STAIRCASE PRODUCED BY 3D PRINTING OF A CEMENTITIOUS MATERIAL

The present invention pertains to the manufacture of staircases and the resulting staircases.

The invention relates more particularly to spiral staircases.

A spiral staircase, also called a helical staircase or circular staircase, includes a central core which bears the steps. This core is placed in a stairwell.

It is known to produce the core with the steps as concrete prefabricated elements which are assembled as the construction of the structure progresses.

A first manner of manufacturing the concrete staircase consists in a factory-producing each element as a step and a ring. During the construction, the rings are stacked upon one another to form the central core.

Another approach consists in factory-producing also cast elements representing, for example, a quarter-turn of the staircase, which are placed at their final location using a crane.

These techniques offer limited possibilities in terms of design and generally require substantial finishing works.

The patent application FR 2 765 604 discloses a helical staircase made up of four cast-concrete prefabricated elements including the stairwell of the staircase.

Summary

There is a need to further improve spiral staircases and the present disclosure meets this need through a spiral staircase including a flight held by a central core and an external stairwell, characterized in that the flight and the stairwell are produced by 3D printing from a material.

The present disclosure takes advantage of the possibility to produce complex shapes by printing in order to simplify the manufacturing of the staircase and facilitate the construction thereof.

According to a first aspect, the present disclosure refers to a spiral staircase including a flight held by a central core and an external stairwell, characterized in that the flight and the stairwell are produced by 3D printing from a material.

According to a second aspect, the present disclosure refers to a building

including a staircase as defined in the first aspect.

According to a third aspect, the present disclosure refers to a method of manufacturing a staircase as defined in the first aspect, including the step consisting in printing the staircase using a material.

Preferably, the core is also produced by printing the cementitious material.

Preferably, the stairwell is produced with a wall hollowed internally at least in places. This makes it possible to reduce the used quantity of cementitious material and to lighten the staircase.

The flight can be produced with steps at least partially hollowed internally.

The central core can be interrupted by an opening accompanying the steps and vertically marking out a stair railing. This avoids the cost and the spatial requirement of an added stair railing and it is possible to facilitate the movement in the staircase of objects with large dimensions like a stretcher.

The staircase can advantageously include a handrail produced by printing.

The staircase can be printed in sections and these sections can be assembled with one another.

The staircase can include, at each storey, a setback extending over some of the thickness of the wall of the stairwell, in order to receive the corresponding floor slab.

The staircase may include, in particular in its wall or walls, a reservation for receiving a system for hanging walls and concrete sails.

The staircase may include, in particular in its wall or walls, a reservation for receiving an electrical system.

The staircase may include, in particular in its wall or walls, a reservation for receiving a fluid transport system or a dry riser.

The staircase may include, notably in the flight, a reservation for receiving a fluid transport system or a dry riser.

The wall or walls of the staircase can be used as formwork and be filled with a material.

The carpentry, including the doorframe, of at least one landing door can be incorporated during the printing of the staircase.

The wall or walls of the staircase may include reservations for pouring structural posts.

The wall or walls of the staircase may include reservations for the incorporation of reinforcement.

The staircase can be produced conventionally with a vertical axis. In a variant, there is the opportunity to produce complex shapes by means of printing in order to give the staircase a shape which extends along a curved axis.

An elevator shaft can be printed at the same time as the staircase.

A technical duct can be printed at the same time as the staircase.

The elevator shaft and the technical duct can be printed at the same time.

Another subject matter of the present disclosure is a staircase section for producing a staircase as defined above.

Another subject matter of the present disclosure is a building including a staircase according to the invention, as is defined above.

Another subject matter of the present disclosure is a method of manufacturing a staircase as defined above, including the step consisting in printing the staircase using a cementitious material. The staircase can be printed in sections that are intended to be assembled. The staircase can be printed on site or *in situ*. The staircase can be printed at the same time as the stairwell.

The subject matter of the present disclosure can be better understood upon reading the following detailed description, of nonlimiting implementation examples thereof, and upon examining the appended drawing wherein;

- Figures 1A and 1B schematically show a staircase section example according to the invention,
- Figure 2 is a view similar to Figures 1A and 1B of an alternative embodiment,
- Figure 3 illustrates the assembly of the sections,
- Figure 4 is a partial section showing a handrail variant,
- Figure 5 is a top view of a section variant,
- Figure 6 is a partial and schematic section along a radial plane,
- Figure 7 is a section illustrating the production of the steps with a nosing produced by printing and,
- Figure 8 schematically shows a core forming a stair railing.

The helical staircase section 10 shown in Figures 1A and 1B includes a stairwell 11 inside which a flight 12 resting at the centre thereof on a solid core 13 extends.

The assembly is produced in accordance with the invention by the printing of material.

Various concrete printing devices are proposed today which allow the section 10 to be produced. These devices include a head supplied with a nozzle through which the cementitious material is extruded, the head being borne by a robotic arm making it possible to move the head three-dimensionally, the movements being controlled according to the structure to be produced.

The material is chosen for the compatibility thereof with the printing process.

The sections 10 can be manufactured in a workshop outside the building site or on the site itself, or *in situ*. In this case, the device used for printing hangs, for example, on the section of the bottom that has just been produced and/or on a column passing through, for example, the core.

The material used can be a conventional concrete, a HPC, a UHPFRC, etc.

The stairwell 11, the flight 12 and the core 13 can be produced without a metal reinforcement.

The stairwell 11 can include a curved wall 14 which substantially describes, when seen from above, three quarters of a circle, and which is closed by a wall 15 forming a right angle, in which the opening 17 for the entry door is produced.

The walls 14 and 15 can be produced, as is illustrated, with a double-wall 20, 21 hollow structure, which makes it possible to lighten the staircase.

The outermost wall 21 can extend over a height that is less than that of the inner wall 20, such as to allow the latter to fit into the corresponding opening of the floor slab.

Once printed, the wall or walls of the staircase can advantageously serve as formwork and thus be filled with a material. The formwork consisting of the walls of the staircase can be completed by other formwork elements.

The inner wall 20 can be printed with a handrail 23, as is illustrated.

A landing 26 can be printed with the steps 30 of the flight 12.

In a variant, the staircase section 10 can be produced with a solid wall instead of the double wall 20, 21.

The stairwell 11 can be given an outer shape that is different to that illustrated in Figures 1A and 1B.

By way of example, Figure 2 shows a section 10 variant in which the stairwell 11 includes an outer wall 33 with a section that is, for example, square-shaped as seen from above, and an inner wall 34 with a circular section, that follows the curvature of the flight 12 and includes sectors 35 placed in the corners of the stairwell 11, with the exception of the corner including the opening 17.

A set-back 38 is formed in the thickness of the wall 33 such as to allow fitting in a corresponding hole of the floor slab, like the example of Figure 1A.

Figure 3 illustrates the formation of the complete staircase by stacking of the prefabricated sections 10 of a variant of Figure 1A in which the stairwell is formed by a solid wall. It is seen that, between the sections, there is a recess 60 for accommodating the thickness of the floor slab.

The handrail 23 can be produced not as a projection but as an indentation in the wall of the stairwell 11, as illustrated in Figure 4.

In the variant illustrated in Figure 5, the stairwell 11 is produced with solid parts 43a to 43d.

The solid parts 43a and 43b extend in the mid-region of the stairwell sides located opposite the corner including the entry opening 17.

The solid parts 43c and 43d join in the corner including the entry opening 17.

In the three corners opposite the entry opening 17, the wall of the stairwell 11 can be hollowed out, as illustrated, such as to lighten it and define passages 50 for networks, for example water, gas, telephone and/or electricity.

It is possible to produce the steps 30 with an arch 52, as is illustrated in Figure 6. This arch 52 can be asymmetrical, and have a depth, at the connection to the stairwell 11, which is greater than that at the connection to the core 13.

The arch 52 can be hollowed internally, as illustrated, in order to lighten it.

The steps 30 are preferably printed with a nosing 54, as illustrated in Figure 7.

The core 13 can be given various shapes.

It is possible for the core 13 to not be solid but hollow.

It is possible to place, in the hollowing of the core 13, a lighting, for example a lamp or a light guide where daylight is injected using a light concentrator.

It is also possible to produce it hollow, with an aperture 55 that is helical in portions, as is illustrated in Figure 8, following the flight 12, including straight portions when arriving on the landing. The non-apertured part of such a core 13 forms a stair railing.

The invention is not limited to the examples that have been described above.

For example, it is possible to produce the staircase such that the axis thereof, i.e. the longitudinal axis of the core 13, is not vertical but curved, which can be interesting for superstructures where the last storeys are set back.

It is possible to produce the stairwell 11, the core 13 or the flight 12 at least partially from light-transmitting concrete, and the stairwell 11 can be apertured elsewhere other than at the entry opening 17.

It is possible to produce the steps 30 such that the nosing thereof, when seen from above, is not rectilinear in radial orientation, but curved. This offers greater possibilities as regards aesthetics and can also make the staircase more pleasant to travel through by giving the steps a shape that is more suited to the stride of a person climbing the staircase.

It is possible to further produce, by printing, a skirting along the steps.

The flight 12 of the staircase can have a shape other than circular. For example, it is elliptical or polygon. The same applies to the stairwell 11.

It is possible, for example, to make, in the wall or walls of the staircase, reservations for example for receiving a system for attaching concrete walls and sails, to receive an electrical system, or for receiving a fluid transport system or a dry riser.

Reservations can also be made in the wall or the walls of the staircase for casting structural posts or for the incorporation of reinforcement, notably prestressing or post-stressing reinforcements.

In the flight, a reservation may be made for receiving a fluid transport system or a dry riser.

It is also possible to incorporate during the printing of the staircase the doorframe of one or more landing doors.

It is also possible to print an elevator shaft at the same time as the staircase.

It is also possible to print at the same time as the staircase a technical duct. This duct may for example serve as a conduit for supplying or discharging cold or hot water, or as a ventilation column or air conditioning. The duct can also serve as a sheath for an electrical network.