# Size and Block Shape – do they matter?

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SUMMARY

This paper considers the importance of dimensional tolerances of both rectangular and shaped blocks on the surfacing's structural efficiency and its ease, or otherwise of construction. It is shown that if the structural efficiency of a block surfacing is to be optimised then every plan dimension of blocks has to be specified and controlled within strict tolerances. It is also shown that both rectangular and shaped blocks need to be designed to include their surrounding space, and that their length:width ratio depends upon the final laying pattern.

## 1 Introduction

1.1 Work by many researchers and practical experience have both shown that correctly designed and constructed block surfacings contribute to the load spreading ability of the whole pavement. There are disputes however on how block load spreading ability compares with that of others, for example bituminous materials. Altercations have also arisen on the relative structural merits of rectangular and shaped blocks. These disputes between experts does little to help the practising designer concerned with an overall scheme in which the paving may represent only a small part of the work, in financial terms. What is required is both a simple design as well as a simple construction technique.

1.2 The design and construction of a block pavement relies on there being sound specification for the blocks themselves and the associated materials, such as the laying course sand. A specification has to cover the quality of the block materials, to ensure their long term durability, retention of adequate slip and skid-resistance, but also consistency of their physical dimensions and uniformity of shape.

1.3 As far as the UK is concerned BS 6717:Part 1[1], and its predecessors has resulted in concrete blocks with good properties both in terms of durability and resistance to polishing. Blocks must resist damage by both frost and de-icing agents, and retain enough micro-texture over many years to preserve adequate slip and skid- resistance to meet the needs of any of the normal vehicular and pedestrian trafficked situations where they have been widely adopted.

## 2 Dimensional Tolerances

2.1 The currently specified dimensional tolerances appear, for concrete blocks[1] to be principally based on what were considered practical and economic to manufacture. In the case of the U.K. these were and still are ±2mm of the work size plan dimensions, and ±3mm of the work size thickness. The width dimensions are required to be measured at three different positions on each side of a concrete block, the length at two different positions on the ends and thickness at four separate representative locations. The average of each set of measurements is reported to the nearest 1mm.

2.2 According to BS 6677:Part1[2] the British Standard for clay pavers presently uses a different method of measurement, one traditional for building bricks. In this case 24 selected pavers first have any blisters, small projections or loose particles removed, after which they are placed in straight lines and their overall length, width and thickness measured within one millimetre. These values are compared with tabulated values, shown in Table 1 for plan work sizes of 200x100mm . There are two qualities of clay paver allowed in BS 6677[2], the use of PA pavers being limited to extremely lightly trafficked pavements. These particular pavers are made to lower standards of dimensional tolerance, to those detailed in Table 1 and are consequently little used.

TABLE 1

Limits of sizes for 200x100mm clay pavers.

| Limits of overall measurement of 24 pavers. | | | | |
|---|---|---|---|---|
| Work size mm. | Type PA | | Type PB | |
| | Max. mm. | Min. mm. | Max. mm. | Min. mm. |
| Length 200 | 4870 | 4730 | 4852 | 4748 |
| Width 100 | 2444 | 2356 | 2433 | 2367 |
| Thickness | | | | |
| 65 | 1605 | 1515 | 1594 | 1526 |
| 50 | 1235 | 1165 | 1226 | 1174 |

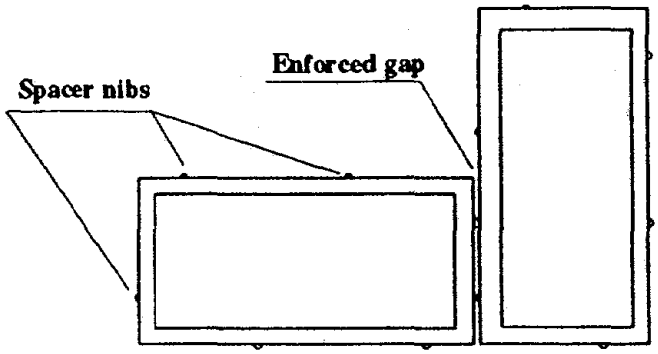
2.3 Considering only the PB pavers, if the length dimensions of individual blocks are examined statistically then 95% of the 200x100mm pavers may vary in length from 196.42 to 203.82mm, (an overall range of 7.4mm) and still comply with the Specification requirements. A similar range is possible within paver widths. This standard of dimensional tolerance is not adequate to maximise the potential structural benefit of the surfacing. It is understood that in the revision of BS 6677[2] the manner of prescribing dimensions of clay pavers will be changed to one similar to that currently used for concrete blocks.

2.4 The thickness variation of blocks is less critical than their plan dimensions. According to Lilley[3] thickness dimensions should not vary by a total of more than 10mm if a regular running surface is to be retained over the life of the pavement. Historically most blocks have been formed by pressing the concrete inside a multi-chamber mould, between bottom and top which has meant that block thickness is the most difficult dimension to control. To increase output some manufacturers have attempted to make blocks on end, in which case their length becomes their thickness, during production. This introduces two difficulties, the depth is much greater than thickness meaning a longer pressing time, and production control has to be even stricter to ensure that the block lengths meet the most exacting demands. This method of manufacture has been used in parts of Europe, but to the author's knowledge not beyond some early trials in the U.K.

3 Spacers

3.1 Although not required in the current British Standard[1] spacers are now formed on virtually every rectangular concrete block made, and are included to secure a space between adjoining blocks, as shown in Figure 1. The spacers ensure that there is a minimum joint of $1\frac{1}{2}$ to 2mm.

3.2 Some manufacturers define the size as the overall dimensions of a block, inclusive of the spacers, while others exclude the spacers in the measurement. Consequently there are some blocks deliberately 3 to 4mm shorter and narrower than others and are incompatible.




TYPICAL SPACE ARRANGEMENT ON RECTANGULAR BLOCKS

FIGURE 1

4 Laying patterns

4.1 There are a number of different laying patterns used all based on three basic bonds, Stretcher, Stack and Herringbone, as shown in Figure 2.

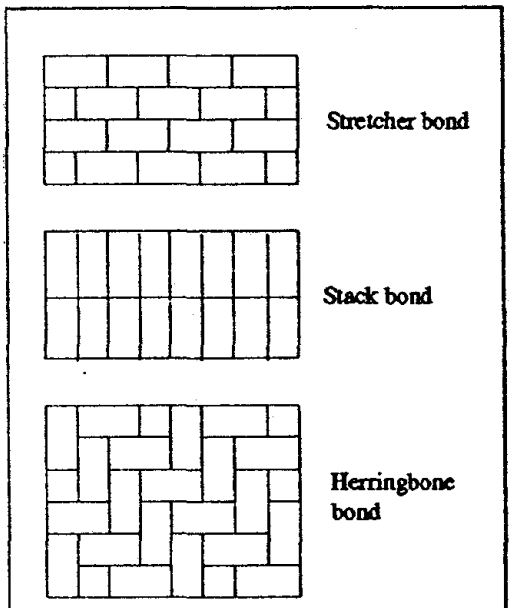
4.2 The herringbone pattern should be adopted for rectangular blocks if the pavement is to carry vehicular traffic, as this prevents the block creeping horizontally, under the action of accelerating and braking vehicles.

4.3 Most shaped blocks lock together via their shaped sides, in a similar manner to gears. This "gearing" limts relative horizontal movement, allowing blocks to be laid in non-herringbone patterns, even where there is vehicular traffic. Protagonists of the shaped blocks stress this point and often neglect some of the less favourable aspects, which include problems with cutting at edges. It is commonly recommended, for example that where blocks have to be cut to fit against an edge restraint the insets should not be smaller than $^1/_4$ to $^1/_3$ of the full block area, to avoid pieces that are too small both to cut cleanly, and to stay in place. This requirement does not present a problem with rectangular blocks but cannot always be achieved with shaped blocks because of the "gearing", and as a result when using shaped blocks some in-filling with a sand:cement mortar is unavoidable.

5 Significance of joint widths

5.1 The space between adjoining blocks has a significant influence on the structural performance of a block surfacing. When a block surfacing is carrying load there is a degree of vertical deformation, which in turn generates horizontal forces. If two blocks are in close contact when such forces are repeatedly generated the block arrises maybe over-stressed and spall. Such stress is reduced by chamfers at the block edges, and by sand in the joints acting as a "cushion".

5.2 Clifford[4] has shown that if the joint widths exceed 5mm the structural ability of the surfacing decreases. Considering this in conjunction with the need to have a significant joint width implies that joints need to be within a range of 2 to 5mm. This 3mm range has to cater for dimensional tolerances, deviations in laying, arising from the laying pattern and possibly the setting-out of edge restraints.

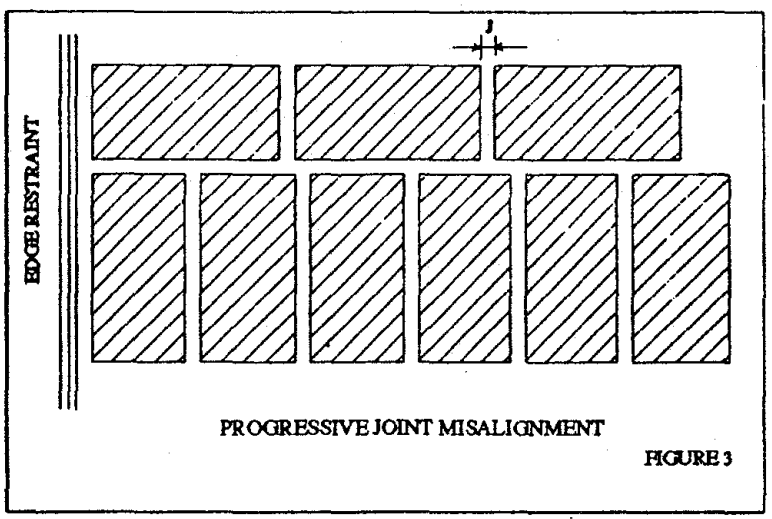



BASIC BOND PATTERNS

FIGURE 2

6 Laying Patterns

6.1 If blocks are precisely 200x100mm and the stretcher and stack bonds are laid in combination the significance of joint width on joint misalignment becomes obvious, and is




PROGRESSIVE JOINT MISALIGNMENT

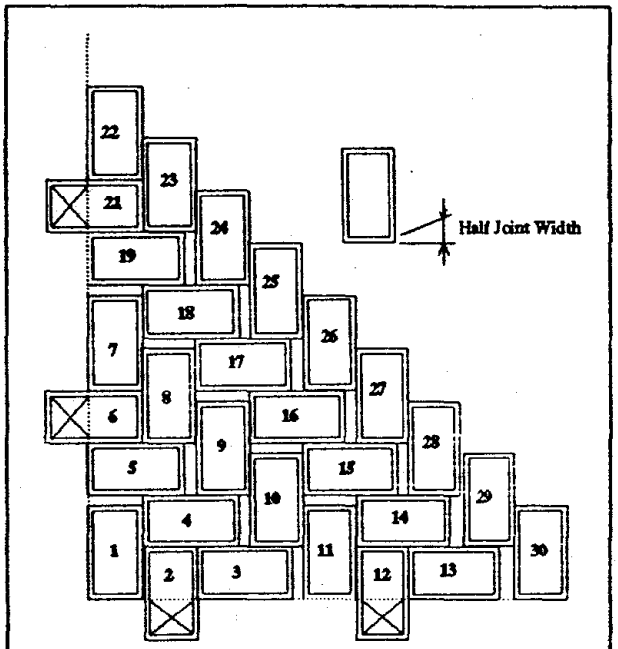
FIGURE 3

illustrated in Figure 3.

6.2 This shows that if a row of blocks is laid widthwise, across a pavement the amount of mis-alignment compared with blocks laid lengthwise is increased by one joint width for every two blocks laid. If all joint widths were constant (J) this problem could be eradicated by reducing the block widths by J.

6.3 The herringbone bond is a laying method in which blocks are laid as a combination of headers and stretchers. When block length equals twice its width the form of joint misalignment shown in Figure 4 occurs.

This Figure was produced using a computer aided drafting system, first drawing a block with a 2:1 length:width ratio, then copying it and laying copies in a similar manner to that used by a block layer. The numbers indicate the sequence of laying.




EFFECT OF UNIFORM SPACERS ON JOINT WIDTH

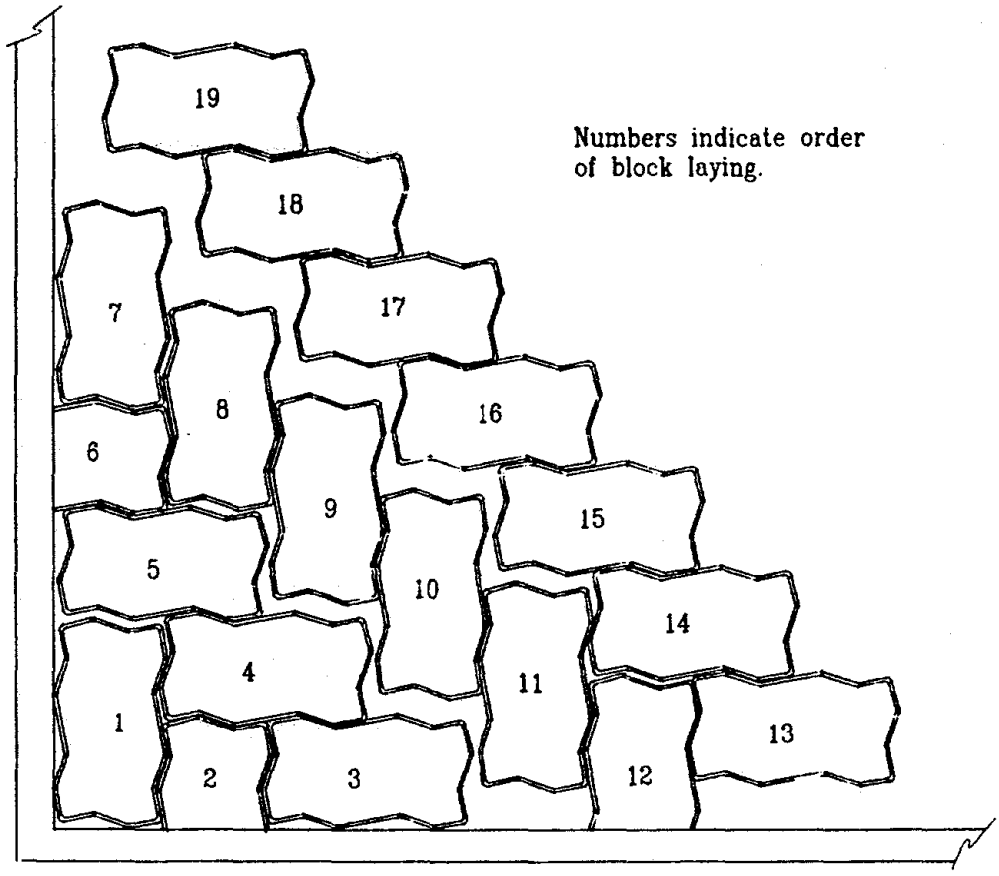
FIGURE 4

6.4 A similar drawing method was used with a complex shaped block which disclosed a further problem. The block (not available commercially) was first drawn, copied and laid, as shown in Figure 5. In this case the joint width grew progressively, as laying continued because of the blocks having to "gear" together.

6.5 The examination of these laying models illustrates the need to design blocks to include a peripheral space of half a joint width from all the block sides.

6.6 BS6717:Part1[1] presently requires that only the length and width dimensions to be specified, with the additional provisos in the case of shaped blocks that no plan dimension shall be less than 80mm, and the block shall fit within a 295mm square coordinating space. This is not considered adequate. To ensure that shaped blocks will fit close together it is necessary to specify **all** its dimensions.

6.7 For example consider the simple "H" shaped block shown in Figure 6. In this case every dimension marked must be strictly toleranced if this block is to fit its neighbours, as intended. Derivatives of this type of block sometimes have their sides at acute angles intended to allow them to fit more readily. In such a case the angles of slopes also need to be specified and controlled closely.

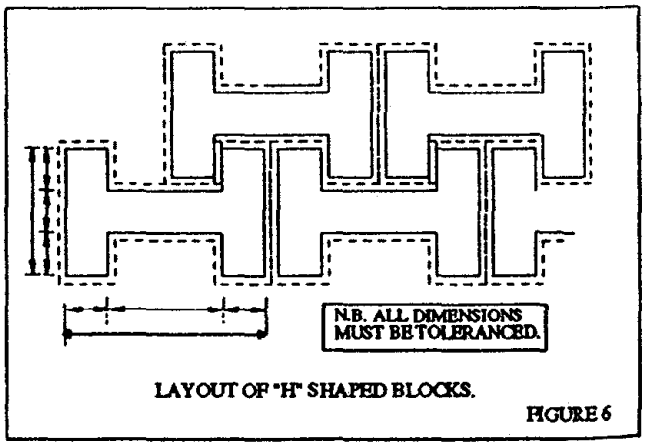



COMPLEX SHAPED BLOCK IN HERRINGBONE PATTERN

FIGURE 8

7 Range of Joint Widths

7.1 BS 6717:Part 1[1] allows a range of ±2mm, in both the length and width block dimensions, overall ranges of 4mm. It is theoretically possible that this range could be added to the minimum joint width, 2mm. In the case of 2:1 rectangular blocks, laid in herringbone pattern some joints , as explained previously will be a minimum of 4mm. Therefore. joint widths in rectangular blocks complying with BS6727[1] could range from 2 to 8mm.




LAYOUT OF "H" SHAPED BLOCKS.

FIGURE 6

7.2 In practice joint widths are not likely to reach the largest of these values as this would

only occur where there was a sudden change of block dimensions from the minimum to the maximum permitted. This in turn would only occur when a worn mould was replaced by one forming blocks to the minimum specified size. Most manufacturers of concrete blocks do not use moulds worn to the maximim permitted block limits and as a result block plan sizes vary less than the overall 4mm permitted range.

7.3 Clay pavers are produced with and without spacers. As explained above close laying may result in spalling. Pavers have to be laid with a positive space, either by extra careful placing, or using pavers provided with spacers. This means that joint widths may range from 2 to 9.4mm and subsequently a loss of some structural integrity.

8 Block Laying

8.1 Most blocks are still laid manually but there have been many attempts to do this mechanically, usually on very large projects. Most mechanical laying methods lift layers of blocks by clamping their sides which also presses the blocks together. If rectamgular blocks are not made with spacers this results in a certain amount of "zero" joint spacing. Shaped blocks laid mechanically rely on their "misfit", arising from their shape to give some joint space.

8.2 Architects are often more interested in the alignment of joint lines than the structural performance of the pavement in which case alignment may take precedence over joint width.

8.3 If all blocks were to be fitted with spacers this would simplify block placing as each block could be placed firmly against its neighbours, but still ensuring a minimum positive space. This would be much simpler than trying to lay "hand tight".

8.4 Rectangular blocks should be designed to create a uniform joint width when laid in a herringbone pattern. This could be achieved by making the blocks, say 3mm narrower than their length, assuming a basic length:width ratio of 2:1. If the length:width ratio was to be, say 3:1 block widths would have to be reduced by two joints (6mm). This would simplify laying giving better control of both joint width and alignment. These apparently minor changes in the true length:width ratio will not adversly affect joint alignment when laying in either stretcher or stack bonds.

9 Joint Width Measurement

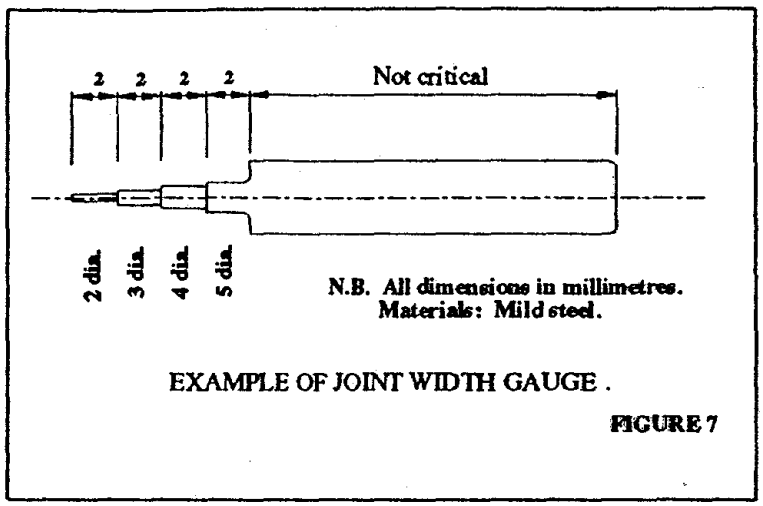
9.1 The sheer number and length of joints in a block pavement makes it impractical to measure all their widths on any particular job. There are two possible suggested methods, for localized checking, one using a probe, such as that shown in Figure 7, or by counting the number of blocks contained within a unit area.

9.2 With a little experience it is not difficult to identify joints that are greater than 5mm, from a visual inspection, verifying this opinion with a suitable probe. Ideally such an inspection would need to be made during block laying so that unsuitable areas would be located before there had been much laid beyond the suspect portion.

9.3 Such a requirement would put a considerable extra restraint on a laying contractor and should not be introduced until block dimensions are modified, as indicated above.

9.4 It would not be practical to specify that all joints are not greater than 5mm, and the specification would need to read, for example, "In any area of ....square metres, not more than 5% of the joints should be wider than .....mm, with none greater than 8mm."

9.5 An alternative method would be to specify the number of blocks per unit area, say 2 x 2 metres. For this it would first be necessary to calculate the number of blocks at say a 2mm spacing and compare this with the actual number, Counting would be simple. blocks with less than half their plan area being discounted, and all others included. In the author's experience this technique works well to show poor, as opposed to reasonable laying.




EXAMPLE OF JOINT WIDTH GAUGE .

FIGURE 7

10 Conclusions

10.1 Specifications of the dimensions of all pre-formed paving products should follow the method presently in the British Standard specification for concrete blocks[1], that is by measuring and limiting the plan dimensions of ind ividual units, but also make spacers mandatory.

10.2 Shaped blocks should be specified by **all** their dimensions and angles.

10.3 All blocks, both rectangular and shaped should be designed to include a space around their periphery equal to half the intended joint width.

10.4 Rectangular blocks should be designed so that their width is reduced to half the block length minus a nominal joint width, say 3mm.

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