

## **AN INNOVATIVE DESIGN FOR PAVING USING VERTICALLY-INTERLOCKING ARTICULATED CONCRETE MATS**

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### **SUMMARY**

**Paving mat systems using cast concrete block held together with embedded wire rope or cable have found wide use in erosion control, and paving fords, boat ramps and low-volume roads. Cable-linked paver blocks have the advantage of being less subject to displacement than separated pavers. They are less subject to washout, are difficult to vandalize and are not lifted by tracked vehicles. Their disadvantage has always been that the sections of the mats have to be connected to be effective. This requires that U-bolts or wire splices be installed between mat sections. The bolts and splices have to be unbolted or cut to move the mat sections.**

**A new design of vertically-interlocking paving mats has been developed to overcome the problems of placing and removing connections between mat sections. This makes a paving system that is easily placed and easily lifted and moved. Also, since this new paving system consists of two distinct layers of blocks, each upper block rests on parts of four blocks below it; so the load on the upper block is effectively distributed over four lower blocks. The lower ground pressure makes the paving system useful where the sub grade soils are not ideal. The upper layer of block is staggered so the openings from the top of the upper block to the ground are smaller and the problem of vegetation growing up between the blocks is reduced.**

**The complete system consists of two layers of paver mats. Each layer of mat consists of concrete pavers cast on a grid of intersecting cables that hold the pavers together. The shape used for the block is the key to interlocking the mats vertically. In the casting process, one vertical half of the block is formed as a square paver (the square side); but the lower vertical half of the block is formed as a square rotated 90-degrees (the diamond side) and dimensioned so that the corners of the square are at the mid-point of the sides of the upper square side. When the mat is laid down with the square side on the ground surface, the diamond side has spaces between the diamonds that are sized to allow another mat layer to be placed diamond side-down with the diamonds from the upper mat fitting between the diamonds on the lower mat. The exposed top of the two-layer mat consists of the square-faced side of the pavers. One three-paver by three-paver mat section can be laid down over the intersection of four similar mats below it to lock them together. Under normal circumstances the weight of the upper mat will guarantee that the lower mats remain locked together until the upper mat is lifted off.**

**The design of the articulated paving mat system is based on selecting two tessellating shapes for the sides of the blocks. It is possible to develop paving using this system that is both functional and aesthetically pleasing.**

## 1. INTRODUCTION

Army engineers have very successfully employed steel cable and concrete articulated mats to stabilize river banks and the prevent scour at the bottom of navigation channels. These articulated concrete mats are assembled from precast concrete panels that are approximately 7.6 m × 1.2 m × 10.2 cm thick. The panels are typically assembled into articulated concrete mats: 35 panels 43 m wide (Mississippi Dept. of Transportation, 2002). The mats are assembled using a wire-wrapping system.



**Figure 1. Articulated concrete mats (left) are assembled by using wire ties (right) to attach the panels to each other and to adjacent rows panels.**

Applications of smaller articulated concrete mat have been used in creating fords or landing area on streams and in reinforcing gravel roads in Army training areas. Applications in training areas have typically involved the use of single blocks cast with segments of cable imbedded in the block or arrays of blocks cast with continuous sections of steel cable between blocks. In either the single block or the arrays of blocks the system used to attaching the blocks or arrays to one another is a persistent problem.



**Figure 2. Cable articulated mat made by attaching the blocks at four points to form a block paving for a landing ramp.**

While the more permanent scour-control mats are attached by wire splices the smaller single blocks and arrays are attached block to block or section to section using U-bolts, clamps, washers and nuts. U-bolt splices require a significant amount of labor and a degree of dexterity is involved that allows for little or no automation. When the mats must be placed below water they have to be assembled on land and lifted and placed into the water. If the splices have to be installed on submerged blocks, the work becomes very laborious and slow.

The problems of fasteners become more complicated when the blocks are used for temporary paving in a training area. Corrosion on the fasteners can be enough of a problem that cutting the cable attachments may be the only practical option.

The goal of this project is to develop an articulated concrete mat that can be laid in two layers in such a way that the overlap between layers can be used to lock the lower layer and upper layer together. The block could be placed such that it acts in a fashion similar to “Velcro” so that protrusions on one mat would plug into similarly shaped holes in the lower mat, and the weight of the upper mat would prevent the lower mat from shifting. Simply placing the upper mat over an adjacent bottom mat attaches all of the mats together. The process of laying mat can move more quickly and even placing mats underwater becomes more practical Without having to have wire splices or U-bolt attachments. When it is necessary to lift the articulated mats, simply lifting off the upper layer releases the lower layer and all of the pieces of the mat can be moved without having to remove any fasteners

## 2. SHAPES OF THE INTERLOCKING BLOCKS

A vertically-interlocking array can be made by casting copies of a block that has one tessellating shape (for example squares) on one side and a second tessellating shape (say diamonds) on the other.

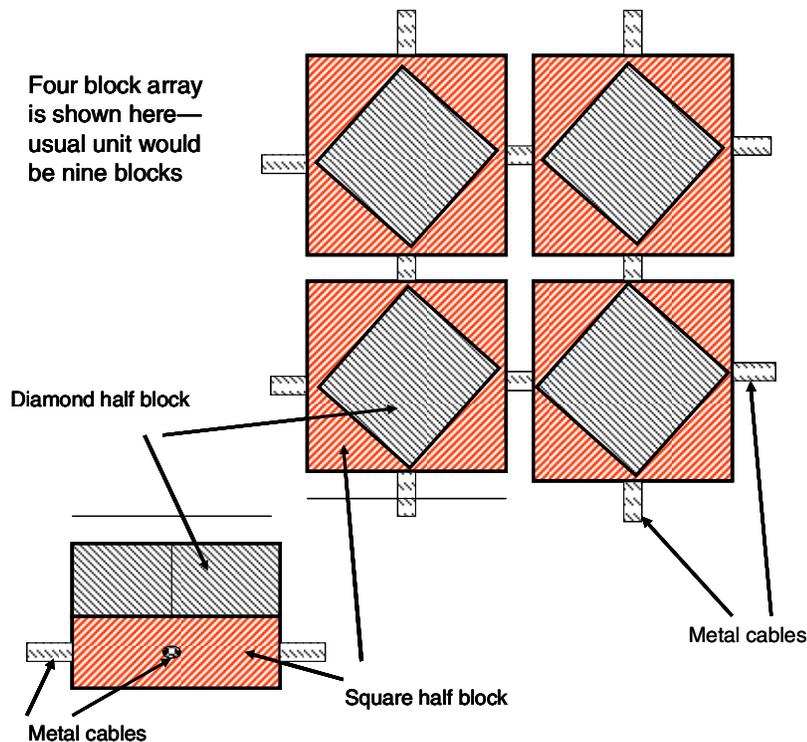
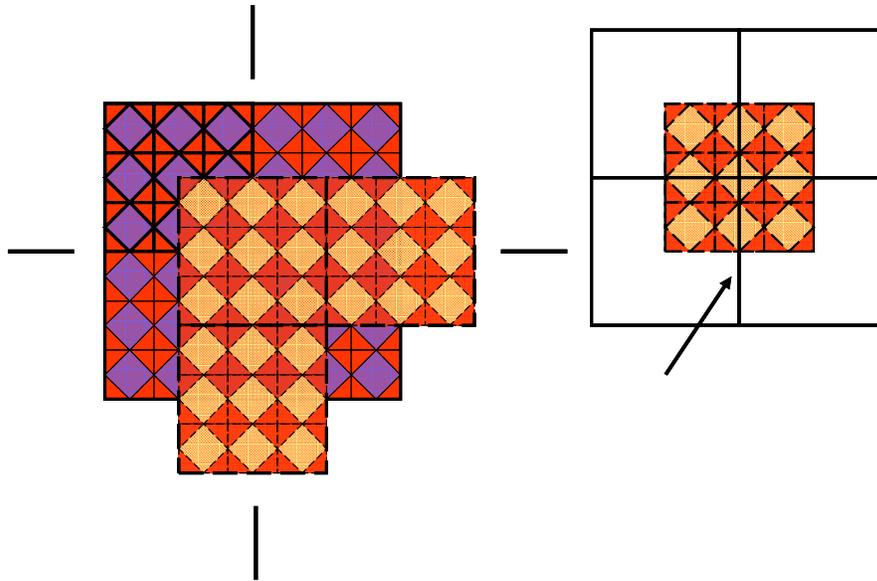


Figure 3. Array of vertically-interlocking blocks. Note the two layers are similar.

### 2.1 Blocks in Arrays

Blocks are assembled in arrays that can be overlapped to lock sections of mats together. A very useful array consists of a three-block by three-block unit. If four arrays are laid down in a square, one nine-block array centered in the square will lock all four units below it together (Figure 4).



**Figure 4. Schematic drawing of four nine-block arrays joined by overlapping the intersection of the array with a fifth identical block array.**

### 2.2 Construction Details

The size of the openings between the blocks on the upper side of the lower layer of blocks is controlled by the spacing of the blocks on the cables. The fit of the block from the upper layer into the holes in the lower layer can be varied by specifying the space allowed between the lower blocks as they are cast on the cables (Figure 5). The fitting of the blocks can be facilitated by casting the diamond half of the block with slightly tapered rather than straight sides



**Figure 5. Nine-block array with an additional block fitted into the opening on the upper surface. Test array is assembled with a clamp cable arrangement to allow the effect of block spacing to be evaluated.**

### **3. INSTALLATION OF THE INTERLOCKING BLOCKS**

Standard subgrade preparation procedures used in horizontally-interlocking block paving procedures are appropriate for the vertical-interlocking paver system (Rollings, 1983; Leong, et al., 2005). Cable-restrained pavers are held in position without an edge restraint or curb that is typically needed for pavers laid as individual units (Portland Cement Association, 1984). Vertically-interlocking pavers are unusual in the each upper paver distributes any load applied to it to four pavers located below it. The arrangement produces lower ground pressure on the sub grade materials below the lower pavers. The end result may be that conventional approaches may produce very conservative designs.

### **4. BENEFITS OF THE VERTICALLY-INTERLOCKING BLOCKS**

Vertically-interlocking blocks offer some unusual features:

- a. The block arrays can be laid without using U-bolts or wire splices.
- b. The block arrays can be easily lifted and reinstalled at alternate locations.
- c. Paving can be made permanent by grouting between block arrays and between pavers.
- d. Each upper paver rests on four lower pavers distributing the force applied to the paver over a broader area of subgrade.
- e. The design can be modified to include a variety of tessellating shapes on both the top and bottom sections of the blocks.
- f. All of the usual pigmenting and surface finishing techniques applied to conventional pavers can be used with the vertically-interlocking arrays.

### **5. CONCLUSIONS**

Vertically-interlocking paver systems have unique capabilities and many beneficial features that make them attractive for various applications. If conventional paving installation design procedures are used, the resulting pavement may have a longer service life due to the lower pressure on the subgrade. Refinements in design and potentially useful modifications of the installation procedures are expected as the work on this system continues.

### **6. REFERENCES**

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