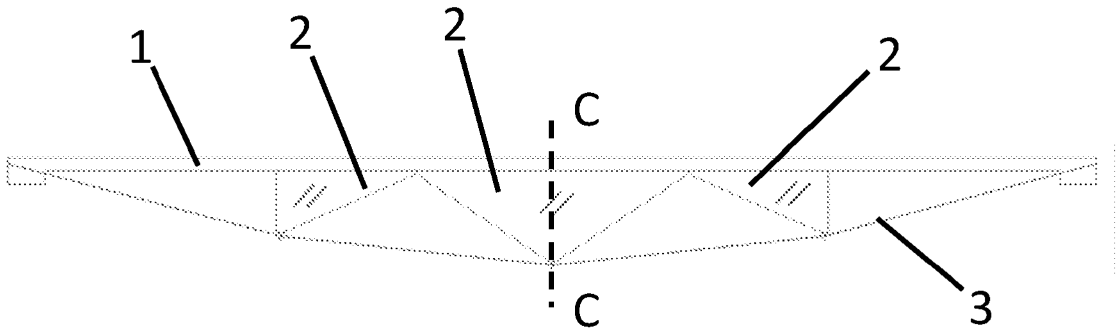

Fig. 1A

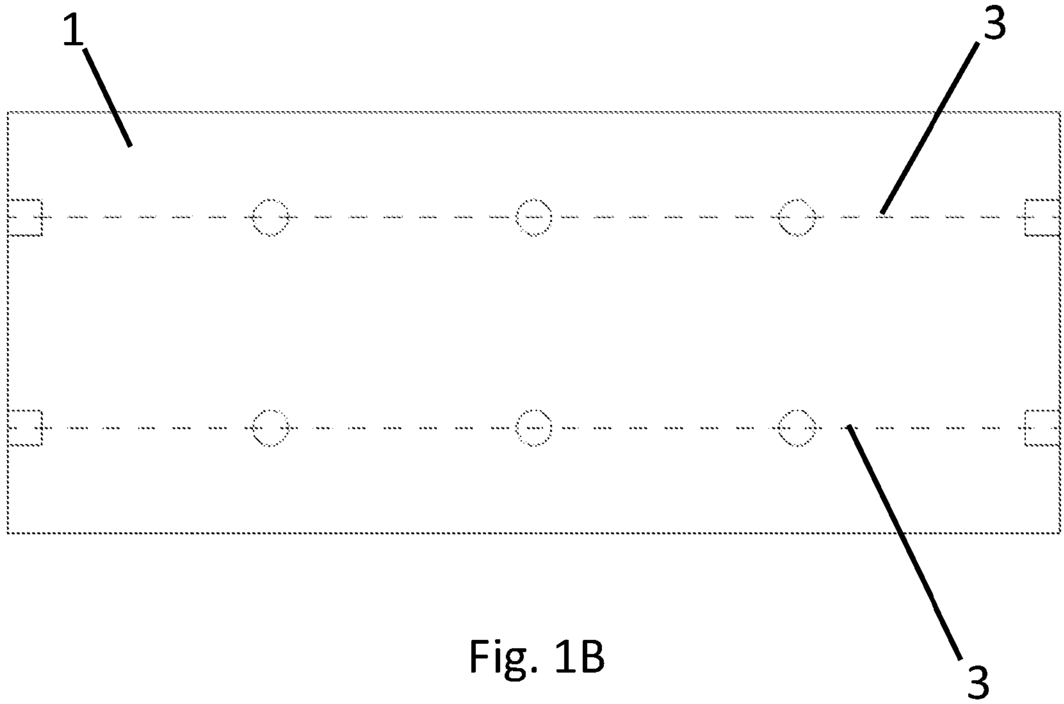

Fig. 1B

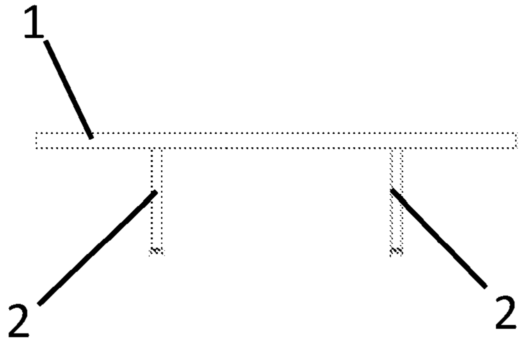

Fig. 1C

14 06 22

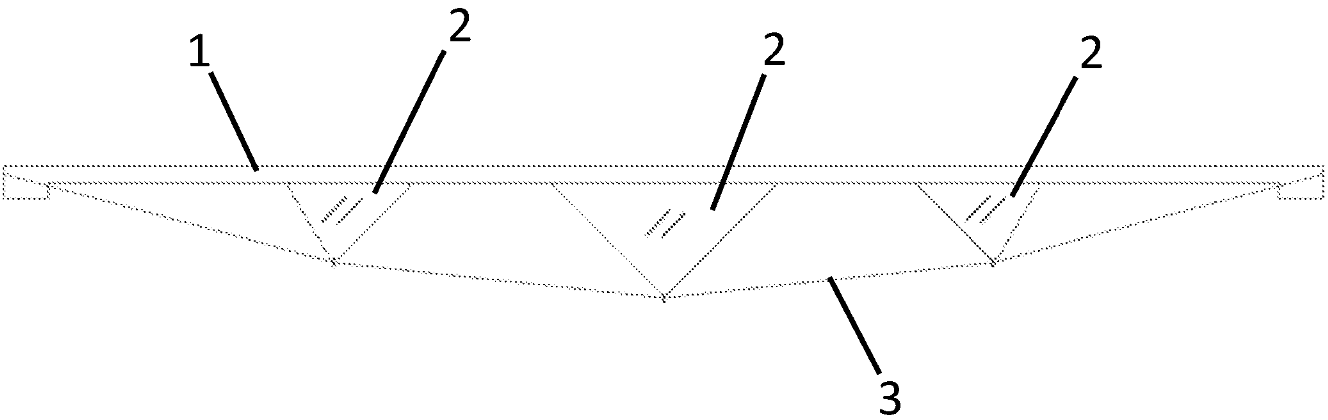

Fig. 2A

14 06 22

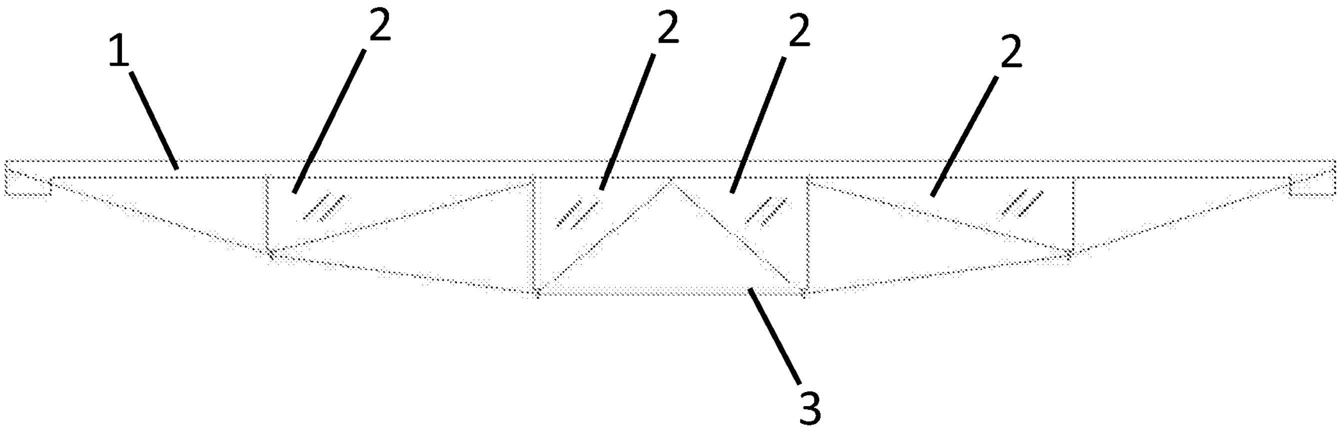

Fig. 2B

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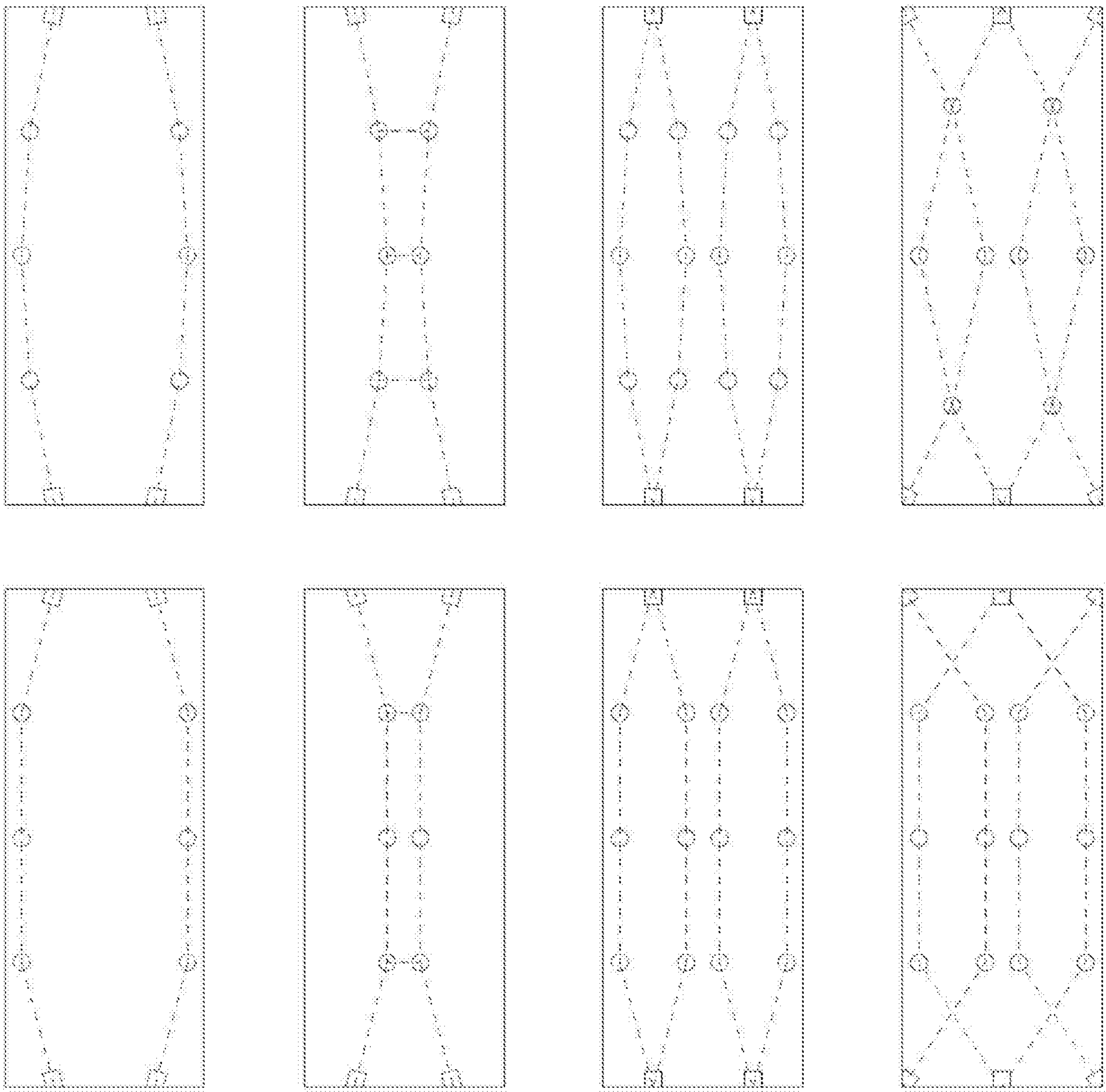

Fig. 3

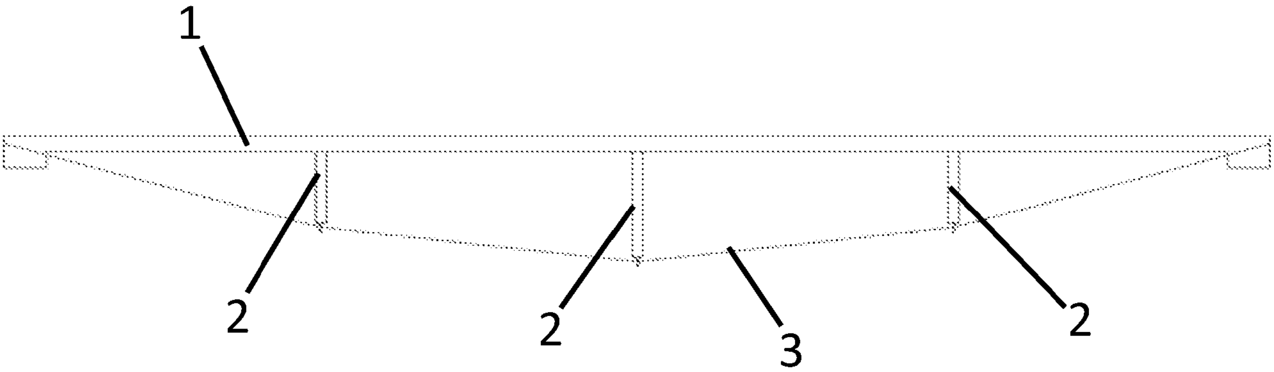

Fig. 4A

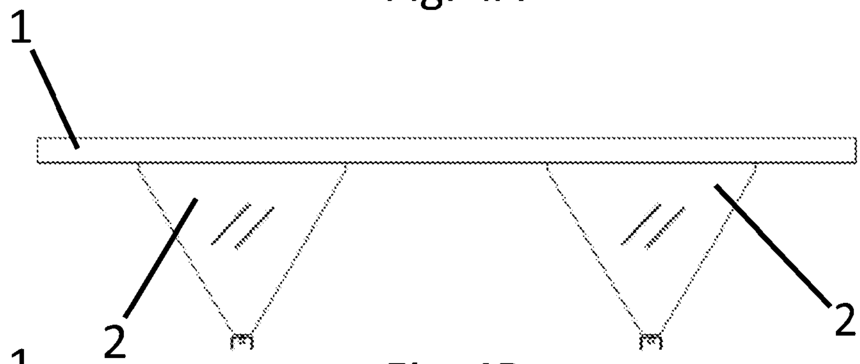

Fig. 4B

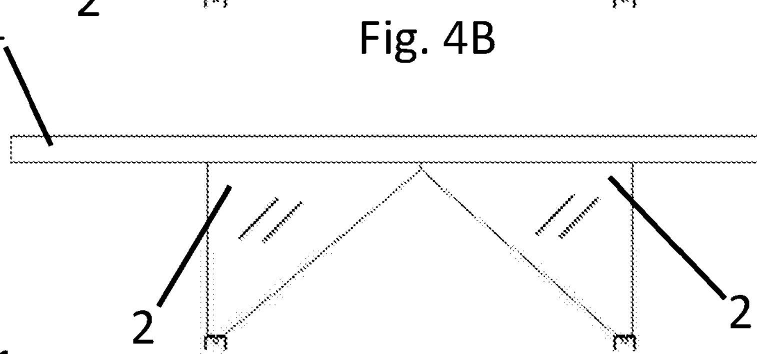

Fig. 4C

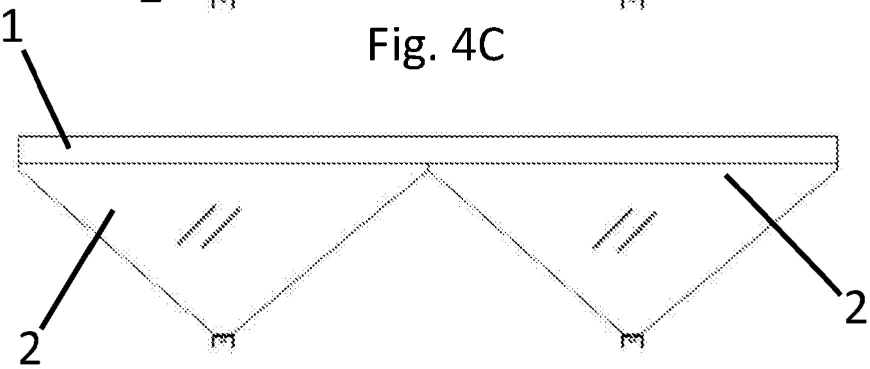

Fig. 4D

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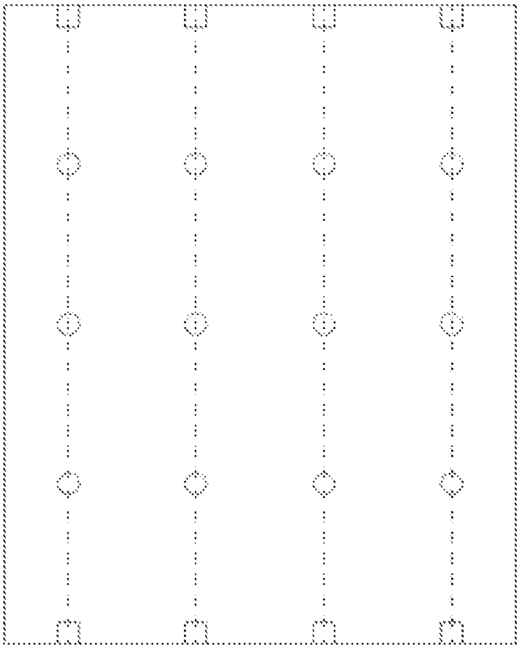

Fig. 5A

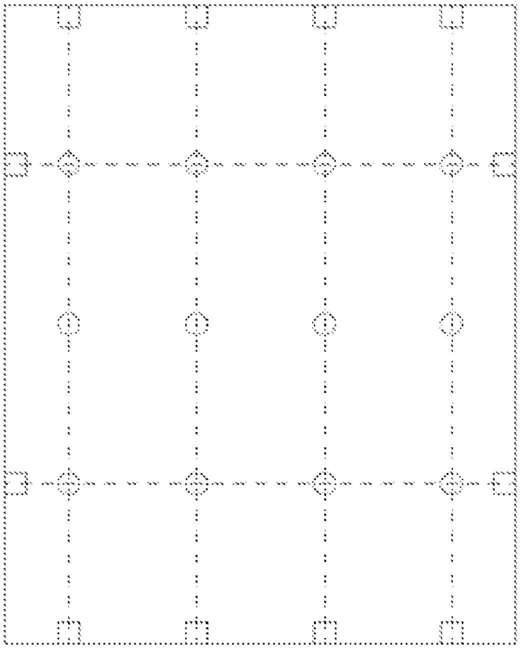

Fig. 5B

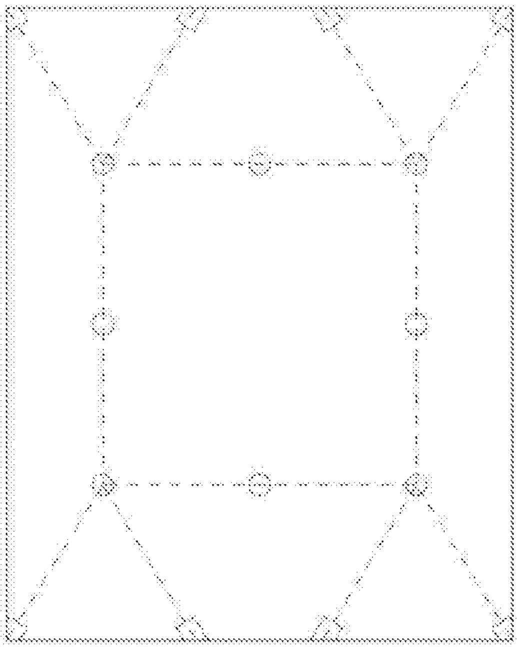

Fig. 5C

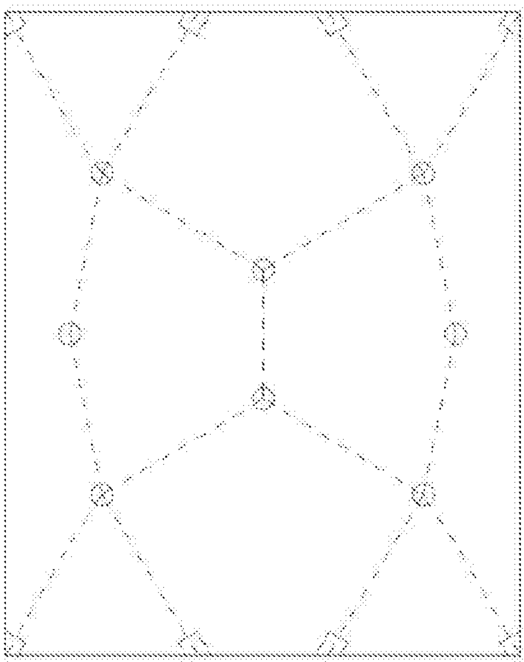

Fig. 5D

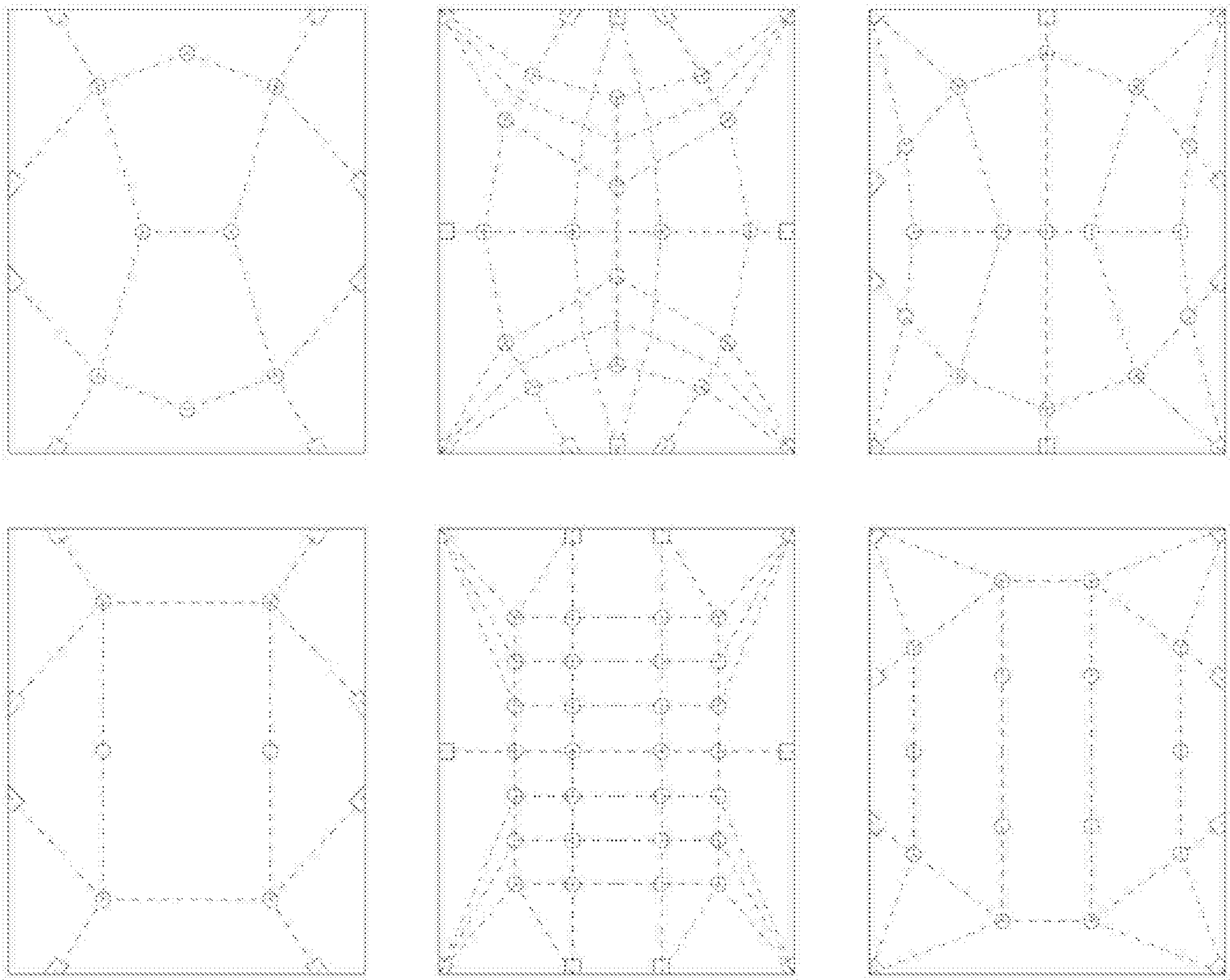

Fig. 6

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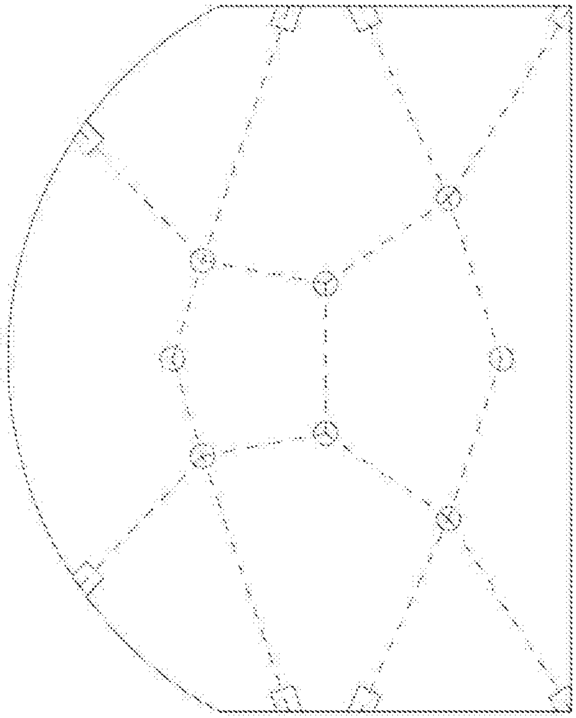

Fig. 7A

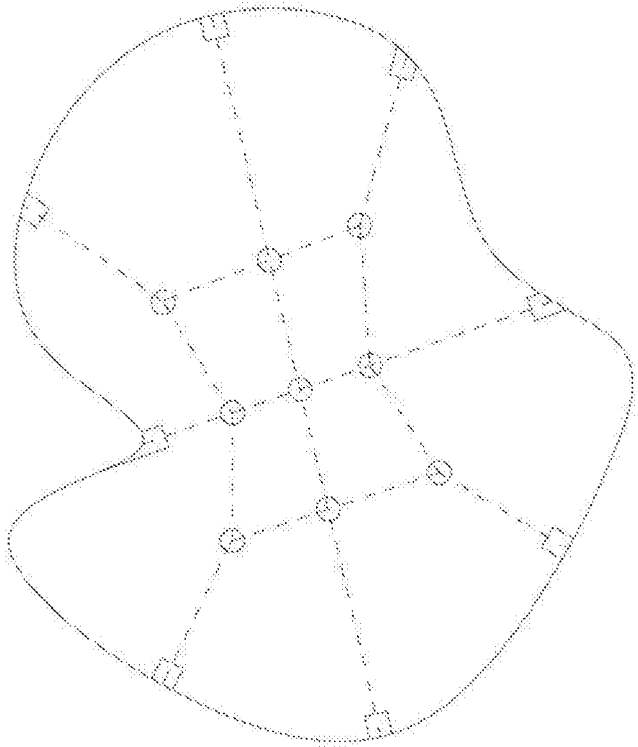

Fig. 7B

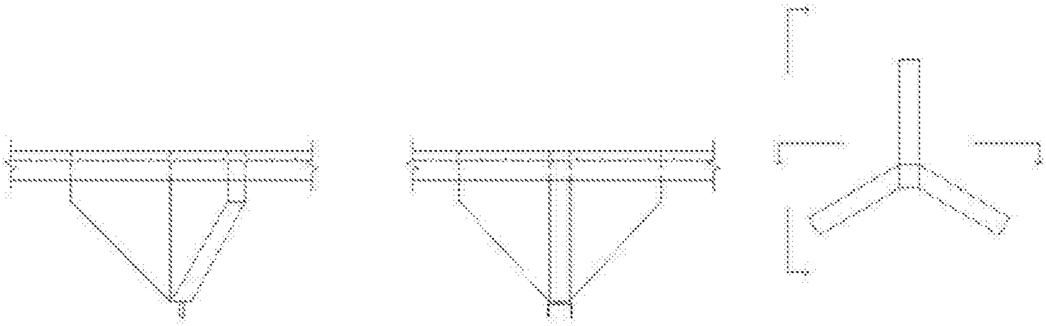

Fig. 8A

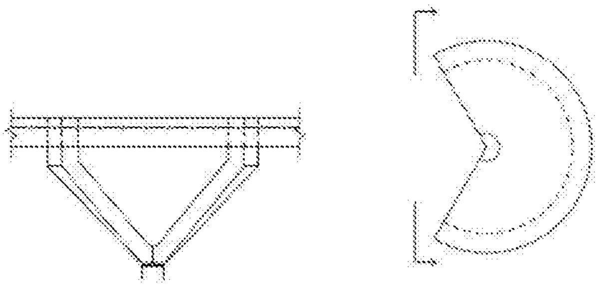

Fig. 8B

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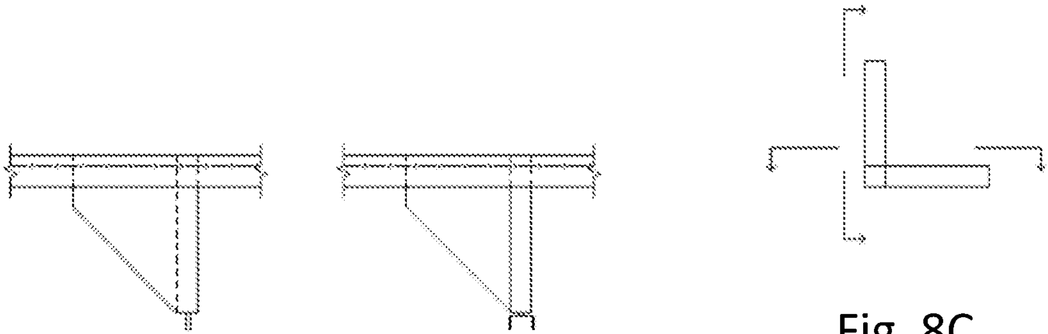

Fig. 8C

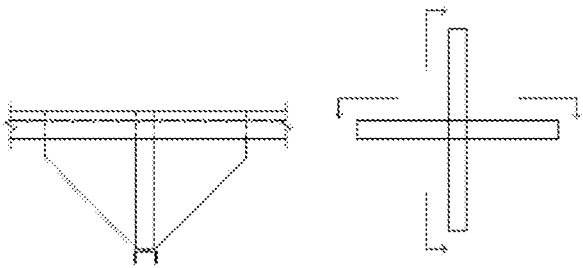

Fig. 8D

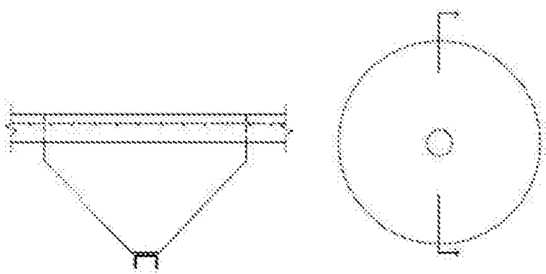

Fig. 8E

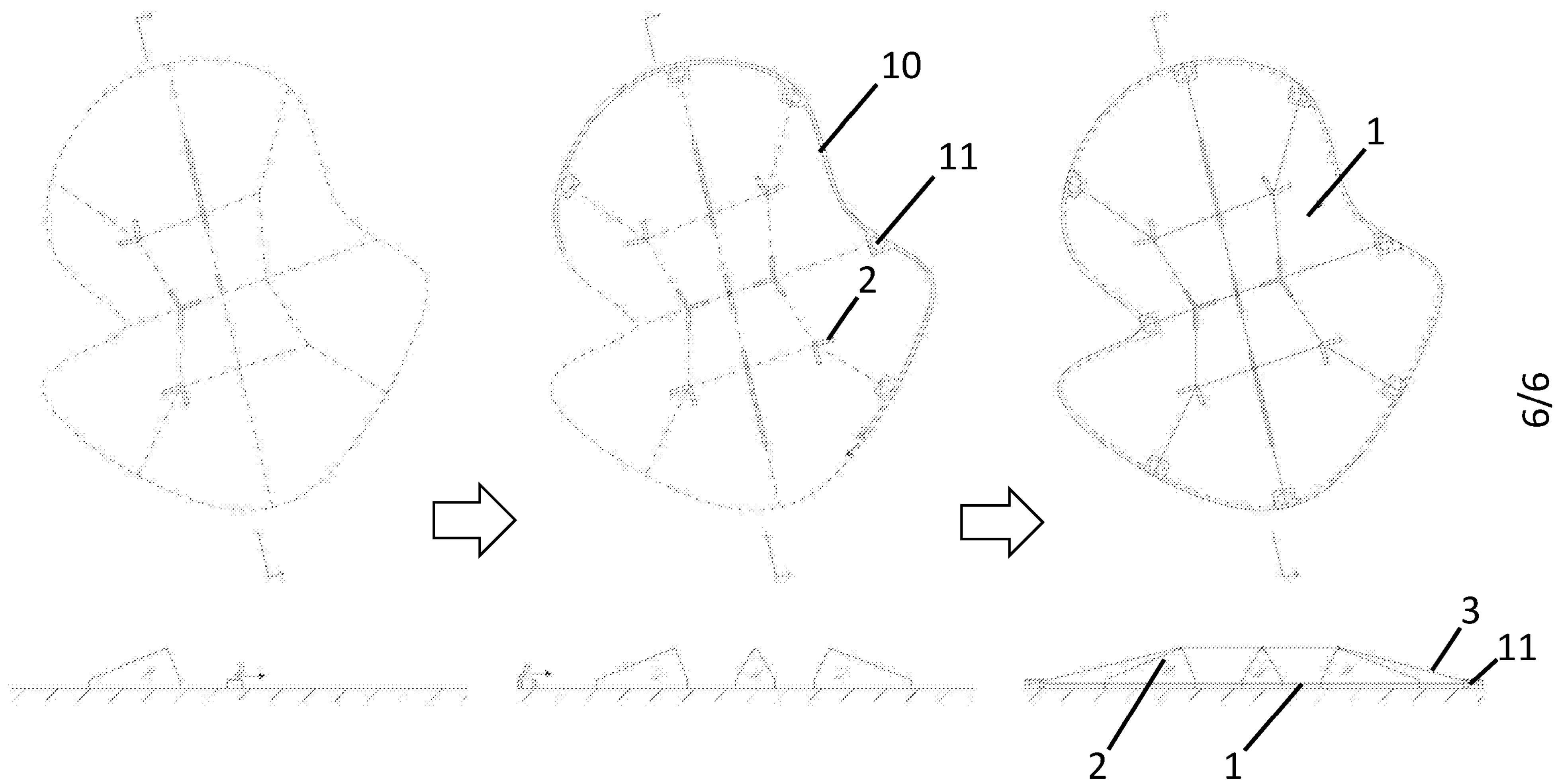

Fig. 9

A structural slab and method of manufacture

FIELD OF THE INVENTION

This invention relates to structural slabs and methods of manufacture.

BACKGROUND

Concrete is a common construction material that is generally low in cost. It is strong in compression and weak in tension. When combined with steel reinforcing bars to make reinforced concrete (RC), the composite material can be strong in both tension (for flexural resistance) and compression.

Concrete is commonly used in the construction of slabs. A common form of concrete slab is the double tee (or double-T) slab. These slabs are load-bearing structures that resemble two T-beams connected to each other side by side. The strong bond of the flange (horizontal section) and the two webs (vertical members, also known as stems) creates a structure that is capable of withstanding high loads while having a long span. Double tees are necessarily pre-manufactured off-site in factories from prestressed concrete.

Double-T slabs do, however, suffer from a number of drawbacks. They are limited in form. They are always rectangular. They are limited in size since they are manufactured off-site and must be transported to site. The width of the roads impose restrictions on the width of loads. They also lack strength other than in a direction of a major axis.

The field of 3D printed concrete can reduce manual labour input and costs by forming structural elements using robotics. In principle, any geometry can be created at no additional cost, which means that the cost of a 3D printed structural element is directly related to the efficiency of the geometry and therefore the quantity of material. However, for a structural element, such as a slab, to resist bending, it must still have some tension capacity regardless of the method of manufacture. There are examples of printing layers of concrete and having a person (or a second robot) lay a piece of reinforcing steel in between the layers before the printer head returns to the original location but this is slow, imprecise and interrupts the printing process which can bring its own disadvantages. Therefore, 3D printed concrete remains a technique that is useful for compression-only structures, such as walls, arches and, in some cases, columns.

However, it is not at present possible to benefit from a 3D concrete printing process to print a slab structure because the resultant structure is unable to provide a bending structure due to the inability to incorporate appropriate reinforcing means in the concrete structure without interrupting the printing process: the reinforcing bars are necessary to resist the tension loads present in some of the structural elements.

The present invention arose in a bid to provide an improved slab.

The present invention provides a slab and method of manufacture according to the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the present invention can be more readily understood, embodiments thereof will now be described, by way of example, with reference to and as shown in the accompanying drawings, in which:

Figures 1A to 1C show side, plan and end views, respectively, of a slab according to a first embodiment of the invention;

Figures 2A and 2B show side views of slabs of similar form to the slab of Figures 1A to 1C but with differently configured webs;

Figure 3 shows plan views of 8 alternatively configured slabs, which each comprise different chord arrangements;

Figure 4A shows a side view of a slab according to another embodiment in which the webs are arranged perpendicular to a longitudinal axis of the slab, whilst Figures 4B to 4D show possible web configurations for the slab of Figure 4A;

Figures 5A to 5D shows plan views of 4 alternatively configured slabs, which each comprise different chord arrangements;

Figure 6 shows plan views of 6 alternatively configured slabs, which each comprise different chord arrangements;

Figures 7A and 7B show plan views of 2 alternatively configured non-rectangular slabs;

Figures 8A to 8E show a number of possible web configurations; and

Figure 9 shows a manufacturing process for forming a slab according to the present invention.

DESCRIPTION OF EXAMPLES OF THE INVENTION

The present invention relates to slabs and methods of manufacture.

With reference to Figures 1A, 1B and 1C, there is shown a slab according to a first embodiment. The slab comprises a substantially planar flange 1, a plurality of webs 2, and a plurality of chords 3. As clearly seen, the webs 2 connect between the flange 1 and the chords 3. The flange 1 is separated from the chords 3 by the webs 2. The arrangement is such that, in use, the flange 1 and the webs 2 are in compression and the chords 3 comprise tension members. The material of at least the webs 2 is an additive material. It is preferable that the material of the webs 2 and the flange 1 is the additive material.

The flange 1 is a planar rectangular section, i.e. a block of concrete that would lie substantially flat or horizontal on a level surface when upside-down from the condition shown in figure 1A. The flange 1 may, however, take numerous alternative forms, with wide variation possible in at least the size and shape for the flange in plan view, as will be discussed further below.

The slab has nodes where the respective chords 3 and webs 2 meet. The nodes are indicated schematically in the figures as circles

In the present arrangement, there are two chords provided. The chords extend parallel to one another along their entire lengths, as shown in Figure 1B. There may be more chords provided in alternative arrangements, particularly if the flange is widened. Moreover, the arrangement of the nodes/chords may be varied significantly between different arrangements, as again will be discussed further below.

The slab may be considered to comprise panels comprising the internal spaces within the webs 2. The webs may be solid or void. They may have a constant thickness, as seen in Figure 1C or may have a varied thickness. In particular, the webs may comprise thickened edges. The webs are preferably triangular in form. Moreover, whilst the webs of the present arrangement are shown to be substantially planar, as discussed below with respect to alternative arrangements, they may otherwise be non-planar, taking a variety of three-dimensional or multi-planar forms.

The chords 3 may each comprise a steel cable or a bundle of steel cables. The chords each have a first connection point to the flange 1, a second connection point to the flange 1, which is spaced from the first connection point, and one or more intervening connection points, between the first and second connection points, each intervening connection point being located at an end of one of the webs 2 that is distal from the flange 1 at one of the nodes. In the figures, the first and second connection points are indicated schematically as squares, whilst the intervening connection points/nodes are indicated by circles. The dashed lines in the plan views indicate chords. In the present arrangement, the first and second connection points are adjacent opposed edges of the flange 1. As will be clear from the discussion of the alternative arrangements below, this need not be the case.

The slab of the present arrangement may be used as a direct replacement for a conventional double-T slab. For such purposes it may have a width of 2.4m. The depth of the slab, from an upper surface of the flange 1 to the end of the deepest web 2 that is distal from the flange 1 may be 0.6 to 0.9m. It should be appreciated that the dimensions will depend on various factors, including the span of the slab, and may be varied. A particular benefit of the slabs of the present invention is that, in contrast to the prior art double-T slabs, they may be manufactured on site, avoiding size constraints associated with transportation. They may be provided in various sizes to suit the needs of any particular project, moreover, they are not constrained to any particular shape.

The connection points of the chords 3 to the flange 1 may be configured with standard components familiar to those working in the concrete structure industry.

Chord tension members may be provided, which comprise typical pre-stress cables/wires (which do not necessarily have to be pre-stressed to any particular force level other than to make them tight to the concrete, but may be pre-stressed in some embodiments to further reduce material use). The cables may be terminated with typical pre-stress end anchors, which may be received in suitable channels, grooves, or other features that are printed or otherwise formed in the concrete of the flange so that the cables and anchor are thereby seated in the concrete.

The chords 3 may otherwise comprise steel cables in the form of a steel rope, similar to the material used in cranes, hoists and elevators. The ends of the steel ropes may be provided with load bearing hooks or eyes. The hooks can hook the cable over a suitable anchor such as a steel bar anchor in the flange 1. The steel ropes example can use one or more turnbuckles along the length of each rope to tension/shorten the rope length to tightly seat the rope in the end anchorages and the web channels or grooves.

The ends of the webs 2 are preferably profiled to prevent rubbing with the chords at the nodes. Shoes, brackets or other convenient means for capturing the chords at the respective nodes may be provided.

In one possible arrangement, shoes may be provided that have pin inserts which can be located at the nodes before the concrete has fully hardened. Regardless, the shoes, when provided, sit at the ends of the webs 2 and restrain the chords from lateral movement. The shoes preferably have a rounded (half-moon horizontal profile) contact surface so that the cables can pass over the shoes with minimal friction – thus the cables can slide with respect to the shoes. The chords 3 are restrained from lateral movement at the ends of the webs 3 by the shoe structures and the chords can slide with respect to the shoes - there is no bending moment between the chords and the webs 2.

In some arrangements, the shoes at the connection points on the ends of the webs 2 may be channels or grooves formed as an integral part of the ends of the printed webs 2 so that the chords 3 sit within the ends of the webs 2 distal from the flange 1. Preferably, the chords 3 are encased in a plastic or steel duct which avoids the cables rubbing directly on the concrete webs 2. The cable duct with the tension member 3 inside may sit in the web channel or groove so no discrete shoe or positive connection is required at the web connection points.

Standard (e.g. 12.5mm, 15.7mm) diameter steel cables can be used, the same as those used for post-tensioning concrete which would be familiar to precast concrete manufacturers. The cables can be coated to provide enhanced fire protection in most circumstances, unless the slabs are used in external locations (in which case they would only need corrosion protection). This fire protection is to be determined but could be achieved using a post-applied intumescent paint, or other spray-on coating.

In the case of using a duct to contain the cables, the duct can also provide the necessary fire and corrosion protection. The cables can be individually coated in the factory prior to being bundled during the slab assembly.

The cables could be replaced with a chain (or other element possessing no bending stiffness), solid bars, or steel flats or other suitable high tension materials such as carbon fibre rods and other composite materials such as glass-fibre reinforced plastic, graphite-fibre reinforced polymer and fibre reinforced plastic. Whilst the strength of the material is significant, it is the stiffness (Young's modulus) which is potentially more important so no minimum yield strength is specified. In practice, with post-tension cables, the yield strength will be 1860 MPa, far higher than is actually required in this application.

Preferably, the chords 3 are curved (or at least the location of the chord nodes follow curves) and the flange 1 lies substantially flat, in a main plane. The webs 2 transfer shear between the flange and the chords but because the chords are curved, or at least lie below, in use, the flange 1, the flange 1 and webs 2 always stay in compression under uniformly applied gravity loads.

If cables are used for the chords 3, then they will become straight between nodes when the truss is loaded, i.e. the chords end up being faceted, and the location of the nodes follows a curve.

In general, the 3D printing technique allows infinite variability in slab length, depth and width. The flange 1 is horizontal, the chords are preferably curved. The specifics of the curve are tailored to suit the slab design loading conditions. For a uniformly applied load, a catenary curve, or parabolic curve may be used. The curve can be varied to suit different loading scenarios so could be a parabolic, an arcuate or even a triangular distribution, if the slab loading is predominantly a point load, for example.

Preferably, the flange and webs are unitarily formed. It is otherwise preferable, that the webs and at least a portion of the flange are unitarily formed. By unitarily formed it is meant formed as a single unit from homogenous material, preferably concrete. When 3D printed, the webs 2 and the flange 1 can be printed in a continuous printing action, i.e. without interruption of printing. The flange 1 can be either printed using the same printer head P as the webs 2, or can be printed using a larger nozzle than the printer head P to achieve a faster print time. As discussed below, in a preferred method a unitary formation of the webs and flange may be achieved by a combination of 3D printing and pouring.

As mentioned numerous alternative arrangements are possible to the arrangement discussed with respect to Figures 1A to 1C.

Figures 2A and 2B show side views of slabs of similar form to the arrangement of Figures 1A to 1C. The slabs of Figures 2A and 2B differ primarily from the slab of Figures 1A to 1C with respect to the form of the webs 2. The webs 2 are again preferably substantially planar and triangular in form, however, the webs 2 of the Figure 2A arrangement are spaced apart from one another, whilst the webs 2 of the Figure 2B arrangement contact one another, as in the Figure 1A to 1C arrangement, but with an altered configuration to that arrangement. As should be appreciated by those skilled in the art, the arrangements of Figures 2A and 2B merely represent two exemplary non-limiting alternative configurations from the numerous alternatives that are possible.

Figure 3 shows plan views of eight alternatively configured slabs, which each comprise different chord/node arrangements. The slabs are shown to be rectangular, in the manner of the arrangements of Figures 1A to 1C, 2A and 2B, and may be constructed substantially as discussed with respect to the slabs of those arrangements. The slabs of Figure 3 represent a small selection of non-limiting exemplary alternative chord configurations. As discussed, the chords are represented schematically by the dashed lines, the first and second connection points are indicated schematically as squares, and the intervening connection points/nodes are indicated by circles. As is evident from the various different arrangements shown, a huge variety of different chord arrangements is possible. The chords may extend non-parallel to one another along their entire lengths, as seen in the top four slabs of Figure 3. Otherwise, the chords may extend parallel to one another over a part of their lengths only, as seen in the bottom four slabs of Figure 3. The chords may cross one another, as seen in the bottom right slab of Figure 3. There may be supplementary transverse chords provided. The configuration of the chords and the webs may be adapted to suit structural and load bearing requirements for the slab, substantially without limit. Highly complex configurations are possible.

Figure 4A shows a side view of a further alternative arrangement, which comprises a slab of similar construction to the slabs of Figures 1A to 1C, 2A and 2B but in which substantially planar webs 2 are provided that are arranged substantially perpendicular to a longitudinal axis of the slab. Figures 4B to 4D show some exemplary, non-limiting web configurations for the slab of Figure 4A. It should be appreciated that the webs may alternatively be provided at an oblique angle to the longitudinal axis of the slab.

Figures 5A to 5D shows plan views of 4 alternatively configured slabs, which comprise different chord/node arrangements. The slabs are rectangular but are wider than the slabs of the arrangements of Figures 1A to 4D. The slabs may have any desired width over 2.4m. They have a width of 3m or greater, for example. The width need not be particularly limited, particularly since the slabs may be manufactured on site to any desired specification. The slabs moreover need not be limited to any specific number or arrangement of chords. In Figure 5A, there are four chords provided, which are parallel to one another along their entire lengths. There could be more or less parallel chords provided. In the arrangement of Figure 5B, there are transverse chords introduced to the arrangement of Figure 5A. Figure 5C provides an arrangement in which chords are parallel to one another along only part of their lengths, and chords are provided that extend parallel, transverse and at an oblique angle to a longitudinal axis of the slab. Figure 5D provides a further alternative arrangement, as shown.

Figure 6 shows plan views of 6 further alternative arrangements, which each comprise different chord/node arrangements.

Figures 7A and 7B shows plan views of 2 alternatively configured non-rectangular slabs. Figure 7A shows a slab comprising three straight sides and a single curved side. Figure 7B shows a slab of abstract shape with entirely curved sides.

As discussed, the arrangements shown are merely examples of the numerous forms of slab that are possible within the context of the present disclosure, the size and shape of the slabs may be varied extensively, as may be the configuration of the webs and the chords. The slabs may be configured to suit the specifics of any project and any desired loading and support requirements. Notably with 3D printing utilized, very complex arrangements can be provided with no additional formwork costs.

Regardless of the shape of the flange or the configuration of the webs and chords, the flange may be reinforced. For example, a mesh may be embedded in the material of the flange, which will be useful to stop cracks forming. There could also be additional reinforcement around any openings in the flanges or webs, discrete punching shear reinforcement at positions of high permanent loads and extra slab reinforcement for wide bays between cables, or for cantilevers.

Figures 8A to 8E show a number of possible web configurations, which may be implemented in the any of the arrangements as discussed herein. Whilst the webs of the arrangements of Figures 1A to 1C, 2A, 2B, and 4A to 4D are substantially planar, this need not be the case. The webs may take various forms that extend in multiple planes. Some non-limiting examples are shown in Figures 8A to 8E. Non-planar webs will find particular use in arrangements that feature more complex web arrangements, i.e. web arrangements in which the webs are not straight and parallel to one another in plan view. However, even in simpler arrangements, the webs need not be substantially planar. Moreover, it must be noted that web arrangements may use multiple different types of web, including, for example, a mix of planar and non-planar webs and/or a mix of different forms of non-planar web. Figures 8A, 8C and 8D show alternative web arrangements that are non-planar but, which comprise a number of substantially planar triangular elements. Figure 8B shows a partially conical web that is of hollow form. Figure 8E shows a web that is substantially conical and is of solid form. Numerous alternative web arrangements will be readily appreciated by those skilled in the art. With the 3D printing of the webs there are few limitations to their specific form.

The preferred method of manufacture is by printing with concrete, i.e. 3D printing. The design-specific geometry is preferably created by 3D printing the slab in an “upside-down” condition. This orientation of printing is especially preferred and convenient since no specialised jig or bed to receive the “upside-down” flange is required. Further, gravity-drop printing is possible in this configuration.

It is noted that most of the tailoring of the structural characteristics of the slab are undertaken by manipulating the configuration of the webs 2 and the locations of the chord nodes. So, it is extremely convenient and very flexible to be able to print the webs 2 in whatever configuration is called for. The printer can be programmed to deliver the desired web configuration and the program can simply be changed for the next “print run” and a different web configuration delivered. Embodiments of the present invention facilitate an extremely adaptable mechanism for delivering customised or tailored slabs. Controlling and delivering the critical web configurations by 3D printing to order and providing a chord 3 in the form of an easily draped, attached and tensioned tension member provides a technically advantageous method of manufacture. The flange can moreover be formed in any desired size and shape, as discussed.

An exemplary manufacturing process will be discussed with reference to Figure 9.

Initially, the webs 2 are printed in the "upside-down" condition. The webs are printed to a height that factors in the thickness of the flange. The flanges may or may not be reinforced.

During the step of printing the webs 2, or subsequent to the printing of the webs 2, a boundary 10 of the flange 1 is printed. The boundary 10 comprises a perimeter of the flange and will be formed in the appropriate size and shape. At the time of printing the boundary 10, pockets 11 may be formed at the boundary for receiving anchors for the chords. The boundary 10, when complete, creates a formwork for the flange of the slab.

Once the boundary 10 is printed, the flange 1 may be formed by pouring concrete in a traditional manner. Any reinforcement for the flange may be placed prior to pouring. Any desired detailing, such as edge detailing, including, for example, steel plates for connection to adjacent slabs, may be introduced prior to pouring. Also, any reinforcement for the anchors to be received by the pockets may also be introduced prior to pouring.

The pouring will preferably occur prior to the webs (and boundary) fully curing so that a unified structure is obtained, which comprises the flange 1 and the webs 2. Regardless, the webs will be received within the thickness of the flange 1, as discussed.

Once the flange material has been poured and the slab has sufficiently cured, the cables forming the chords 3 may be added and stressed. The slab may then be turned over and moved to position for installation.

The claimed invention is applicable to materials other than concrete which share similar characteristics in that the material is suitable for additive manufacturing (3D printing) and is useful for compression-only structures but is not suitable to make a bending structure, such as a beam, as the material does not perform well in tension without incorporating some form of reinforcement. The chords can be any material, like steel, which is suitable for use in tension. The claimed invention is applicable to concretes with and without the presence of aggregates.

When used in this specification and claims, the terms "comprises" and "comprising" and variations thereof mean that the specified features, steps or integers are included. The terms are not to be interpreted to exclude the presence of other features, steps or components.

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof. Further, features disclosed in the text and/or drawings of the specification can stand alone or may be combined, in any combination, with one or more other features disclosed in the text and/or drawings of the specification where there is no conflict between those features.

Protection may be sought for any features disclosed in any one or more published documents referenced herein in combination with the present disclosure. Although certain example embodiments of the invention have been described, the scope of the appended claims is not intended to be limited solely to these embodiments. The claims are to be construed literally, purposively, and/or to encompass equivalents.

CLAIMS:

1. A slab comprising a substantially planar flange, a plurality of webs, and a plurality of chords,

wherein the webs connect between the flange and the chords, the flange being separated from the chords by the webs,

wherein, in use, the flange and the webs are in compression and the chords comprise tension members; and

the material of at least the webs is an additive material.

2. The slab of claim 1, wherein each of the chords has a first connection point to the flange, a second connection point to the flange, which is spaced from the first connection point, and one or more intervening connection points, between the first and second connection points, each intervening connection point being located at an end of one of the webs that is distal from the flange.

3. The slab of claim 1 or 2, wherein the material of the flange and webs is selected from one or a combination of: an additive material, a mortar and a concrete (including aggregates).

4. The slab of any preceding claim, wherein the flange, or at least a portion thereof, and the webs are unitarily formed.

5. The slab of any preceding claim, wherein the material of at least the webs is a 3D printed additive material.

6. The slab of any preceding claim, wherein the chords are restrained from lateral movement at the ends of the webs.

7. The slab of any preceding claim, wherein a shoe or channel is provided at the ends of the webs distal from the top chord so that the chords can slide with respect to the shoe or channel.

8. The slab of any preceding claim, wherein the webs have a single thickness.

9. The slab of any preceding claim, wherein the webs comprise variable thickness webs.

10. The slab of any preceding claim, further comprising one or more tensioning devices for adjusting the tension of one or more of the chords.

11. The slab of any preceding claim, further comprising one or more anchoring end connectors.

12. The slab of any preceding claim, wherein, in plan view, two or more or all of the chords extend substantially parallel to one another along their entire lengths.

13. The slab of any of claims 1 to 11, wherein, in plan view, one or more of the chords follows a non-linear path along at least part of its length.

14. The slab of any of claims 1 to 11 or 13, wherein, in plan view, two or more or all of the chords extend parallel to one another over a part of their lengths only.

15. The slab of any preceding claim, wherein, in plan view, two or more of the chords extend perpendicular to one another along part or all of their lengths.

16. The slab of any of claims 1 to 11, wherein, in plan view, two or more or all of the chords extend non-parallel to one another along their entire lengths.

15. The slab of any preceding claim, wherein the flange is rectangular in plan view.

16. The slab of any preceding claim, wherein the flange is an irregular shape in plan view.

17. The slab of any preceding claim, wherein the flange has one or more curved edges in plan view.

18. The slab according to any preceding claim, wherein one or more of the webs is substantially planar.

19. The slab according to any preceding claim, wherein one or more of the webs is non-planar.

20. A structural assembly including one or more slabs according to any preceding claim.

21. A method of manufacturing a slab comprising a substantially planar flange and a plurality of webs, the method comprising:

3D printing the webs;

3D printing a boundary of the flange; and

pouring material inside the boundary to a desired depth to form the flange.

22. A method as claimed in claim 21 further comprising, during the boundary printing step, 3D printing anchor support features.

23. A method as claimed in claim 21 or claim 22 further comprising inserting one or more reinforcing members during or prior to pouring the material inside the boundary.

24. A method as claimed in any of claims 21 to 23 further comprising attaching a plurality of chords to the slab, wherein the webs connect between the flange and the chords, the flange being separated from the chords by the webs.

Application No:	GB2207369.6	**Examiner:**	Mr Tom Simmonds
Claims searched:	1-20	**Date of search:**	15 November 2022

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-20	CA 2332751 A1 (STANG TERRENCE VICTOR) See Figures and abstract noting concrete floor slab with tension cables (cords) and concrete masts (webs).
X	1-20	GB 0650030 A (LEO COFF) See Figures noting steel plate with concrete slab in which tensioning cords are anchored and separated from the slab by steel webs.
X	1-20	WO 2009/001388 A1 (CIOCCHETTA ALESSANDRO) See Figured noting concrete slab and strut (web) with tension cables embedded in and spaced from the floor.
X	1-20	CN 112982787 A (ARCHITECTURAL DESIGN AND RESEARCH INSTITUTE OF TSINGHUA UNIV CO LTD) See Figures noting concrete floor slab supported by cables spaced by steel braces.
X	1-20	CN101285329 A (UNIV TIANJIN) See Figures noting concrete floor with steel webs and tension guy cables.
X	1-20	CN103883054 A (UNIV SHIJIAZHUANG TIEDAO) See Figures noting concrete flange 1/2, webs (steel tubes 10) and cable 5.
X	1-20	NL1033619 A1 (HENNING) See Figures noting concrete floor with cable 3 spaced from floor by web 4.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

E01D; E04B; E04C

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
E04B	0005/43	01/01/2006
E04B	0001/19	01/01/2006
E04B	0001/22	01/01/2006
E04B	0005/16	01/01/2006
E04C	0002/28	01/01/2006
E04C	0002/30	01/01/2006
E04C	0003/293	01/01/2006
E01D	0002/00	01/01/2006