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(54) **Continuous floor slab construction**

Durchlaufbodenplattenkonstruktion

Construction de dalle de plancher continu

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Description

[0001] The invention relates to the production of a floor slab construction suitable for an industrial floor, on solid ground, and with a continuous concrete floor slab occupying at least 500 m² of surface area and reinforced with 25 to 50 kg/m³ of uniformly distributed steel reinforcement fibers.

[0002] Industrial floors are floors having a relatively large surface area of at least 500 m² and often more than 10,000 m², which are capable of supporting an average load of at least 4 kN/m², and normally more than 10 kN/m², in the form of stacked pallets, the legs of stacking racks and the wheels of fork-lift trucks or other stacking vehicles. They are usually built on solid ground, i.e. the original natural ground, whether or not a top layer has been dug up and/or tamped down and leveled. The upper surface of the floor comprises one or more separate concrete floor slabs, in which the latter are separated from one another by construction joints and/or expansion joints. The construction joints are the joints which are left between the slabs at the end of each continuous pouring period, which is usually one day. The expansion joints are the joints which are set between floor slabs to enable them to expand during warm weather. Such a separate concrete floor slab of itself already has a large surface area, being at least 500 m² and sometimes more than 2000 m². This depends on the anticipated exposure of the floor to fluctuations in temperature (inside or outside floor) and on the pouring method which is used (long or short continuous pouring periods).

[0003] Such a concrete floor slab rests via a foundation layer on the solid ground. Thus the unevenly distributed load on top of the floor slab is transmitted via the floor slab and via this foundation layer in a more evenly distributed form through to the solid ground, which ultimately bears the load. If necessary, depending on the quality of the ground and the anticipated average load, the ground will first be dug up and/or tamped down and leveled before the foundation layer is laid over it. If so desired, the foundation layer can consist of several partial layers. The invention relates to the production of such a floor slab construction, i.e. to the entirety of such a concrete floor slab and underlying foundation layer, on solid ground, and regardless of whether this construction is part of a larger floor with several concrete floor slabs separated from one another by joints running through the entire thickness, or whether it covers the entire surface area of the floor.

[0004] The invention relates further to a floor slab construction described above in which the concrete floor slab is "continuous". This refers to the fact that the floor slab comprises no sawed contraction joints, which serve to solve the problem of the contraction cracks which arise when, after pouring, the concrete contracts while drying out and hardening. The risk here is that the contraction of the entire slab will be taken up either by one

single or by a small number of wide cracks, which are very detrimental. One means of preventing this consists in sawing a number of so-called "contraction joints" in the upper surface of the floor slab after the initial hardening. These are grooves cut down a portion of the way into the depth of the concrete slab and arranged in a relatively dense configuration. Upon contracting, the concrete then cracks along this configuration such that a greater number of narrow, less detrimental cracks are produced. These contraction joints themselves, however, are also places where damage is initiated when the floor is used, and methods are known for avoiding the use of these contraction joints by solving the problem of contraction cracks in another way.

[0005] Hence, instead of letting the contraction cracks develop in a controlled manner as described above, methods are known for counteracting the development of the contraction cracks themselves by means of reinforcing the concrete. This is done either with the use of ordinary steel reinforcement nets or with evenly distributed steel reinforcement fibers distributed uniformly throughout the fresh concrete during the concrete mixing phase. The contraction tensions are then taken up by the reinforcement. In addition, these contraction tensions are kept low by known means (including the use of an anti-friction sheeting, usually a double sheet of polyethylene, over which the floor slab can freely glide during contraction and which also helps to prevent the process of drying out along the underside of the poured slab from proceeding too rapidly, which is one of the causes of contraction cracks). For steel fiber reinforcement, steel fibers will, as usual, be utilized which possess optimal reinforcement efficiency. When all these measures are carried out with sufficient care, then a quantity of between 25 and 50 kg/m³ of steel fiber will usually suffice, in any case for the purpose of taking up the contraction stresses in order to prevent contraction cracks. This will also suffice to prevent cracking due to bending stress under the load, provided the concrete slab is sufficiently thick in relation to this load. However, even with the greatest of care being taken in the construction, one can never be sure that during the drying and hardening process a number of contraction cracks will not form, which can then no longer be controlled.

[0006] The present invention relates to a floor slab construction for an industrial floor in which a continuous floor slab of at least 500 m² can also be reinforced with 25 to 50 kg/m³ of uniformly distributed steel fibers, and in which the problem of contraction cracks which are too wide is also solved, though in another manner - a manner in which the problem of unexpected and uncontrollable contraction cracks does not arise. The invention also relates to a floor slab construction thus obtained.

[0007] According to the invention, the production of the floor slab construction is characterized by :

- (a) the covering of said solid ground with an initial layer of stabilized sand material ;

(b) the covering of said initial layer - before it hardens - with a quantity of between 50 and 130 kg/m³ of stone material evenly distributed over the surface, and the tamping of this stone material into the initial layer, as a result of which, after hardening, this sand material forms, together with the stone material, a supporting layer with a rough surface, this roughness being produced by said stone material ;
(c) the pouring of the concrete for the floor slab directly onto the rough surface of said supporting layer, followed by finishing and hardening to obtain said floor slab.

[0008] By means of this method, a contact surface between floor slab and supporting layer is obtained which, with the sharp points of the protruding stones, is very irregular in a continuous manner over the entire surface, as a result of which the floor slab is continuously anchored against horizontal movements and is nowhere left free to contract. Because of this, thanks to the presence of the steel fibers the contraction will be taken up by a great number of randomly distributed micro-cracks in the concrete, each with a maximum width of 0.5 mm and normally less than 0.2 mm, and with these dimensions, said micro-cracks are regarded as being non-detrimental to the floor. Such a distribution over a large number of micro-cracks is achieved thanks to the fact that when the first crack develops, the fibers which bridge over the crack offer an increasingly strong resistance to the further opening of the crack, (in particular, when the fibers are provided with anchoring ends, such as mentioned below). Because of this, upon further contracting, the concrete will seek out a different place to generate a crack rather than widening the existing crack.

[0009] What is of particular importance in the construction according to the invention is that a system for preventing contraction be avoided which would cause the floor slab to be very tightly attached, for example with a cement slurry, to a solid supporting layer of concrete. In such case, there is the risk that upon hardening, the supporting layer will develop contraction cracks which, due to the strong adhesion, would propagate upwards through the contact surface, thus producing cracks in the floor slab which would be copies of the cracks in the supporting layer underneath it. However, in the system according to the invention, on the one hand, the chance of cracks developing in the supporting layer will be much smaller because this layer consists of a very dry mixture containing a low percentage of cement with little propensity to contract. And, on the other hand, if a crack nevertheless does develop in the direction of the surface of contact with the floor slab, then the anchoring stone material at the contact surface around the crack will loosen, thus allowing a relative movement between supporting layer and floor slab, such that the crack will not propagate further upward. Thus a very local automatic detachment is produced between sup-

porting layer and floor slab, though only at the places where needed, while at the other places the stone material continues to perform its function of restraining contraction.

[0010] The floor slab thickness required to resist bending under this load can then be calculated in the usual manner as a function of the quantity of steel fibers used, the K-modulus (Westergaard) of the supporting layer, and the anticipated load. In addition, care should be taken that the supporting layer has a Westergaard K-modulus of preferably at least 50 MPa/m. The solid ground underneath it should also have sufficient bearing capacity. With a supporting layer such as described below, a K-modulus of the ground of approximately one-third the value of the K-modulus intended for the supporting layer will suffice. If necessary, the ground is first dug off and/or further tamped until it possesses the desired K-modulus, and then well leveled horizontally till there is a difference in level, for example, of not more than 15 mm for a distance of 25 m between the measuring points.

[0011] For the supporting layer, an initial layer of stabilized sand material is then first laid down over the ground, which possibly has been prepared as described above. By "sand material" is meant : inert granular aggregate with a grain size equal to that of sand or smaller, such as sand, fly ash or mixtures thereof. Mixtures of large and small grains are by preference used here in order to increase the compactness of the sand material. A relatively small quantity of cement, preferably between 4 % and 8 % of the total dry weight, is mixed into this material and the entire mass is then moistened to obtain a water/cement ratio which is lower than the amount required to make all the cement react, by preference a ratio of between 0.15 and 0.25. This then is the stabilized sand material which is dumped onto the solid ground, and spread out and tamped down to form an initial layer.

[0012] The initial layer is compacted to as great an extent as is economically feasible, for example to at least 95 %, and preferably to at least 97 %, of the total volume, (which means that the volume actually filled is then at least 95 % or 97 %, respectively, of the total apparent volume). The thickness of the initial layer will depend on the compactness of the supporting layer in its final form, including the initial supporting layer and the stone material lying on top of it, and on the planned K-modulus of this supporting layer.

[0013] A common thickness for the total supporting layer will lie somewhere between 25 and 50 cm.

[0014] Before the initial layer hardens, an amount of between 50 and 130 kg/m² of stone material is placed on top of this initial layer, evenly distributed over the surface of this initial layer. This can be done, for example, either by evenly spreading it out or by unevenly pouring it out and then evenly distributing it. "Stone material" here means : gravel or crushed stone (broken stone) or other similar inert filling material intended for concrete

and of a size greater than 3 mm. This stone material is then firmly compacted and pressed into the surface of the initial layer by pneumatic tamping or, preferably, by rolling it in with a heavy roller. For good compaction, a mixture of stone material is used with a uniform distribution of size up to a maximum of 20 mm. This means, not greater than 20 mm and well distributed between large, medium large and small stones, so that the space which develops between the large stones can be well filled up with the smaller ones. After thus compacting, a 1.5 to 4 cm deep stone layer is obtained, more or less anchored in the initial layer of stabilized sand material. Apart from the unevenness which is caused by the stone material, care is taken that the average surface lies very horizontal, with a difference in level, for example, of not more than 15 mm over a 25 m distance between the measuring points.

[0015] Then the stabilized sand material with the stone material on top of it is left to harden, preferably for two or three days. Thereafter, directly on top of the rough surface thus obtained, the steel fiber concrete for the floor slab is poured, leveled, and then further finished in the usual manner. By "directly on top of the rough surface" is not necessarily meant that there is direct contact between the stone material of the supporting layer and the concrete material of the floor slab. This will indeed usually be the case, but what is meant here is that if there should be an intermediate layer between the stone material and the concrete material, then this intermediate layer must be sufficiently thin so as not to spoil the roughness of the upper surface of the supporting layer, thus allowing the micro-crack mechanism to function as explained above. What must in particular be kept in mind in the system according to the invention is that the use of anti-friction sheeting must be avoided in order that the second function of this sheeting, viz. the prevention of a too rapid drying out of the concrete along the underside (which is a cause of contraction), will also no longer be present. It is therefore not out of the question that a very thin film should be sprayed on top of the stone material to serve as a membrane to close the pores along which the not fully compact supporting layer might (by capillary action) suck the water of the concrete down into the remaining cavities. By preference, however, the concrete will be allowed to come into direct contact with the stone material of the surface. In this case, a too rapid drying out of the concrete along the underside will be prevented by seeing to it that when the concrete is poured for the floor slab, the supporting layer is moistened nearly to the point of saturation. For this purpose, an amount of water will be poured onto it, depending on the thickness and the compactness of the layer, of the order of 8 to 20 l/m² so that, for example, at least 75 % of the cavities in the supporting layer are filled with water. However, when the concrete is poured, there should be no water left standing on the surface of the supporting layer. Hence, it is preferable to begin pouring the water the day before.

[0016] For the concrete which is to be poured, the usual economically justified compositions are used, with the usual measures being taken to ensure, in the first place, that the concrete will display the smallest possible propensity to contract. Thus the amounts of cement which are common for industrial floors will continue to be used, somewhere in the range of between 300 and 340 kg/m³, with the proper amount being chosen as a function of the ambient temperature, the humidity level and the type of cement : rather towards the higher end in the winter than in the summer, and rather a cement with a low heat of hydration, especially in the summer (with a quantity of fly ash as for blast furnace slag cement), rather than a common Portland cement. In any case, as dry as possible a concrete composition will be used in order to minimize the tendency to contract in the process of drying. Thus a water/cement ratio will be utilized which is certainly under 0.52, including the water already present in the sand and gravel. If this should lead to difficulties in terms of the workability of the concrete, then the required amount of superplasticizer can be added according to the known procedure, so that the concrete, with the steel fibers mixed in, falls in a consistency class with a slump of between 15 and 18 cm using the Abrams cone. As for the strength of the concrete, the aim will preferably be to achieve a characteristic compression strength in the range between 30 and 42 N/mm², measured on cubes with 150 mm sides after 28 days. Thus, for example, a concrete can be used with a sand composition of between 700 and 800 kg/m³ and an aggregate granulate with a limited maximum grain size. Thus the recommendation for crushed gravel is to use 50 % size 4/14 mm and 50 % size 4/28 mm. For crushed stone, it is better to use 40 % size 2/7 mm and 60 % size 7/20 mm.

[0017] As for steel fibers for reinforcing the concrete, fibers of the usual dimensions are used in order to reconcile good fiber efficiency with good miscibility, which means fibers with a thickness of between 0.5 and 1.2 mm and a length/thickness ratio of between 40 and 130, by preference between 65 and 85 with a thickness of between 0.7 and 0.9 mm. The fibers must exhibit good 'post-cracking' behavior, i.e. after the appearance of the first crack, the concrete must exhibit a further increasing resistance to further deformation. This is in any case promoted by the use of fibers which have anchoring ends. These are fibers whose ends comprise deformations, such as hook shapes or thickenings, which improve the anchoring of these ends in the concrete, so that their behavior with respect to tearing out of the concrete is improved. The steel of the fibers has a tensile strength that as a rule lies somewhere in the range between 800 and 2000 N/mm², and usually between 900 and 1250 N/mm². These fibers are put into the fresh concrete during the mixing phase and homogeneously distributed throughout the concrete by the mixing action. Fibers with such anchoring ends and with the preferred dimensions as mentioned above will by preference be

used in quantities of between 33 and 40 kg/m³ of concrete.

[0018] After being poured over the supporting layer, the concrete is first finished and then left to harden, thus forming the floor slab. The finishing comprises, in any case, the leveling off flat of the concrete surface to form the floor slab with a level surface. When an additional wearing course is laid over the hardening concrete by means of strewing hard granulates such as quartz or carborundum into the surface, followed by compaction with a polishing machine, then this is also part of the finishing process, along with the possible use of wax-based follow-up treatment products as surface pore fillers. After the concrete is poured and leveled, it is left to harden, and during approximately the first fourteen days no loads should be put upon it. During the hardening period, in accordance with common practice, this concrete must be protected against a too rapid rate of upward evaporation of the water it contains, which is a cause of contraction. Thus, for example, an anti-evaporation product (curing compound) can be sprayed over the surface, or protective plastic sheeting can be laid over this surface. The floor can also be put under water for approximately fourteen days and covered with plastic sheeting so that the floor can harden under conditions of 100 % humidity. From fourteen days onward, the use of the floor can gradually increase, depending on the ambient temperature during the hardening process : e. g. from 0 % of the nominal load after two weeks to 100 % of this load after roughly six weeks when the hardening process takes place at 15°C.

[0019] The floor slabs poured are preferably made to approach as closely as possible the shape of a square, which means that the ratio between the longest and the shortest side of the rectangle is not more than 1.5, and as close as possible to 1. If construction joints and/or temperature expansion joints are needed, then they are preferably set at a distance of between 30 and 55 meters from one another, and the construction joints are by preference made to coincide with the temperature expansion joints.

Claims

1. Method for producing a floor slab construction suitable for an industrial floor, on solid ground and with a continuous concrete floor slab occupying at least 500 m² of surface area and reinforced with 25 to 50 kg/m³ of uniformly distributed steel reinforcement fibers, which method is characterized by :

- (a) the covering of said solid ground with an initial layer of stabilized sand material ;
- (b) the covering of said initial layer - before it hardens - with a quantity of between 50 and 130 kg/m² of stone material evenly distributed over the surface, and the tamping of this stone ma-

terial into the initial layer, as a result of which, after hardening, this sand material forms together with the stone material a supporting layer with a rough upper surface, this roughness being produced by said stone material ;

(c) the pouring of the concrete for the floor slab directly onto the rough surface of said supporting layer, followed by finishing and hardening to obtain said floor slab.

2. Method according to claim 1, wherein said stabilized sand material consists mainly of sand and/or fly ash mixed with a quantity of cement amounting to between 4 % and 8 % of the total dry weight of the mixture, and moistened to obtain a water/cement ratio of between 0.15 and 0.25.
3. Method according to claim 2, wherein said initial layer is compacted to the point that it occupies at least 95 % of its total volume, and that said supporting layer has a thickness of between 20 and 50 cm and a K-modulus of at least 50 MPa/m.
4. Method according to one of the foregoing claims, wherein said stone material consists mainly of gravel and/or crushed stone, and has a uniform size distribution ranging up to a maximum of 20 mm, which stone material is pressed into the initial layer by rolling.
5. Method according to one of the foregoing claims, characterized in that when the concrete for the floor slab is poured, said supporting layer is moistened nearly to the point of saturation and the concrete has a water/cement ratio of less than 0.52.
6. Method according to one of the foregoing claims, wherein for pouring the floor slab a concrete is used containing a quantity of cement in the range of between 300 and 340 kg/m³, and containing steel fibers with a thickness of between 0.7 and 0.9 mm and a length/thickness ratio of between 65 and 85, and which are provided with anchoring ends.

7. Continuous concrete floor slab with a surface area of at least 500 m², reinforced with 25 to 50 kg/m³ of uniformly distributed steel reinforcement fibers, and suitable for an industrial floor, produceable following a method according to one of the claims 1 through 6.

Patentansprüche

1. Verfahren zur Herstellung eines für einen Industrieboden geeigneten Bodenplattenaufbaus auf festem Untergrund und mit einer durchgehenden Betonbodenplatte, welche wenigstens 500 m² des Oberflä-

chenbereichs einnimmt und mit 25 bis 50 kg/m³ von gleichförmig verteilten Stahlbewehrungsfasern bewehrt ist, welches Verfahren gekennzeichnet ist durch:

- (a) das Bedecken des festen Untergrundes mit einer Anfangslage von stabilisiertem Sandmaterial,
- (b) das Bedecken der Anfangslage - bevor diese aushärtet - mit einer Menge von zwischen 50 und 130 kg/m² von über die Oberfläche gleichmäßig verteiltem Steinmaterial und das Einstampfen dieses Steinmaterials in die Anfangslage, wobei als Ergebnis davon, nach dem Aushärten, dieses Sandmaterial zusammen mit dem Steinmaterial eine Tragelage mit einer rauen oberen Oberfläche bildet, wobei diese Rauigkeit durch das Steinmaterial gebildet wird,
- (c) das Gießen des Betons für die Bodenplatte direkt auf die raue Oberfläche der Tragelage, gefolgt durch die Endbearbeitung und das Aushärten zum Erhalten der Bodenplatte.

2. Verfahren nach Anspruch 1, worin das stabilisierte Sandmaterial hauptsächlich aus Sand und/oder Flugasche gebildet ist, gemischt mit einer Zementmenge im Bereich von zwischen 4 % und 8 % des gesamten Trockengewichts des Gemisches und befeuchtet, um ein Wasser/Zement-Verhältnis von zwischen 0,15 und 0,25 zu erhalten. 25 30
3. Verfahren nach Anspruch 2, worin die Anfangslage soweit verdichtet wird, daß sie wenigstens 95 % ihres Gesamtvolumens einnimmt und daß die Tragelage eine Dicke von zwischen 20 und 50 cm und einen K-Modul von wenigstens 50 MPa/m aufweist. 35
4. Verfahren nach einem der vorangehenden Ansprüche, worin das Steinmaterial im wesentlichen aus Kies und/oder Schotter gebildet ist und eine gleichförmige Größenverteilung aufweist, die bis zu einem Maximum von 20 mm reicht, welches Steinmaterial durch Einwalzen in die Anfangslage gepreßt wird. 40 45
5. Verfahren nach einem der vorangehenden Ansprüche, dadurch gekennzeichnet, daß dann, wenn der Beton für die Bodenplatte gegossen wird, die Tragelage näherungsweise bis zum Sättigungspunkt befeuchtet ist und der Beton ein Wasser/Zement-Verhältnis von weniger als 0,52 aufweist. 50
6. Verfahren nach einem der vorhergehenden Ansprüche, worin zum Gießen der Bodenplatte ein Beton verwendet wird, der eine Zementmenge im Bereich von zwischen 300 und 340 kg/m³ enthält und Stahlfasern mit einer Dicke von zwischen 0,7 und 0,9 mm 55

und einem Länge/Dicke-Verhältnis von zwischen 65 und 85 mm enthält, welche mit Verankerungsenden versehen sind.

- 5 7. Durchgehende Betonbodenplatte mit einem Oberflächenbereich von wenigstens 500 m², welche mit 25 bis 50 kg/m³ von gleichförmig verteilten Stahlbewehrungsfasern bewehrt ist und für einen Industrieboden geeignet ist, welche nach einem Verfahren gemäß einem der Ansprüche 1 bis 6 herstellbar ist. 10

Revendications

1. Procédé de production d'une construction de dalle de plancher appropriée pour un plancher industriel, sur un terrain résistant, et avec une dalle de plancher en béton continue qui occupe au moins 500 m² d'une aire de surface et qui est armée avec 25 à 50 kg/m³ de fibres d'armature en acier uniformément distribuées, caractérisé en ce qu'il comprend :

(a) le recouvrement dudit terrain résistant avec une couche initiale de matériau sableux stabilisé ;

(b) le recouvrement de ladite couche initiale - avant qu'elle durcisse - avec une quantité d'entre 50 et 130 kg/m³ d'un matériau pierreux uniformément répartie sur la surface, et le damage de ce matériau pierreux dans la couche initiale, avec pour résultat qu'après le durcissement, ce matériau sableux forme, avec le matériau pierreux, une couche support possédant une surface supérieure rugueuse, cette rugosité étant produite par ledit matériau pierreux,

(c) la coulée du béton pour la dalle de plancher directement sur la surface rugueuse de ladite couche support, suivie par la finition et le durcissement pour obtenir ladite dalle de plancher.

2. Procédé selon la revendication 1, dans lequel ledit matériau sableux stabilisé est principalement composé de sable et/ou de cendres volantes mélangés avec une quantité de ciment qui représente entre 4 % et 8 % du poids sec total du mélange, et mouillés pour obtenir un rapport eau/ciment d'entre 0,15 et 0,25.
3. Procédé selon la revendication 2, dans lequel ladite couche initiale est compactée au point d'occuper au moins 95 % de son volume total, et en ce que ladite couche support a une épaisseur d'entre 20 et 50 cm et un module K d'au moins 50 MPa/m.
4. Procédé selon une des revendications précédentes, dans lequel ledit matériau pierreux est essentiellement composé de gravier et/ou de pierre con-

cassée et présente une distribution granulométrique uniforme allant jusqu'à un maximum de 20 mm, lequel matériau pierreux est pressé dans la couche initiale par roulage.

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5. Procédé selon une des revendications précédentes, caractérisé en ce qu'au moment où le béton pour la dalle de plancher est coulé, ladite couche support est mouillée pratiquement jusqu'au point de saturation, et le béton a un rapport eau/ciment de moins de 0,52. 10
6. Procédé selon une des revendications précédentes, dans lequel, pour couler la dalle de plancher, on utilise un béton qui contient une quantité de ciment comprise dans l'intervalle d'entre 300 et 340 kg/m³, et qui contient des fibres d'acier ayant une épaisseur d'entre 0,7 et 0,9 mm et un rapport longueur/épaisseur d'entre 65 et 85, et qui sont munies d'extrémités d'ancrage. 15 20
7. Dalle de plancher en béton continue ayant une aire de surface d'au moins 500 m² renforcée avec 25 à 50 kg/m³ de fibres de renforcement en acier uniformément réparties, et appropriée pour un plancher industriel, qui peut être produite par application d'un procédé selon une des revendications 1 à 6. 25

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