

## PRESTRESSED SLAB ELEMENT

The invention relates to a prestressed slab element according to the preamble of Claim 1 and a preferred use of such a slab element according to Claim 14 and a manufacturing method for a slab element according to Claim 15.

It is already known to produce particularly slim slab elements of concrete and thus more preferably flat ceiling constructions based on hollow elements embedded therein. The slab elements specified therein are so-called "unstressed reinforced" elements whose reinforcement consists of orthogonally arranged reinforcing bars which absorb the tensile forces that develop in the concrete. The structural efficiency of this light construction technology allows for example the construction of slim yet wide-spanned flat ceiling constructions with simultaneous resource efficiency. Dependent on the diameter and the geometry of the hollow elements the embodiment of ceiling thicknesses from approximately 20 cm is possible.

With so-called "prestressed" slab elements however additional stressing elements such as cables are installed which are stressed after the hardening of the concrete. Because of this it is possible to create additional forces which can offset the loads created by the deadweight up to a certain degree. Depending on the geometric arrangement of the cables only a compressive force is created through the prestressing, that is the cables lie parallel to the ceiling plane or additionally a deflection force acting perpendicularly to the ceiling plane, in the case of a parabolic or trapezium-shaped or so-called "free position" of the cables. The deflection force created through the prestressing varies in practice between 80% and 100% of the ceiling deadweight. Depending on the building standard it is also possible in addition to the deadweight to addi-

tionally offset the live load acting on the ceiling through the deflection forces of the tensioning cables.

Thus, prestressed slab elements also include tensioning elements in addition to the "unstressed" reinforcing bars.

5 In an extreme case, the addition of "unstressed" reinforcement can be reduced to a design minimum for example to accommodate parasitic, locally occurring constraining forces and as reinforcement against surface cracks when the deadweight and the live load of the element are completely offset through the deflection forces.  
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Devices necessary for the prestressing are tensioning cables, sleeves, which surround the cables, injection materials, which are introduced between sleeve and cable after the tensioning depending on the installation method, anchor heads, couplings, support aids for the sleeves and  
15 cables and tensioning devices.

The mass of ceiling deadweight to be offset through the deflection forces of the tensioning cables is directly proportional to the applied tensile force and consequently  
20 to the cross section of tensioning cables employed.

The tensioning cables consist of high-strength steel which has a particularly high tensile strength. The manufacture of the cables is therefore subject to stringent qualitative specifications as a result of which the costs of the  
25 cables are many times higher than the costs for conventional "unstressed" reinforcing steel.

At the edges of the ceiling the stressing cables are set in anchor heads which discharge the cable stresses into the concrete. Each stressing cable requires its own anchor  
30 heads on both opposite edges of the ceiling. These anchor heads additionally drive up the costs.

The use of prestressing allows the bridging of larger spans with the simultaneous minimisation of the ceiling thickness and thus the ceiling deadweight. In addition, prestressing allows better control of crack formation in the concrete through the horizontal tying-together. A further advantage of prestressing are the minimised deformations of the ceiling which with dimensioning of concrete ceilings frequently is the decisive criterion for the ceiling thickness. By employing prestressing the construction time can be additionally optimised since the shuttering of a prestressed ceiling can be removed earlier.

A further increase of the efficiency of unstressed reinforced or prestressed slab elements however does not appear possible to date.

The publication AU 505 760 B2 discloses components of a slab element which have a region that is hollowed out towards the bottom and can be prefabricated of concrete. These components are then arranged relative to one another on site and fastened. To this end, stressing elements are used which run along the lateral edges of the respective components.

The publication DE 12 22 643 B discloses a slab element which is prefabricated in a concrete plant. The slab element in top view of its surface contains at least one hollow element region with hollow elements contained therein. Stressing elements or reinforcing mats are cast into the bottom and top ceiling which run in two directions at a right angle to one another.

It is the object of the present invention to provide an improved slab element which can be manufactured carefully in terms of the material, light in weight and capable of carrying load as well as cost effectively.

This object is solved through a slab element and more preferably through a ceiling element according to Claim 1.

In the context of this application the term "lattice-shaped" arrangement of stressing elements is to mean a structure wherein these elements cross one another at an angle or various angles that need not necessarily be right angles. The stressing elements need neither run in a straight line but more preferably with geometrically sophisticated slab geometries can also be installed curved, e.g. arc of a circle-shaped, parabolically, orthogonally or similar in order to satisfy the relevant load case.

The invention is based on that stressing elements passed over hollow element regions allow only limited prestressing because of the reduced material. In addition, a geometrical problem arises since the space to accommodate these elements is greatly restricted. Thus, if installation was at all possible in the past, the combination of hollow element regions and prestressing did not necessarily result in improved efficiency of the slab element. Excessive prestressing in these regions can even damage the slab element and thus render it unusable.

An essential point of the present invention initially consists in the specially reinforced support strips which join the individual support regions of the slab element with one another. This makes possible a hybrid combination of hollow element regions and prestressed regions of a slab element, which increases the optimising effect of both reinforcements in a technical, economical and ecological manner.

The approach of employing entire modules with hollow elements to reduce ceiling deadweight known from the "unstressed reinforced" flat ceilings can also be applied to

prestressed ceilings wherein either only the deadweight or the entire loads are offset through stressing cables. Here, the technical advantages of both methods can be combined and the deadweight reduction of the ceiling compared with unstressed-reinforced concrete ceilings of solid design or prestressed ceilings further increased. The loads acting on the vertical elements such as supports, walls and foundations of a carrying structure are thus reduced even further. At the same time, the use of material in terms of stressing cables and anchor heads is optimised, more so since the deadweight of the ceiling additionally reduced by between 25% and 30% has a directly proportional influence on the required stressing cable cross section. In addition, the concrete volume required is reduced and the deformation of the ceiling additionally minimised.

Depending on the ceiling outline and support grid a planner has various possibilities of arranging the cables. He can, for example, select areal prestressing during which the cables are arranged evenly distributed over the ceiling length and width. Another option is offered by the support strip prestressing, wherein the cables are arranged in a concentrated manner in the zones passing over the supports in strips arranged orthogonally relative to one another. However, a combination of both arrangements can also be selected wherein one direction is worked areally, the other using support strips.

A further reinforcement of the slab element is achieved in that in its lateral view the stressing elements are installed in the slab element wave-like and support themselves on at least one lattice system of bars with hollow elements held therein, whose respective height is adapted to the wave shape. Since the lattice system discharges the forces introduced from the stressing element past the hol-

low spaces these are protected against destruction. This allows hitherto unknown stressing element guidance and thus prestressing even across hollow element regions. Preferred further developments of the slab element according to the invention are stated in the subclaims and relate to reinforcing types of the element with areal, support strip and combined prestressing.

In the event of areal prestressing a support strip preferentially comprises at least one solid material region via which the introduced loads can be discharged. However, in order to nevertheless obtain a particularly lightweight construction it is preferred that laterally adjoining fields of the lattice-shaped structure at least form a longitudinal carrying strip with hollow element regions which is arranged between two support strips.

In the case of support strip prestressing however additional stressing elements are preferentially arranged in longitudinal direction of a support strip to reinforce the slab element. These stressing elements need not necessarily run laterally off the strip. They can more preferably be arranged distributed over its width or be located only in its middle region. These additional stressing elements can also be configured comparatively thicker than others.

Alternatively or additionally the stressing elements which run in longitudinal direction of a support strip can themselves be reinforced, e.g. have a larger cross section or a material of greater tensile strength than the other stressing elements. To reduce weight, a support strip can comprise at least one hollow element region.

In the case of combined areal and support strip prestressing additional stressing elements of solid material can for example be provided within a support strip while an-

other support strip is only reinforced laterally and comprises hollow element regions. To further reinforce the support strip, additional stressing elements can be provided which are distributed over its width or only run in  
5 its middle. If these stressing elements engage over hollow element regions of the support strip these are provided with reduced prestressing. Weight reduction of the slab element can be achieved through carrying strips which run in lattice structure between the support strips.

10 In each of the cases a slab element is obtained which is particularly simple in construction and can be unidirectionally loaded if its lattice-shaped structure forms a grid of rectangular fields. Dependent on the case of application, any other structure consisting of stressing  
15 elements running in a straight line or curved line can also be provided, which cross at a certain or a plurality of different angles.

It is preferred if the rods of the lattice systems relative to a normal of the surface of the slab element are  
20 arranged with a slightly oblique orientation. Modules designed in such a manner thus offset local reduction of the transverse force load carrying capacity of the slab cross section caused through the hollow elements. In addition, these lattice bars can absorb the local parasitic stresses  
25 vertically to the ceiling plane generated in the concrete through the prestressing if applicable.

Also in the zones covered by the stressing cables, where the cables in the lower region of the ceiling cross section run parallel to the ceiling plane, additional modules  
30 can be installed if required. To this end, these are positioned by means of a spacer at a suitable spacing to the stressing cables and above these, dependent on the standards and the manufacturer's details for the minimal con-

crete sheathing of the cables. However, the hollow element diameter that can be employed is reduced if applicable.

Lateral strips of the hollow element regions can still be reinforced in that the lattice system comprises support  
5 bars which in longitudinal direction protrude over a receiving region for hollow elements and over which the stressing elements are installed. The lateral support can be further improved in that individual lattice systems of bars with hollow elements held therein are so arranged  
10 relative to one another that their support bars on both sides mutually overlap one another. At the same time, reinforcement which in longitudinal direction runs over at least two lattice systems is created.

Dependent on structural specifications it can however be  
15 preferred that lattice systems comprise receiving regions which do not contain any hollow elements and over which the stressing elements are installed. As a result, an extremely flexible reinforcement of the slab element even over regions containing hollow elements but despite exist-  
20 ing areal or support strip prestressing require additional reinforcement is possible.

Preferably the slab element according to the invention is to be used as ceiling element since especially loads occurring there require low weight and large load carrying  
25 capacity of the ceiling construction. However, its use is not only limited to this since it can also be utilised in any other form of application where particularly lightweight and yet particularly sturdy elements are demanded at the same time. This is not only the case in residential  
30 and commercial construction but also includes more preferably power plants, bridges, dams etc.

The aforementioned object is solved also through a method

for producing a slab element according to Claim 15.

A substantial point of the method according to the invention herein consists in its simple executability both in the classic in-situ concrete application and also with  
5 prefabricated elements manufactured in a concrete precasting plant. The application of this method is conceivable both for use with concrete of conventional composition and quality as well as for concrete of alternative mixture and concept such as lightweight concrete and fibre concrete.  
10 Lattice systems with hollow elements contained therein are preferably supplied as modules.

These modules are directly installed in the zones of the ceiling not occupied by the stressing cables between the lower and upper unstressed reinforcement. If in the zones  
15 occupied by the modules no unstressed reinforcement is provided the modules are directly placed onto the spacers which rest on the shuttering. This is advantageous insofar as the ceiling cross section through the absence of the upper and/or lower unstressed reinforcing layers can be  
20 better utilised in favour of the modules. Taking into account the required minimum lower and upper concrete coverage of the modules, larger hollow elements can be employed as a result.

With areal or support strip prestressing stressing elements can additionally reinforce the slab element which  
25 run over hollow element regions. Here, these elements need not have the basic stress of the areal or the support strips but can be prestressed to a lesser degree. Unstressed reinforcement is then no longer absolutely re-  
30 quired so that a larger spacing between modules and surfaces of the slab element can be utilised to accommodate the stressing elements. Here, the modules can simultaneously serve as support aid for the prestressing cables. In

such a case modules in stepped size are selected according to the geometrical course of the stressing cables and in the regions where the stressing cables are located in the upper region of the ceiling cross section, placed under the stressing cables. Because of this, additional areas can be covered with modules and the weight saving further optimised as well as conventional support aids saved. In addition, the geometry of the modules used here can still be adapted to the circumstances and specific requirements of the stressing cables if required. Preferably the at least one stressing element is placed on support bars of the lattice system which in longitudinal direction protrude over a receiving region for hollow elements. As a result, respective end regions of the lattice system can be additionally reinforced since no hollow elements will come to be positioned there any longer.

In an advantageous manner at least two lattice systems are so installed here that their respective support bars overlap one another. On the one hand this provides greater support for the stressing elements. In the case of ceilings, where unstressed reinforcement is entirely omitted or such is only locally installed in certain areas of the ceiling, or only a minimum of unstressed reinforcement is required, the presence of the modules has the effect that the lower and upper longitudinal bars of the modules can be considered as unstressed additional reinforcement. Because of this, the minimum additional reinforcement can be reduced at least in the reinforcement direction of the modules and the function of the crack reinforcement partially or completely assumed by the modules. However, for this to be possible it must be ensured that the protrusions of the longitudinal bars of the modules are extended by an overlap dimension defined by the standards and subsequently arranged in a superimposing manner. Because of

this, the continuity of the reinforcement required by the standards is achieved.

In the following, the invention is explained by means of examples wherein reference is made to the appended figures. Identical or identically acting parts are provided with identical reference figures. It shows:

Figure 1 the schematic construction of a slab element according to the invention with areal prestressing in a top view of its surface;

10 Figure 2 the schematic construction of a slab element according to the invention with support strip prestressing in a top view of its surface;

Figure 3 a lateral view of the first and second slab element with a course of a stressing element over lattice systems with hollow elements held therein;

Figure 4 a lattice system according to the invention with hollow elements held therein and protruding bars and

20 Figure 5 a combination of two lattice systems of Figure 4 arranged in an overlapping manner about the protruding bars.

Figure 1 shows the schematic construction of a slab element 10 according to the invention with areal prestressing in a top view of its surface 11. The element 10 in this case comprises hollow element regions 20 and support regions 30. In this example, orthogonally arranged stressing elements 40 form a lattice-shaped structure 50 whose respective fields 51 limit the regions 20 and 30. Laterally adjoining fields 51 form support strips 60 which connect the support regions 30 with one another over fields 51, wherein these fields are embodied as solid material re-

gions for reinforcement of the support strip. Laterally adjoining fields 51 in contrast form rows of longish carrying strips 80 with hollow element regions 20 which are areally stressed via the stressing elements 40. Such a slab element 10 is preferably employed as ceiling element which is mounted in the support regions 30. In connection with the areal prestressing via the lattice system 50 the solid material support strips 60 provide adequate stability for the carrying strips 80 that run in-between so that a ceiling element is created which is light-weight yet capable of carrying load at the same time. Through the right-angled installation of the stressing elements 40, simple and cost-effective manufacture of the element 10 is ensured at the same time.

Figure 2 shows the schematic construction of a slab element 10' with support strip prestressing according to the invention in a top view of its surface 11'. The element 10' again comprises support and hollow element regions 20 and 30. Here, too, orthogonally orientated stressing elements 40 forms a lattice-shaped structure 50 whose fields 51 limit the regions 20 and 30. Along support strips 60, which run orthogonally relative to one another over the slab element 10', the stressing elements 40 however are reinforced, in this example of double design. However, for reinforcement, a larger cross section and/or a material of greater tensile strength of the stressing elements can be provided. The support strips 60 are thus reinforced in such a manner that these can also comprise hollow element regions which render the element 10' more lightweight. Through the reinforcement of the support strips 60, carrying strips 80 can be provided with large area hollow element regions 20 which run vertically and horizontally between the support strips 60. Although all fields 51 possible here are embodied with hollow element regions 20, not

only a weight optimum but also a load-carrying capacity optimum is thus achieved with such an element 10'. Here, too, the right-angled installation of the stressing elements 40 makes possible the simple and cost-effective manufacture of the element 10'.

Figure 3 shows a lateral view of the first and second slab element 10, 10' with a course of a stressing element 40 over lattice systems 90 with hollow elements 21 held therein. The size of the lattice systems 90 here is so selected that these determine the desired course of the stressing element 40. The lattice systems are constructed of bars 91 whose for example trapezium-shaped frame on the one hand brings about particularly high stability and on the other hand particularly high force discharge of the prestress of the stressing element 40 into the material. The stressing element 40 here rests on longitudinal bars 91 of the lattice systems 90 which run vertically to the blade plane. These bars 91 have a reinforcing effect which corresponds to that of a reinforcement 100 and can even replace the reinforcement 100 under the circumstances still to be described in the following. The combination of lattice systems 90 and stressing elements 40 makes possible prestressing in hollow element regions 20 of the slab elements 10, 10' of Figures 1 and 2 and thus reinforcement of the element 10, 10'.

Figure 4 shows a lattice system 90 according to the invention with hollows 21 held therein and protruding bars 92 which protrude over receiving regions 93 for the hollow elements 21. The stressing element 40 only shown exemplarily in Figure 3 can however be installed at any desired point over for example the uppermost longitudinal bar 91 of the lattice system 90. It is advantageous however to guide it over for example the uppermost support bar 92 of

the lattice system 90 on the one or the other end of the lattice system 90 since these ends are filled with solid material which permits higher prestressing and thus reinforcement. Obviously it is also possible to remove individual hollow elements 21 from the lattice system 90 in order to create solid materials zones at this location or these locations in which specific reinforcement through particularly highly stressed elements 40 is provided.

Figure 5 finally shows a combination of two lattice systems 90 of Figure 4 arranged in a overlapping manner about the protruding bars 92. Because of this overlap, all longitudinal bars 91 of both lattice systems 90 act like the correspondingly orientated reinforcements 100 in Figure 3. At the same time, the overlapping bars 92 provide a more stable support for the stressing cable 40 likewise shown there if it is installed over these bars 92.

Through the presented measures according to the invention, deliberate reinforcement of a wall element dependent on the planned use thus becomes possible. The slab element according to the invention has a clearly higher load-carrying capacity and is simultaneously lighter in weight than a known slab element. The simple construction allows cost-effective manufacture at the same time. Because of its efficiency it is to be preferably employed as ceiling element which carries over wide areas.

## Patent claims

1. A prestressed slab element (10), in particular a concrete slab element, manufactured according to the in-situ concrete method or prefabricated in a concrete precasting plant which in top view of its surface (11) comprises at least one hollow element region (20) with hollow elements (21) contained therein and at least one support region (30) for supporting or holding the slab element (10) without hollow elements (21), as well as stressing elements (40) for reinforcing the slab element (10), which each are installed through the slab element (10) and form a lattice-shaped structure (50), wherein individual fields (51) of this structure (50) establish a support or hollow element region (20, 30), and laterally adjoining fields (51) of the lattice-shaped structure (50) form at least one longish support strip (60) which joins individual support regions (30) with one another and which is embodied in a reinforced manner, **characterized by** stressing elements (40), which in a lateral view of the slab element (10) are installed in the slab element (10) wave-like and which support themselves on lattice systems (90) of bars (91) with hollow elements (21) held therein whose respective height is adapted to the wave shape in such a way that the heights of said lattice systems (90) determine said wave-like shape of the stressing elements (40).
2. The slab element (10) according to Claim 1, wherein the at least one support strip (60) comprises at least one solid material region (70).
3. The slab element (10) according to Claim 1 or 2, wherein the laterally adjoining fields (51) of the lattice-shaped structure (50) form at least one longish carrying strip (80) with hollow element regions

(20) which is arranged between two support strips (60).

4. The slab element (10) according to any one of the preceding claims, wherein in longitudinal direction at least of one support strip (60) additional stressing elements (40) are provided.
5. The slab element (10) according to Claim 4, wherein the additional stressing elements (40) are arranged distributed over a width of the at least one support strip (60) or are located in its middle region.
6. The slab element (10) according to any one of the preceding claims, wherein in longitudinal direction of a support strip (60) reinforced stressing elements (40) are provided, which are reinforced compared to other stressing elements (40).
7. The slab element (10) according to any one of the preceding claims, wherein a support strip (60) comprises at least one hollow element region (20).
8. The slab element (10) according to any one of the preceding claims, wherein the lattice-shaped structure (50) forms a grid of rectangular fields.
9. The slab element (10) according to Claim 8, wherein the bars (91) of the lattice systems (90) are arranged in a slightly oblique manner relative to a normal of the surface (11) of the slab element (10).
10. The slab element (10) according to Claim 8 or 9, wherein the lattice system (90) comprises support bars (92) which in longitudinal direction protrude over a receiving region (93) for hollow elements (21) and

over which the stressing elements (40) are installed.

11. The slab element (10) according to any one of the Claims 8 to 10, wherein the lattice systems (90) comprise receiving regions (93) which do not contain any hollow elements (21) and over which the stressing elements (40) are installed.
12. The slab element (10) according to any one of the Claims 8 to 11, wherein the individual lattice systems (90) of bars (91) with hollow elements (21) held therein are arranged relative to one another in such a manner that their support bars (92) on both sides mutually overlap one another.
13. Use of the slab element (10) according to any one of the preceding claims as ceiling element.
14. A method for manufacturing a slab element (10), more preferably of a concrete slab element according to any one of the Claims 1 to 12 with the steps:
  - Placing of a lower, unstressed reinforcement (100) on spacers of a shuttering;
  - Placing of at least one lattice system (90) of bars (91) with hollow elements (21) held therein on to the reinforcement (100) or on to the spacers;
  - Placing of at least one stressing element (40) on to the at least one lattice system (90);
  - Placing of an upper, unstressed reinforcement (100) on to the at least one lattice system (90) or on to spacing cages;
  - Introducing and initially hardening of a first

concrete layer for securing the hollow elements (21) against lifting pressure;

- Introducing and hardening of a second concrete layer for producing the final thickness of the slab element (10);
- Stressing of the stressing elements (40) for reinforcing the slab element (10).

15. The method according to Claim 14, wherein the at least one stressing element (40) is placed on to support bars (92) of the lattice system (90) which in longitudinal direction protrude over a receiving region (93) for hollow elements (21).

16. The method according to Claim 15, wherein the at least two lattice systems (90) are installed so that their respective support bars (92) overlap one another.