MECHANICAL METHODS OF STEEL PLACEMENT FOR SLIP-FORM CONSTRUCTION OF CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

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•TRADITIONAL methods for the incorporation of steel in concrete pavement slabs have included the use of chair supports, "two-lift" placement with the reinforcement sandwiched between two layers of concrete, and movable sled devices that are used to hold the steel at predetermined heights and are rolled away as the concrete is poured. The rate at which steel could be placed by any of these methods was not compatible with the inherent production capabilities of the slip-form paver. Consequently, during the past several years, major efforts have been directed toward the development of mechanical methods for placing mesh or reinforcing bars or both in conjunction with slip-form paving. Today, because of these improved devices, contractors can lay 6,000 ft or more of reinforcement in less than 10 hours.

The mechanical devices for steel placement in pavement slabs can be categorized into two general groups: the mesh depressors and the bar placers.

MESH DEPRESSORS

The mesh depressor was the first breakthrough in the search for machines to place reinforcement in one lift. It was used in Oregon (1960), Louisiana (1961), and Indiana (1962). The early version of this unit rode on forms and used vibration and pressure to depress the steel. The unit depressed the steel while standing stationary, which precluded the lateral displacement of the mesh during depression. The machine was self-propelled and carried four hydraulic rams under which was suspended a lattice steel frame. On the frame at each ram was a vibrator. Limit chains were used to halt the frame at the correct depth for mesh embedment. The rams then retracted the frame in preparation for the next sinking cycle. Another version, used in Indiana in 1962, consisted of a giant screen or grid that vibrated and depressed the sheet of mesh fabric to its proper depth. The steel placement unit was fitted with large depressing units that left a waffle pattern on the concrete. Its pressing depth was governed by adjustable locknuts on threaded guide rods instead of by limit chains.

At the time of this study, the manufacturers of mechanical mesh depressors were Heltzel Steel Form Co., Rex Chainbelt Co., and CMI, Inc. Each of these companies produces a single model that can be used either with side-form or with slip-form paving. The machine made by the Heltzel Co. is a self-propelled unit, whereas the other two machines are attachments to slip-form pavers, spreaders, or finishers.

The Heltzel Co. unit is adjustable in width from 12 to 24 ft and carries four grids with vibration runners on 20- by 23-in. centers Each grid consists of four blades welded to the vibrator housing. The basic length of the grid is 10 ft.; it can be extended to 15 ft by using detachable end sections. The machine depresses steel from the surface of the full depth slab. Mesh is placed on the surface of the wet slab, and the machine moves forward to position directly over the mesh. As the mesh depressor comes to a full stop, its operator actuates the vibration grids and the hydraulic pressure. Vi-

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bration and pressure are the major factors responsible for sinking the mesh. Vibration helps to move the aggregate particles aside while the wire moves down into the mix. After the mesh has been depressed to the proper depth, hydraulic cylinders lift the grids from the concrete and the machine moves to the next position. The operation of depressing the steel takes between 10 and 18 sec and leaves a waffle pattern on the slab. Although the machine stands squarely on the mesh that is being depressed, a length of 1 ft or more of the next mesh section at the point of overlap is also depressed. This eliminates the possibility of the next sheet being dragged as the machine moves forward. It also eliminates the need for more extensive vibration of the concrete after the initial depression cycle.

The current model of the Rex Chainbelt unit was introduced in 1965. This unit rides on crawler tracks as an attachment to the front of a placer or slip-form paver. It consists essentially of a set of blades, in two banks, that are attached to a frame. A mechanism of gears and springs within this frame produces an eccentric movement with an amplitude of $\frac{3}{4}$ in. This arrangement imparts an oscillatory motion to the blades, and the resulting tamping and tucking action makes continuous steel placement possible without vibration. The final depth for the steel depends on the setting of the rear ends of the blades. Both the blades and the slopes can be adjusted to meet the paving conditions encountered. The depressor blades are evenly spaced across the full slab width and can depress mesh to depths of 6 in. The depressor units are hydraulically lifted to pass over dowel brackets, and crown adjustments are made from the slip-form or placer console.

The unit manufactured by CMI, Inc., also attaches to the front of a slip-form paver. It depresses the mesh into the mix by using high-frequency vibration and low amplitude. The blades are vibrated at 2,000 to 4,000 cpm with an amplitude of $\frac{1}{8}$ in. Vertical baffles are responsible for pushing the steel into the concrete. The machine rides on pneumatic tires and is hydraulically powered from the slip-form unit. It is equipped with side forms to keep the mix within the paving boundaries while the steel is being depressed.

BAR PLACERS

Where bar mats and mesh are used, most of the labor is performed in the shop, and relatively few workers are required in the field. Where reinforcing bars are used, however, workers are required to load and unload the steel and to distribute and tie it. Contractors have therefore developed machines that help to speed the lapping and tying. They have also developed machines that will hold the tied steel in the desired position for pavement construction. Either this position can be the final one, in which case the concrete is placed through and around steel, or the steel can be placed on the surface of the fresh concrete and then depressed to its final position. Three distinct types of equipment can be identified within the bar placer group.

Bar Vibrator Machine

The bar vibrator unit is decreasing in popularity because it is not adaptable for use with the slip-form paver. It is similar in design to the mesh depressor of the Heltzel Co., except that notches are used under the grid to hold the steel bars in their proper position.

In 1964, two Illinois contractors used two machines to place reinforcing bars by a method that eliminated chair supports and permitted single-lift paving. The first machine was a riding platform, 45 ft in length, that traveled behind a concrete spreader. This unit was manned by workers who took bundles of 30-ft long bars from delivery cranes and strung them out in position, spliced and wire tied them, and fed the bar lines into a set of spacing cups. The steel drew itself off as the rig advanced. Transverse bars were placed on 25-in. centers by two reels mounted in front of the machine. These transverse bars were positioned on the longitudinal bars.

The second machine, which performed the actual depressing of the steel, consisted of two 12- by 15-ft assemblies of large vibrating grids. After the machine was moved into position over the slab, a hydraulic ramp depressed the bars a distance of 15 ft.

Grooved surfaces distributed the ram pressure over the steel and ensured its even submergence without local distortion or major disturbance of the fresh concrete.

Tube Assembly

The assembly holds the reinforcement in position while the concrete is deposited, spread, and consolidated. It consists of a form-riding frame that contains flared tubes for receiving and positioning the steel just ahead of the concrete spreader. Two modifications of this machine are currently in use. In the first, 44 or 48 lines of reinforcement are fed through the tubes. In the second, the middle 6 bars are not positioned but instead are supported with tie bars on chairs. The first type has recessed tubes, whereas the second type has tubes of equal length.

The first step in the paving operation is to lay the lapped and tied steel reinforcement out on the subgrade. The steel is then fed individually through flared tubes that are 16 to 30 ft in length. There are either 44 or 48 tubes, depending on the design spacing of the longitudinal bars. The outside diameter of the flares is about 3 in. and the inside diameter of the tubes is $2\frac{1}{2}$ in. After bar feeding has been accomplished, the unit is attached to the front of the concrete placer where it is held at the proper elevation while the concrete is placed and consolidated. The height of the tubes can be adjusted with the aid of double nuts and bolts that are located in the top of the attaching beam in the rear; another set of double nuts at the bottom can be used to adjust the tubes horizontally. The unit itself is controlled from the operator's console. One version now in use has hydraulic cylinders at each corner to control the height. The frame holding the tubes is hinged on the bottom at the centerline of the roadway with a hydraulic cylinder on top of the hinged portion. This center cylinder raises the tubes to the desired straight-line crown. Tie bars, depending on their position, can be inserted by hand or by rotating the notch drum at the back of the placer. They can also be supported on chairs.

Rebar Installer

The installer was introduced by the Rex Chainbelt Co. in 1969. It was designed to be compatible with the company's belt placer although it can be used with the slip-form paver. It consists of four drums. On each drum is mounted a set of helical rows of teeth like those on a mower sickle bar. The drums span the entire width of the slab and are mechanically operated. They are designed to slowly rotate while the individual bars are gradually tamped downward to the desired position. The drums operate independently of each other and are hydraulically controlled from the slip-form console.

The paving operation is started by laying, lapping, and tying continuous lengths of reinforcing rods on the subgrade. There is no need to line up the rods accurately. The steel is then raised above the subgrade by a roller in front of the spreader and is threaded to the belt placer in two separate sets. The steel goes over the belt spreader and out through the back. A rubber-tired unit attached to the trailing forms of the spreader brings the two sets of steel together and roughly spaces them across the width of the pavement. This unit has two horizontal pipes between which is a series of short vertical rollers, placed at either 6 or $6\frac{1}{2}$ in. depending on the number of lines of steel bars (usually 40 or 48 lines). The rods are fed through these rollers for proper spacing.

Another spacing unit, similar in design to the other spacer, is attached to the slip-form paver. Here, all the bars are properly spaced and held in position by the set of vertical rollers. This unit is followed by track-mounted, saw-toothed rotary tampers that are attached to the front of the slip-form paver. As the machine advances, the drums revolve, and the serrations slip over the rods and force them down into the fresh concrete. Because the rebar installer is attached to a slip-form paver and takes its grade from the paver wires, it installs the steel precisely to the desired elevation.

SUMMARY OF FINDINGS

The extent of the use of mechanical steel placers in this country was evaluated through questionnaires directed to selected highway officials, correspondence and in-

terviews with contractors and other highway officials, and observations of actual jobs. The procedures followed on selected jobs were recorded on film with the aid of a time-lapse camera, and the photographs were later used in the analyses of the placement methods and techniques. From the observation and the subsequent analyses, the following summary comments are made:

1. The number of states that have turned to the use of continuously reinforced concrete pavements is rapidly increasing.
2. Machines are now available that can place steel faster, at less expense, and with less labor than the manual operations formerly employed. These machines have been used to the general satisfaction of the state highway officials.
3. Several states have modified their specifications so as to accommodate placement tolerances that are compatible with the mechanical methods.
4. Many states have eliminated the use of transverse bars in the construction of continuously reinforced concrete pavements.
5. Through adequate planning and the use of mechanical methods for steel placement, contractors have demonstrated that they can improve the efficiency of their steel laying operations.
6. Currently available mechanical devices for depressing steel are not yet fully perfected, but additional improvements can be expected in the future.
7. The savings that can currently be realized from the use of mechanical steel placers cannot be specifically identified because of limited experience. However, the potential savings can be sufficiently attractive to warrant the interest of highway officials.

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