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Mechanical Installation of Interlocking Concrete Pavements

Mechanical installation originated in Germany and the Netherlands in the late 1970s. The growth of street, port, and airport projects required timely installation with fewer workers. Machines were developed to increase productivity while reducing fatigue and injury (1-4). Today, over 5,000 mechanical installation machines operate in Germany alone with thousands more in use throughout Europe. They are used for projects as small as 10,000 sf (1,000 m 2) (5). Mechanical equipment was first introduced in North America in the early 1980s. The first mechanically installed project was placed in 1981, a 1,000,000 sf (93,000 m 2) container terminal in Calgary, Alberta. Since then, hundreds of commercial, municipal, port, and airport jobs have been installed mechanically in most states and provinces across North America. Some examples include city streets in Dayton, Ohio (the first mechanically installed street in the U.S.) (6); Cincinnati, Ohio; Toronto, Ontario; Northbrook, Illinois; Naples, Florida; and Palm Desert, California; container yards in Tampa, New Orleans, Baltimore, and Oakland; and an airfield at St. Augustine, Florida. To demonstrate the use of mechanical installation in North America, the ICPI offers a 10-minute video entitled, "Engineered Paving Systems for Ports, Airports and Roadways-the Economical Advantage of Machine-Laid Interlocking Concrete Pavers." Mechanical installation must be viewed as a system of material handling from manufacture to on-site placement of the concrete pavers. This technical bulletin provides guidelines for the manufacturer, designer, and contractor of mechanically installed pavements in order to realize high efficiencies from this system of material handling. Successful mechanical installation relies on four factors that affect efficiency and costs. These include: 1. Equipment specifically designed to efficiently handle (a) transport of packaged concrete pavers onto/around the site, (b) screeding of bedding sand, (c) installation of the concrete pavers. 2. The shape of the paver and configuration of the laying pattern. 3. Careful job planning by the contractor with support from the manufacturer before the job begins. 4. Systematic and efficient execution of the installation on the job site. As of 2003, ICPI has released Tech Spec 15 - *A Guide for Construction of Mechanically Installed Interlocking Concrete Pavements*. The guide is intended for large, mechanically installed projects and is for facility owners, design professionals, contractors, and manufacturers. It provides requirements for quality control of materials and their installation, including bedding sand and pavers. It includes a Quality Control Plan jointly developed and implemented by the paver installation contractor, the paver manufacturer and the general contractor. The specification guide facilitates planning and coordination among these entities, and it supports a systematic approach to manufacture, delivery, installation, and inspection.

Figure 1. Mechanical installation equipment at Port of Tampa, Florida.

Figure 2. A cube of 90° herringbone pattern rectangular pavers ready for installation.

Figure 3. (below) Non-motorized equipment used to set a small layer of pavers.
Figure 4. (right) Motorized equipment with a mechanical clamp.

1. Equipment for Mechanical Installation

Mechanized equipment includes an operator-activated clamp that lifts one layer or cluster of pavers at a time. Each layer can consist of 20 to 72 paving units. The pavers are manufactured in their prescribed laying pattern within the layer. In rare cases, two smaller layers are manufactured and combined in the factory to make one large layer. Layers are packaged in a "cube," i.e., each layer typically stacked 8 to 10 units high. The cubes arrive at the site with each layer ready to be lifted by the mechanical equipment and placed on the screeded bedding sand. Figure 2 shows a cube of pavers opened and ready for installation by mechanical equipment. When grasped by the clamp, the pavers remain together in the layer. They interlock from lateral pressure provided by the clamp while being lifted. Each layer or cluster is typically about a square yard (m^2) in area. The exact layer area varies with each paver pattern. The area covered by the layer can be provided by the manufacturer.

Figure 5. Motorized equipment with a hydraulic clamp.

Figure 6. The vacuum head over the paver layer.

Types of Equipment--Mechanized equipment may be either non-motorized or motorized. *Nonmotorized* equipment consists of a wheeled hand cart and clamp that grabs a half layer, or about 15 to 20 pavers. While it is not as efficient as motorized equipment, a hand-held cart can save time and strain on the installation crew (see Figure 3). Nonmotorized equipment has not been used extensively in North America. However, it may be useful on jobs where noise from vehicles is not permitted (e.g., hospitals), or places with weight limitations and very limited working space, such as roofs. Most *motorized* equipment prevalent in North America is no heavier than a small automobile and is almost as quiet while operating. This equipment can use three different kinds of clamps for placing concrete pavers. The first type is a *mechanical* clamp shown in Figure 4 (7). This clamp consists of many levers that are adjusted to conform to the dimensions of the paver layer prior to starting the job. The initial adjustment of the clamp ensures a tight fit against the layer when activated. When the clamp closes and picks up the layer, the movement in the levers compensates for possible slight misalignment of pavers. Misalignment can be from minor dimensional differences among the pavers in the layer, or caused by small bits of dirt that occasionally lodge between them. When activated by the machine operator, the clamp levers close in unison to pick up a layer. The clamp tightens against its sides while being lifted. The operator then aligns the layer next to the other pavers on the bedding sand. The layer is released from the straight while attempting to wedge the pavers between layers. Wider joints result in a loss of interlock which may reduce the structural integrity and stability of the pavement surface. Therefore, consistent paver dimensions throughout the job helps the crew work efficiently by maintaining straight lines, uniform joint widths, while contributing to interlock. Dimensional growth of pavers is managed by periodically changing molds during manufacturing. This will enable pavers to enlarge consistently while staying within specified tolerances. The number of cycles a mold can run prior to changing will depend on its quality and the abrasiveness of the concrete mix. Dimensional growth is also managed by periodically checking the paver dimensions. This distribution can be done with a ruler, template, or a gauge. An example of a gauge is shown in Figure 16. Dimensional growth is further managed by unloading and installing the largest pavers first. However, loads would need to be marked and distributed on the site in the order of production. This distribution may not be possible on some jobs. Pavers should have straight, square sides to ensure a secure grip by mechanical or hydraulic clamps. Pavers with bulged or slightly rounded, "bellied" sides can drop while being held by these clamps (12). Furthermore, straight lines and consistent joint widths cannot be maintained and interlock decreases. Bulged sides usually result from excessive water in the concrete mix.

Establishing lines--Job site configuration determines the starting point for mechanical installation. Prior to starting, a string line is pulled or chalk line snapped on the screeded bedding sand. The line is perpendicular to the starting face (which may be a curb if it is square to the line) and several layers are placed on the line to establish straight and square courses of layers. Aligning the layers and joint lines at the beginning of the laying process is essential to keeping joints tight and the pattern "in square" as the job proceeds. The lines can guide manual installation of the starting courses (if required) as well as mechanical laying. Parallel string lines are pulled and spaced at intervals equal to several paver layer widths. The distance between string lines should represent the maximum width of the paver layers, i.e., taking into account growth in the layer width from mold wear. The allowable growth, and means of measurement of layers, should be agreed upon between the manufacturer and installer prior to laying the pavers.

Bedding sand--Besides a consistent flow of pavers, there must be a sufficient area of bedding sand screeded and ready to receive the pavers. An oversize area will not get filled with pavers by the end of the day. A small area will fill rapidly, and the crew must work quickly to prepare more screeded sand. The optimum area to screed depends on the productivity of the machine operator and the continuous flow of pavers. This area is different for each project. Spreading of bedding sand can be accomplished with a powered screed bucket as shown in Figure 17 or with an asphalt machine, illustrated in Figure 18.

Figure 17. Powered screed bucket accelerates spreading of bedding sand. The width of the bucket can be adjusted.

Figure 18. An asphalt spreading machine is modified to evenly and rapidly spread bedding sand.