THIN PRE-STRESSED CONCRETE SLAB

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ABSTRACT OF THE DISCLOSURE

A pre-stressed concrete slab having a thickness of substantially 4 inches and a width of 1 or more feet is useful for spans beyond 20 feet. The slab has between 25% and 37% of its cross-sectional area void to provide for longitudinal passages symmetrically disposed between the top and bottom sides of the slab. Steel reinforcement is provided along the neutral plane located half way between the top and bottom slab faces. Such a slab has highly desirable load-carrying characteristics and, in addition, has highly desirable fire resistance characteristics. The slab utilizes light weight aggregate and high strength steel and can receive a topping layer up to about 2 inches in thickness also of lightweight material.

This invention relates to a thin pre-stressed concrete slab of the type having longitudinal passages therethrough and useful for floors in buildings. The slabs employing the present invention are adapted for use in thickness of the order of about 4 inches and having any desired width. As a rule, a slab employing the present invention may range in width from about 12 inches to as much as 3 feet. Slabs having a width of 2 or 3 feet are preferable for installation and generally narrower slabs may be needed for filling. Pre-stressed concrete slabs embodying the present invention are designed for span lengths of no more than about 20 feet between supports.

In multi-story buildings it is desirable to provide concrete slabs having a minimum thickness. For heavy construction, slabs having a thickness of 8 or 10 inches having suitable pre-stressing have been provided. Such slabs are provided with longitudinal conduits or passages therethrough for reducing the amount of concrete, reducing the weight, and, additionally improving the load-carrying characteristics of the slab. As a rule, such relatively thick slabs have been provided with steel reinforcement in the lower half of the slab, generally near the bottom of the passageway, and well below the neutral plane of the slab. Because of the location of the pre-stressing in such slabs, there has been created axial stress and eccentric bending stress. This has resulted in a slab which normally, prior to installation, has a tendency to curve upwardly into a circular arc. This arching combined with deflection due to the dead load of the slab (including topping) results in a camber or rise of the center of the slab with respect to the slab ends. When such a thick slab is installed and has a dead load resulting from a thickness of topping and is additionally loaded with live load, the net result is that the slab deflects or curves downwardly. If the load is uniform along the slab length, the downward curvature has the characteristics of a parabola. The combination of camber plus response to uniform load results in a complex downward curvature.

Reducing the thickness of a thick pre-stressed slab cannot be accomplished without fundamental re-design of the entire slab. An important consideration in the design of fire requirements. Such fire requirements are set forth in ASTM (American Society of Testing Materials) Specification E-119. Briefly, such a specification requires that a slab maintain its general support characteristics under specified conditions of fire for the desired period of fire endurance. Apart from the integrity of the concrete under fire conditions, an important factor is the total load-carrying or load-sustaining characteristics of steel. Within recent years, the manufacturers of pre-stressed concrete slabs have adopted special steel strand for reinforcement purposes (see ASTM-A-416—Uneccated 7 wire stress relieved strand). Such special steel strand, as a rule, does not maintain its stress characteristics as well as hot rolled steel reinforcing under high temperatures which may be encountered in fires. The advantage of such special steels, however, resides in the fact that such special steels under normal temperature conditions are much stronger than hot rolled steel so that greater reinforcement is obtainable with the special steels as compared with steels formerly used. For example, it is customary to tension steel strand in slabs to substantially 70% of ultimate strength, leaving a margin for safety. With higher ultimate strengths obtainable in special steel strand, the reduction in the amount of steel necessary for a slab more than compensates for the increased price of such steel.

Due to a combination of fire test requirements and the desire for thinner slabs, I have determined that a slab substantially 4 inches in thickness (plus or minus about ¼ inch) is practical from both a fire test standpoint and from a structural standpoint if the pre-stressing strands and longitudinal ducts or passages in a slab are disposed in predetermined relation. As a result of such relation, a slab is provided having highly desirable structural and support characteristics and also having desirable fire endurance characteristics. In general, a slab employing the present invention having the thickness specified will have pre-stressing strands of special steel located in the neutral plane half-way between the top and bottom surfaces of the slab and will have passages therethrough whose maximum dimension between top and bottom slab faces is such that no more than about 50% of slab thickness between the top and bottom slab faces is taken up by the passageway. This passageway is symmetrically disposed between the top and bottom slab faces and is of a width (the dimension along the width of the slab extending between the slab sides) which is of the general order of about 3/8 of the width of the slab. The ratio of width of void area to slab width will vary depending upon the desired characteristics of the slab. The distance between adjacent reinforcing regions (there will be steel reinforcement on each side of the slab passage) will also depend upon desired slab characteristics. In general, the number of strand reinforcing regions will be one greater than the number of longitudinal passages. Thus, in a slab having one longitudinal passage there will be two pre-stressing strands with one additional pre-stressing strand unit added for each additional longitudinal passage.

In addition to the details set forth above, the new slab preferably is constructed of lightweight concrete mix which permits maximum utilization of the load-carrying
characteristics of the new slab. This will be set forth in greater detail later.

A highly desirable characteristic of the new slab is the substantial elimination of the eccentricity of the load bearing in conventional thick slabs. A further desirable characteristic resides in the increased load-carrying ability of the new slab when provided with structural topping, particularly if the center of a span is temporarily supported (while the topping cures) at a position substantially below the slab end bearings.

Referring now to the drawings, FIG. 1, shows a section of a slab employing the present invention.

Slab 10 has top surface 11 and bottom surface 12. Slab 10 has sides 13 and 14. Sides 13 and 14 are shaped to provide grout keys 15 and 16. These grout keys may be of any shape and permit the introduction of grout between adjacent slab sides. The slab thickness between top face 11 and bottom face 12 is substantially 4 inches with about $\frac{1}{4}$ inch tolerance above or below this figure. Elongated oval passages 19 and 20 are provided extending the full length of the slab. The number of passages 19 and 20 will depend upon the width of a slab and the dimensions of such passages along the width of the slab will also depend upon the width of the slab. As had been previously indicated, a slab may have any desired width and may have any desired number of passages. The height of each passage 19 (the distance along the line between top and bottom) will be about $\frac{1}{2}$ of the nominal thickness (about 4 inches) of the slab. In this instance the thickness will be substantially 2 inches and each passage will be symmetrically disposed between the top and bottom slab faces. The horizontal dimension of a passage along the section (the dimension along the line between sides 13 and 14) and shape will be such that about 25% to about 37% of the cross-sectional area of the entire slab will be void. In computing this area, sides 13 and 14 of a slab can be assumed to be straight since grout will provide some reinforcement. Each passage generally has flat top and bottom portions 21 and 22 and semi-cylindrical ends 23 and 24.

The slab concrete is of lightweight coarse aggregate such as Haydite B with natural sand and may have a unit weight of about 115 pounds per cubic foot. Slab 10 has a neutral plane 26 which extends horizontally along the section halfway between slab faces 11 and 12. Neutral plane 26 extends for the length of the slab. Along neutral plane 26 are located steel reinforcing 30, 31, 32. Since slab 10 has two longitudinal passages 19 and 20, the steel reinforcing will be three in number. Each steel reinforcing will consist of steel either in the form of a solid rod or strand.

The particular type of steel used in the high strength steel called for by the above identified specification ASTM-A-416 (minimum ultimate strength 250,000 pounds per square inch). The amount of steel used and the tension applied thereto will depend upon the particular characteristics to be developed by the slab. The steel is bonded to the concrete throughout the length thereof and after curing, except for the end few inches of a slab, the full tension in each reinforcement exists by virtue of the bonding of the concrete and steel. Inasmuch as the manufacture of pre-stressed slabs is well-known, no detailed description is necessary. In general, the steel strands are maintained in a tensioned condition in the concrete form during casting and curing of the slab. The important characteristic for strand location insofar as fire resistance is concerned is the distance from bottom face 12 of a slab. A minimum spacing of substantially $\frac{1}{4}$ inch is required for satisfactory fire resistance purposes. The 2 inch spacing thus provides satisfactory fire resistance. The horizontal location will be determined by engineering considerations.

It is understood that neutral plane 26 contains the geometrical centers of the steel reinforcement. The reinforcement will have a transverse dimension of the general order from about $\frac{1}{4}$ inch to about $\frac{1}{2}$ inch depending upon the amount desired.

The reinforcement is disposed about half-way between the slab side and side of passage through the slab. Where a slab has double width as illustrated, two passages 19 and 20 have steel reinforcement 31 midway between them. This relationship would hold true if a wider slab had more than two passages. In general, adjacent passages, such as 19 and 20, are separated by concrete equal to the slab thickness as measured along the neutral plane. The passages are symmetrical with reference to neutral plane 26 and the passage height dimension between neutral faces 11 and 12.

The slab is manufactured and is cured in conventional fashion to develop its full strength. After a slab employing the present invention has been installed, as part of a floor for example, a topping layer 28 can be provided. This topping layer may range up to as much as 2 inches in thickness and is made of lightweight material such as, for example, Haydite 42X having a weight of about 96 pounds per cubic foot. The topping layer, after curing, contributes substantially to the strength of the slab.

What is claimed is:

1. A pre-stressed concrete slab having normally flat top and bottom outer faces for installation in horizontal position, said slab having a thickness of substantially 4 inches and a width between about 1 foot and about 3 feet and having a maximum length of about 20 feet, said slab having at least one passage for the length thereof, there being one passage for substantially each foot of slab width, each passage, in transverse slab section, having substantially flat top and bottom ends spaced vertically 2 inches apart and symmetrically disposed between the slab top and bottom, each passage having its largest transverse dimension as width along a slab center line extending between slab sides, between the top and bottom of a slab, each passage as viewed in cross-section being symmetrical with respect to center lines extending between the slab top and bottom faces and between the slab sides, the maximum width of each passage being about 8 inches, a slab cross-section having between about 25% and about 37% of its area void of concrete because of said passages, said slab having tensioned steel reinforcements extending the full length of the slab and bonded to the slab concrete, the tensioned steel reinforcements having the centers of each reinforcement located when viewed in transverse slab section along the center line extending between the slab sides, steel reinforcements being disposed adjacent slab sides and being located substantially midway between the slab side and passage side, steel reinforcement being disposed between adjacent passages (where a slab has more than one passage) midway between adjacent duct sides, the passage location, as viewed in transverse slab section, and steel reinforcement location cooperating such that said slab is located well within concrete in all directions, said slab material being of lightweight aggregate and the structure as a whole providing excellent protection of steel reinforcement against fire in a building containing such slabs as structural elements, said slab having desirable support characteristics when installed and being adapted to carry a light weight topping layer of a thickness up to about 2 inches.

2. The slab according to claim 1 wherein said steel reinforcement consists of steel having an ultimate strength of at least about 250,000 p.s.i.

3. The construction according to claim 2 wherein said slab is constructed of aggregate having a weight per cubic foot of about 115 pounds.

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