THE G-BLOCK SYSTEM OF VERTICALLY INTERLOCKING PAVING

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SUMMARY

Vertically interlocking load-spreading unit paving systems offer many economic advantages, among which are the reduction of sub-structure and diminished maintenance costs. The designs that have reached the market have often relied on complex, joinery type connection detailing and, because of this, have never fully achieved their possible economies. The patented G-Block System results from an exploration and analysis of solid geometries. The close-packing characteristics of tetrahedra have been developed into the G-Block range of blocks and slabs which, when laid, exhibit excellent load distribution characteristics. The system includes an edge block, a reinstatement unit and also a sophisticated machine-laying technique.

The search for a vertically interlocking paving block has been, for many people in the industry, like the search for the philosospher's stone - a discovery that would turn base metal into gold.

Certainly, an effective vertical interlock would offer two immediate advantages over most current systems. First, in improving the lateral load-spreading characteristics of a paved area it would reduce the sub-structure requirement significantly and thus lower initial capital cost. Second, because of increased stability and resistance to 'punch-in' it would reduce maintenance costs. There can be little doubt that this would not only affect existing markets but must, in time, introduce completely new market areas to the concrete block industry.

Current practice requires - in the broadest terms - an over-thick surface course on a substructure designed to cope with the worst possible condition. It seemed to me that - theoretically at least - there could be two routes for design rationalisation. First, the substructure could be improved to give total support to a block which was substantially reduced in thickness and which was expected to perform simply as a biscuit-like surface. Second, the units or blocks could be designed to have positive structural interdependence, thus allowing for a downgrading of substructure. The first of these options was judged practically unattainable while the second seemed a direction for fruitful research.

Many others have perceived the logic of design development of structural interlock on the vertical axis but, with the benefit of hindsight, it is possible to isolate an error of design thinking in previous examples.

At a larger scale, in precast concrete building for example, mechanical jointing systems are commonplace and are usually descendants of traditional joinery techniques - tongue and groove, dovetail, mortice and tenon, etc. In my view, the small scale of most paving block systems precludes the efficient use of this kind of connection technique.

The disadvantages of complex interlock can be listed :

1. Weight and size. Naturally, if a block is to have particular constructional detailing on its edges, it tends to become larger and heavier than a non-connecting block. The economic repercussions are obvious. Not only are handling difficulties increased at the factory and on site but, in addition, the surface area of paving per truckload gets smaller.
2. Damage. The more precise the connection detail, the greater the risk of damage to it during handling.
3. Difficulty of installation. It has often been the case that a connection detail that is beautiful in theory demands, on site, the kind of care in installation which is either unavailable or expensive.

For these reasons we rejected the 'edge connection' approach and defined the problem in new, and fairly rigorous terms. We were looking for a block configuration which had no 'joinery' type connections, which was easy to manufacture, transport and lay and which would be unlikely to sustain accidental damage in handling. We were looking for a block which would transmit loads laterally and which would close-pack as a fundamental characteristic of its three-dimensional geometry.

It took some time. It was clear that all existing systems were based, topologically, on cubic packing - modified and shaped or not - and we felt that further research in this area might stimulate slight improvements but was unlikely to produce the second generation block we were looking for.

The tetrahedron provided the key. The tetrahedron is a solid with four surfaces, each an identical equilateral triangle. It is usually shown as a three-sided pyramid (Figure 1). When the tetrahedron sits on one of its triangular surfaces, as in Figure 1, then all horizontal sections through it will be triangular.

Figure 2 shows the tetrahedron posed on one of its six edges. In this position the top edge and the bottom edge are horizontal, and at right-angles to each other. A horizontal section taken at mid-height through a tetrahedron in this position is a square - the 'equatorial square'. All other horizontal sections are rectangular.

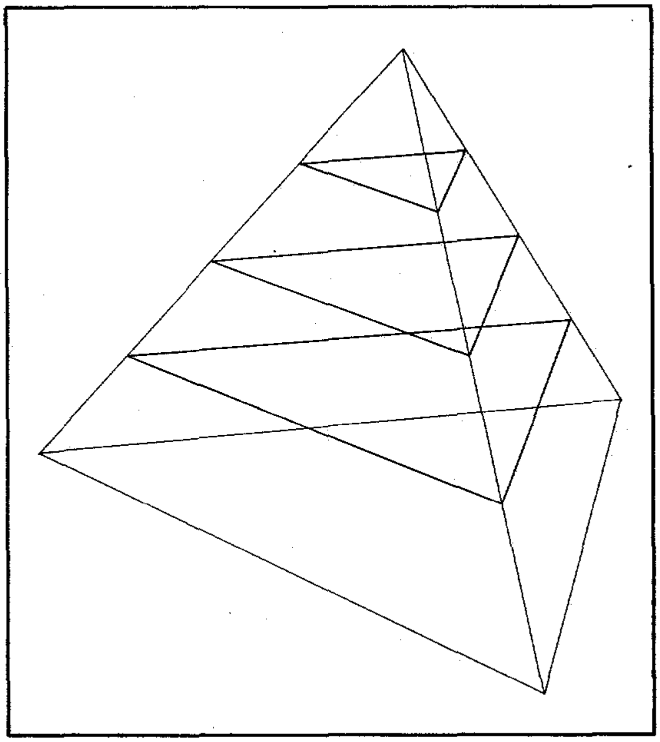

Figure 1: Tetrahedron on one of four triangular surfaces.

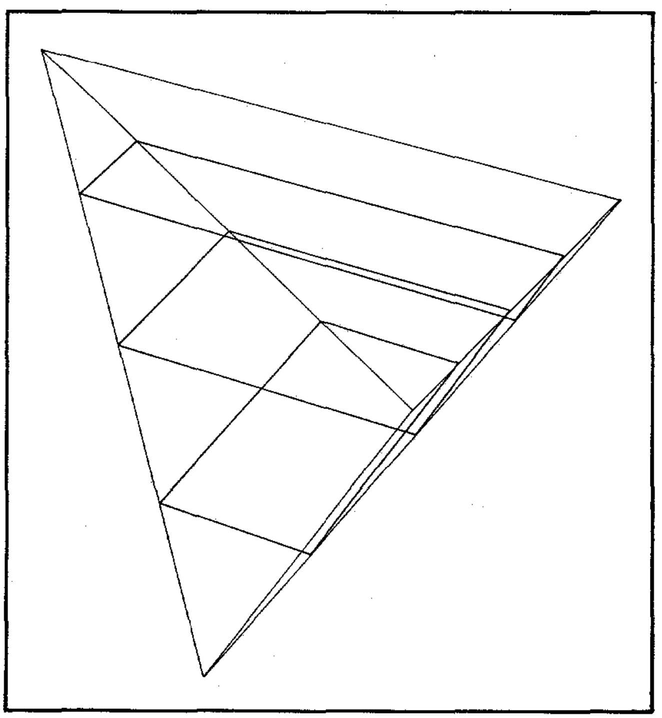

Figure 2: Tetrahedron on one of six edges.

Tetrahedra seated as Figure 1 will not close-pack. Tetrahedra as Figure 2 pack beautifully and form a very stable array (Figure 3). This arrangement demonstrates the interlock on all three axes that we were looking for. However, Figure 3 shows that both the top and bottom surfaces of the array, composed of sharp edges and large pyramidal voids, are most impractical for pavements.

If the top and bottom 'sharp' edges of the tetrahedron are cut down to create top and bottom rectangles one discovers, within the tetrahedron, the solid which is the prototypical G-Block (Figure 4). Ideally, if these top and bottom rectangles are the same distance from the 'Equatorial square', they will be of equal size, the closer the rectangles are to the 'Equatorial square', the larger they will be and the smaller the pyramidal voids will be.

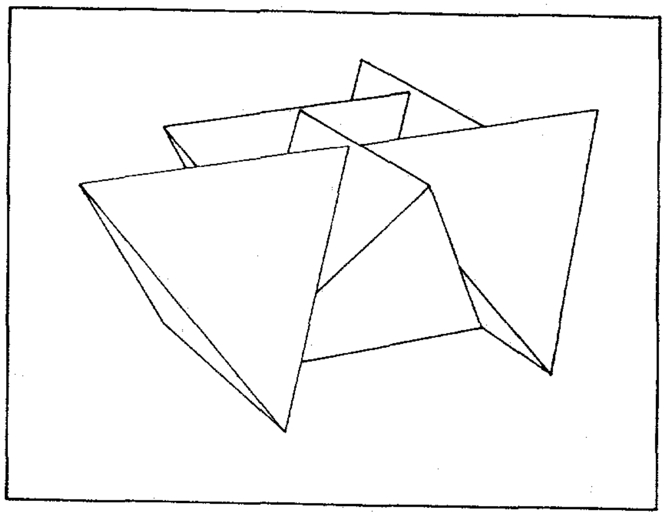

Figure 3: Tetrahedra close-packed.

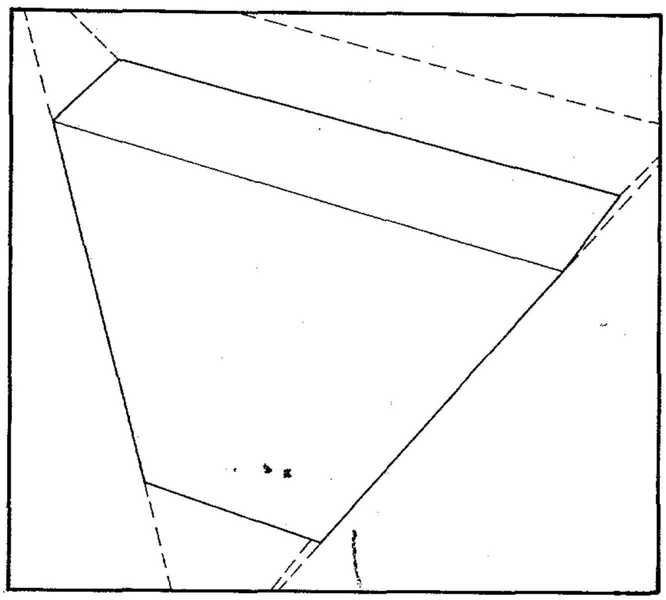

Figure 4: The G-Block solid within the tetrahedron.

Having established the geometrical principals we made the first blocks (Figures 5,6 and 7). These blocks were about 90mm thick, had an 'equatorial square' dimension of 100mm and a slope angle of 14 degrees. Laboratory testing was carried out on wet-cast prototypes. They were laid surface to surface and were vibrated to cause a layer of sand of migrate into the interstices. The tests were very satisfactory, demonstrating an appreciable improvement in load spreading performance when compared with a conventional vertical-sided block. This improvement increased with the load, which is to be expected in a system based on a keystone or wedging configuration.

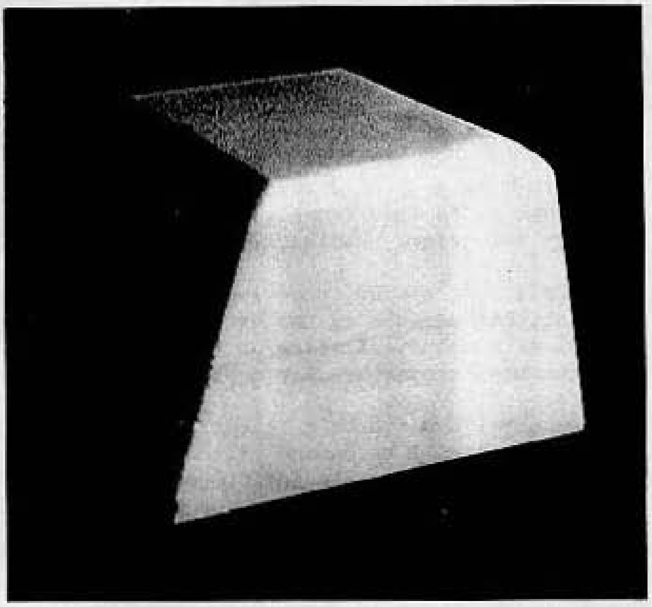

Figure 5: An early G-Block prototype.

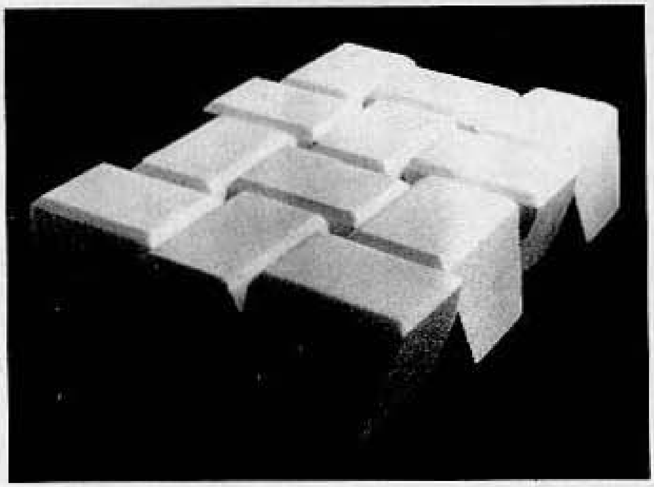

Figure 6: Array of prototypes.

At higher loads, however, though the array performed well, some individual blocks which were not chamfered, spalled on their upper surface. The blocks had been laid conventionally for the purpose of this test - that is they had been placed in contact, with a fine layer of sand vibrated between them. But, unlike most blocks, the G-Block form transmits load laterally to its neighbours, and the concrete-to-concrete stresses proved too much for the material used in the hand-made prototypes. It was as though we had attempted to create a working skeleton, with bone-to-bone movement and load transmission but without any cartilage.
As a result of these tests, which proved the superior load-spreading characteristics of the G-Block, we initiated design adjustments to deal with the problem of surface spalling (Figure 8). In essence, the solution is a system of spacer ribs which guarantees space for a load-equalising 'cartilage' of sand.
At the same time we established the preferred initial dimensions for the individual block. The 'equatorial square' dimension was increased from 100mm to 150mm. This reduced the number of stones per square metre from 100 to about 44 (Figure 9).
We felt at this stage that, as a result of the block's superior performance, it would be possible to reduce the block thickness to 70mm, knowing it could compete structurally with a conventional 80mm block. While initially we knew the advantages of the system in lower capital costs and reduced maintenance, we saw that the G-Block could offer, in addition, a 14% reduction in concrete volume and a 14% increase in transportability.

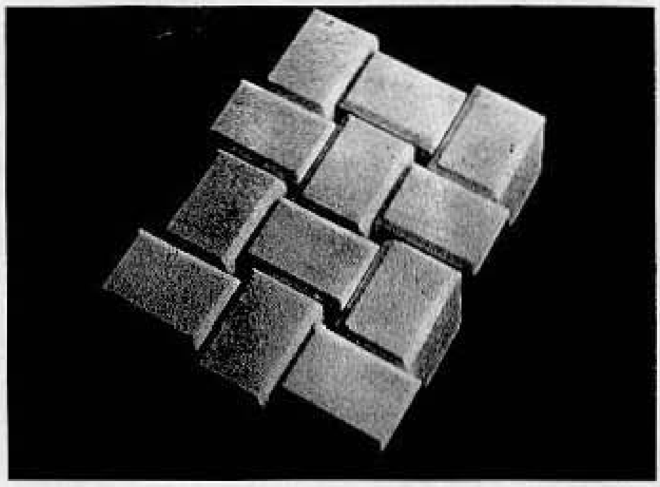

Figure 7: Surface pattern.

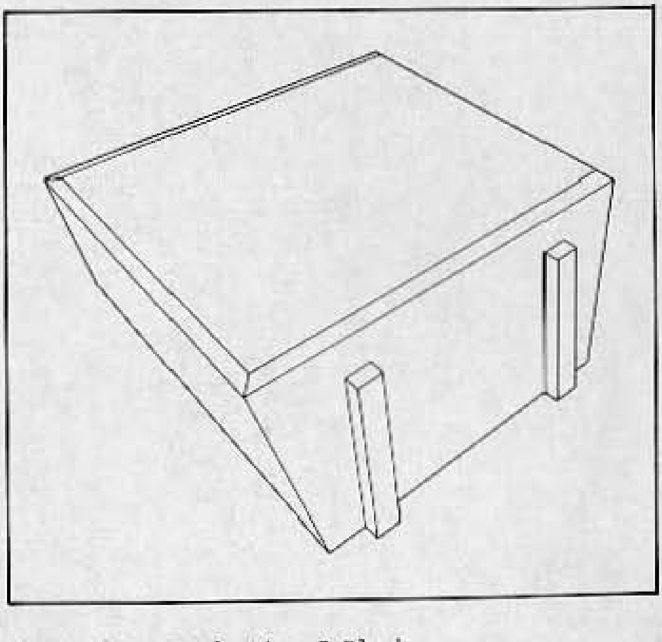

Figure 8: A production G-Block.

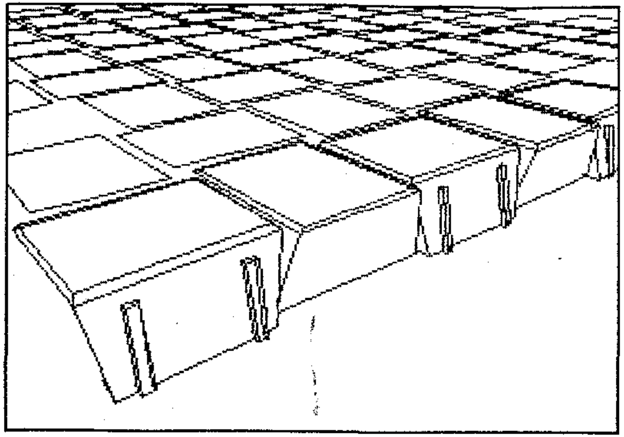

Figure 9: G-Block laid.

Mechanical laying is an increasingly important feature of concrete block paving, especially in developed countries. The most common technique is by hydraulic or mechanical cramping applied to the edges of the panel to be placed. This has the disadvantage that the edge of the panel to be laid is obscured by the cramping bar of the machine. On many machine-laid areas the pattern of laying is clearly signalled by the rhythm of wider joints. The G-Block System uses the shape of the block, rather than externally applied pressure, to effect lift.

Because the system interlocks totally it is impossible to remove a single block from a laid area. For reinstatement, or for 'unzipping' for access to services, it is necessary to destroy some 'starter blocks' to enable the lifting of the paving to proceed. In theory, the geometry will allow the paving to be unpicked if two adjacent blocks are chopped out. In practice we would assume that four adjacent blocks should be removed. For reinstatement, for the same reasons, it is impossible to completely reconstruct the pavement inwards to a diminishing aperture. The surface can be relaid down to an aperture of two adjacent blocks, and the system provides a special reinstatement unit which drops in to this two-block space, locks up the array and, after construction, is unidentifiable.

As with all unit paving, edge restraint is essential, but because of the efficient and multi-directional dissipation of forces through the structure, conventionally designed kerbs are adequate.

The structural and economic features of the G-Block System will recommend it for all areas of the paving market. In addition, its positive and simple vertical interlock suits it perfectly for revetement and embankment work, while its speed of laying and low sub-structure requirements make it ideal for temporary or emergency roadways.