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BRICKLAYERS' PERSPECTIVES ON THE 'BUILDABILITY' OF THE BED-JOINT AND THE THREAT TO STANDARDISATION VIS-À-VIS COST OPTIMISATION

Vasantha Abeysekera
Senior Lecturer, UNITEC, Auckland, New Zealand

A Thorpe
Professor of Construction Information Technology, Loughborough University, Loughborough, UK

ABSTRACT
Although a unique metric size of 10mm has been accepted as the 'standard' for all brickwork joints, current perceptions and practices show the use of a wide variety of joint sizes. The 'buildability' of these sizes was investigated under this study from a bricklayer's perspective, where it was found that most found is easier to build to a size neither small nor large (but larger than 10mm). In contrast, some failed to differentiate size with buildability. Given a free hand, bricklayers would choose a size of their convenience. As such there is a need to exercise control especially when using a small or a large size. These discoveries have brought to light the possibilities of manipulating joint sizes for potential productivity and cost gains – an approach that goes against the use of a 'standardised' approach to joint sizes. Given that the bed joint occupies a larger space than all other joints put together, it presents the greatest potential for manipulation. This is made easier by the use of two powerful concepts labelled as 'cost polarity' and 'cost homogeneity'. Despite the use of brickwork since the dawn of civilisation and an enormous amount of research conducted, there is still much scope for exploration; what has been learnt from science is still incomplete, and sometimes distorted as evidenced by the enormous emphasis placed on the standardisation process despite shortcomings. It is time that an attempt is made to lay the foundations for a 'theory on brickwork'.

KEYWORDS
Buildability, Brickwork, Cost optimisation, Productivity, Standardisation

1. INTRODUCTION

Brickwork consists of bricks and mortar bonded in many different ways with the mortar forming the 'joints'. Arguably, brickwork joints play an important role and in this study, particular attention is placed on the relationship between the size of the bed joint and its buildability. Given that most studies have focussed on the brick rather than the joint, this study is of significance more so because brickwork appears to have been influenced by practice rather by a process of scientific reasoning.

2. THE PARADOX OF A UNIQUE JOINT SIZE

There is no doubt that standardisation provides many benefits (Abeysekera, 1997b). In brickwork, these ideas have manifested in the form of standard brick sizes and wall widths along with a unique metric size of 10mm for all joints. The joint and the brick taken together define a particular space within a wall and it may be argued that these spaces need

to be dimensionally co-ordinated though not absolutely necessary (Architects' Journal, 1967, Brunton, 1972). However, this is not case with the brick and the joint sizes; an infinite number of size combinations could easily be thought of that fit within such a space. Given this scenario, it is a difficult task to understand the reasons for selecting a unique size of 10mm. Although history provides some evidence to understand the reasons for these selections, there are still enough reasons to question the wisdom of these decisions. One such area relates to issue of standardisation. Empirical data from countries such as China, Sri Lanka, Bangladesh, and India show extensive usage of non-standard sizes for bricks and joints. In deed, these situations provide many opportunities to explore and understand reasons that history has failed to provide.

3. THE IMPORTANCE OF THE BED JOINT

Of all the joints in brickwork, the bed joint plays an important role. For example, it accounts for a space more than all other joints put together (Abeysekera, 1997a). It is therefore able to accommodate any irregularities in the brick without creating any problems. The fact that it holds the largest volume of all joints infers that any change in the size of the bed joint could have a significant impact of the volume of mortar used. Indeed there is a delicate balance between the volume of bricks and mortar. Take the case of costs. Surely, if the cost density of mortar was cheaper than bricks, it stands to reason that using more mortar has the potential to reduce costs – a matter that depends on the 'cost polarity' of bricks and mortar (Abeysekera, 1997c). Furthermore, it is important from the point of view of productivity as well. For example, Abeysekera (1997a) has shown that higher levels of productivity could be achieved by using larger size bed joints.

However, there are other issues that must be taken into account, as for example the size of the bed joint and its impact on strength. For example, Hendry (1972) has shown that larger bed joints results in a reduction in strength. However, this is not seen to be significant as the principal element that gives strength to brickwork is not the joint but the brick (BS 5628, 1978). Moreover, brickwork is not always used in load-bearing situations but also in lightly loaded and non load-bearing situations. What about aesthetical considerations? Would the use of a larger joint size affect the appearance in fair-faced brickwork? What about issues related to dimensional co-ordination? No doubt, the size of the bed joint impacts on these issues. However, this is not the case with 'plastered' brickwork; size has no impact on aesthetics and could be manipulated to achieve desired benefits.

4. AIMS OF THE STUDY

Given this background, this study aims to find out issues related to the buildability of the bed joint with respect to its size from the perspective of a bricklayer. Additionally, it aims to investigate the significance of these findings to practice.

5. THE SURVEY AND ITS CONTEXT

5.1 Sizes of Joints Used

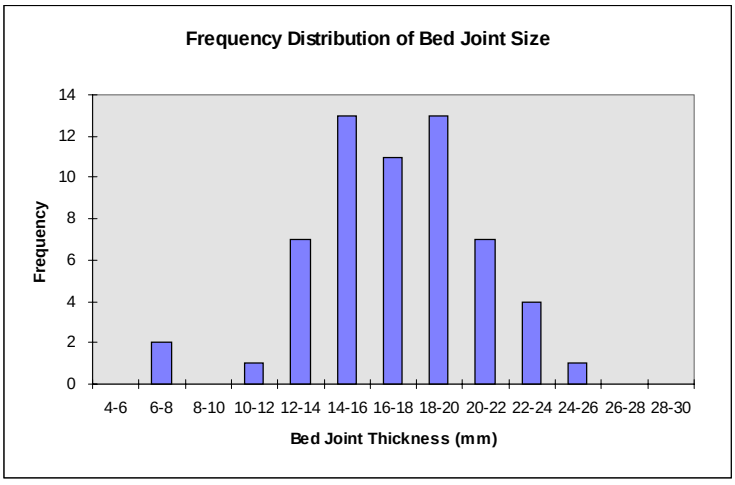

Figure 1: Frequency distribution of bed mortar joint size

(Average bed joint size of wall = $\frac{\text{Average wall height. - No. of courses x Average brick height.}}{\text{Number of courses of bed mortar in wall}}$)

Shown in Fig. 1 are the results of a survey of conducted in Sri Lanka. Sizes of bed joints were computed as an average for the whole wall by using the formula given under Fig. 1. In all, 59 walls were studied selecting only one wall per site. The sizes used were not controlled by the management and was often left to the bricklayer to decide. Clearly, sizes vary widely with an average range of 16-18mm. Additionally, it is seen that almost 95% of the walls were built using a size greater than 12mm, a significant departure from the standard size 10mm!

5.2 Volume of Mortar

Joints hold mortar and in the case of walls built with BS3921: 1995 bricks, 23%of the volume of a wall is taken up by mortar. This is not very significant. However, the situation is much different in the study walls where mortar accounted for as much as 41%. The reasons for this could be traced to the use of large joints and small bricks. Thus, in such situations the mortar volume could play a significant role. Not all joints hold similar volumes of mortar. For example, with BS bricks, the percentage of mortar in the bed joint accounts to about 67% of mortar in all joints whilst the average for the study walls was 73%. Thus, in both cases, the bed joint plays a far more important role than other joints in terms of its volume.

5.3 The Survey on Buildability

No doubt, there are number of plausible reasons for the variations given in Fig. 1. A particular aim of this study as mentioned before was to identify whether buildability was an issue, for which purpose the responses to the following questions were sought:

Question 1: What is the size of the bed joint used in single brick thick walls?
Question 1: Is it easy to build a wall with a large bed joint?
Question 3: Is it difficult to build a wall with a small bed joint?

Bricklayers were preferred over supervisors, foreman, etc. as it was perceived that ‘bricklayers would know better what they do’ than others. In all 38 bricklayers were interviewed restricting to one bricklayer per site. Bricklayers who did not have at least 3 years working experience were excluded from this survey.

6. THE SURVEY FINDINGS

6.1 The Size of Bed Joint

The responses in Table 1 show that bricklayers rarely adopt a size of 10mm and in this respect the results are similar to the data in Fig. 1. However, response R2 which relates to a size of ½” (which accounts for 50% of the responses) does not fully agree with field measurements (see Fig. 1). Thus there appears to be a difference in perception and practice. However, given the diversity of the balance responses it is clear that sizes much larger than the standard size of 10mm are being used.

Table 1: “What is the size of the bed joint used (in single brick this walls)?”

Type	Response	No. of responses
R1	About 3/8", 10 mm	2
R2	About 1/2"	19
R3	About ½ "-3/4"	3
R4	About 3/4"	1
R5	About ½”-1”	2
R6	About 1”	4
R7	Fix course height to 2 3/8" & use gauge-rod	2
R8	As I feel like	3
R9	No response/No meaningful response	2
	Total no. of responses	38

6.2 Ease of Using Large Joints

The responses to the second question are tabulated in Table 2. For the purpose of analysing these responses, those with tags were scored differently as shown. A net positive score reflects the preference of the majority of bricklayers with regard to the ease of using large bed joints.

Table 2: "Is it easy to build a wall with a large bed joint?"

	Response	As responded		As scored	
		Yes	No	Yes	No
1	Difficult.		8		8
2	No, when too much it is difficult.		4		4
3	No, finds it difficult to level courses.		2		2
4	No, the brick tends to tilt.		2		2
	Difficult with 'Chapparu' in the header course (Difficult as it is difficult to plaster)*		5		5
5	Yes.	4		4	
6	No problem.	2		2	
7	Yes, but with 'Chapparu' it is difficult.	1			1
8	Yes, but when too much it is difficult.	3		3	
9	Yes, if too much the wall tends to shake.	1		1	
10	Yes, if too much the bricks tend to topple.	1		1	
11	Yes, use large joints always with coarse sand.	1		1	
12	Yes, but can't raise the wall much.	1		1	
13	Yes, but if 'Chapparu' is not too much	2			2
	Total	16	21	13	24
	Net total	- 5		- 11	
	Probability of a 'yes'			35%	

*Response excluded as the explanation did not make sense

As the net response to this question is substantially negative (i.e. - 11 on a scale of -30 to +30), it suggests that bricklayers do not find it easy to build walls with large joints. Given a free hand, most bricklayers would move away from building walls with large bed joints.

6.3 Ease of Using Small Joints

Table 3 shows the response to the third question, i.e. on whether it is easier to build a wall with small joints. As the net response is positive, bricklayers do not appear find it easy to lay bricks with small joints. Given a free hand, most bricklayers would move away from building walls with small bed joints.

6.4 Ease of Use and Joint Size

The results shown in 6.2 and 6.3 above suggest that building walls with either large or small joints is not easy. This seems to fit well with the distribution of bed joint sizes shown in Fig. 1 although it is not absolutely clear as to what bricklayers perceive as 'large' and 'small'.

6.5 Ease of Use and Type of Bricklayer

A further analysis was carried out using a 2 x 2 matrix and the results are shown in Fig. 2. The sides of this matrix represent large and small joints with each side subdivided to represent the extent of 'buildability' with a scale of 'easy' and 'not easy'. These results show that bricklayers could be categorised based on their convictions on buildability. Accordingly, four types of bricklayers were identified and are described in Table 4.

Table 3: "Is it build a wall with a small bed joint?"

	Responses	As responded		As scored	
		Yes	No	Yes	No
1	No.....		6		6
2	No, but when too small it's difficult.		4		4
3	No, in fact it is faster.		2		2
4	No, but have to use more mortar for depressions/ to level course.		2	2	
5	No, but due to distortions in bricks it is difficult.		3	3	
6	No, but use 3/4" for convenience.		1	1	
7	No, bricks don't get disturbed when the joint is small.		1		1
8	No, when using fine sand./ No, but sand has to be sieved.		3	3	
9	No, but when more mortar is used it is easy to place bricks.		1	1 1	
10	Not very difficult but needs to make an extra effort.	1		1	
11	Not very difficult. Can build the wall by properly sizing the brick*	-	-	-	-
12	Yes	6		6	
13	Yes, can't adjust/level the brick when too small	2		2	
14	Yes, difficult due to distortions in bricks	1		1	
15	Yes, can't place the brick properly.	1		1	
16	Yes, but if sand is sieved, no problem.	1		1	
17	Yes, difficult to plumb. But, can catch up lost time when doing the header course	1		1	
18	Yes, difficult to plaster*	-	-	-	-
	Total	13	23	24	13
	Net Total	-10		9	
	Probability of a 'yes'.....			65%	

*Response excluded from analysis as the explanation did not make sense.
As sand is rarely sieved, response 16 was scored as a 'yes'. Others are self-explanatory.

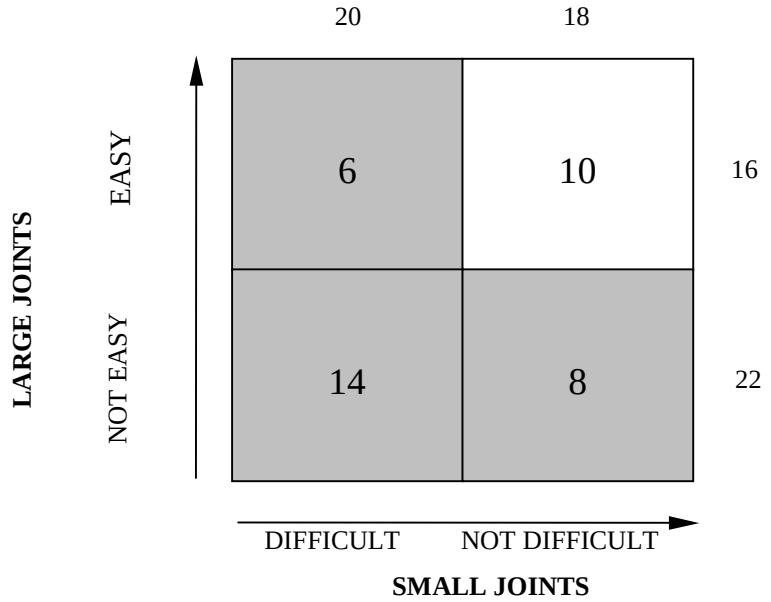

Figure 2: Buildability diagram for all bricklayers

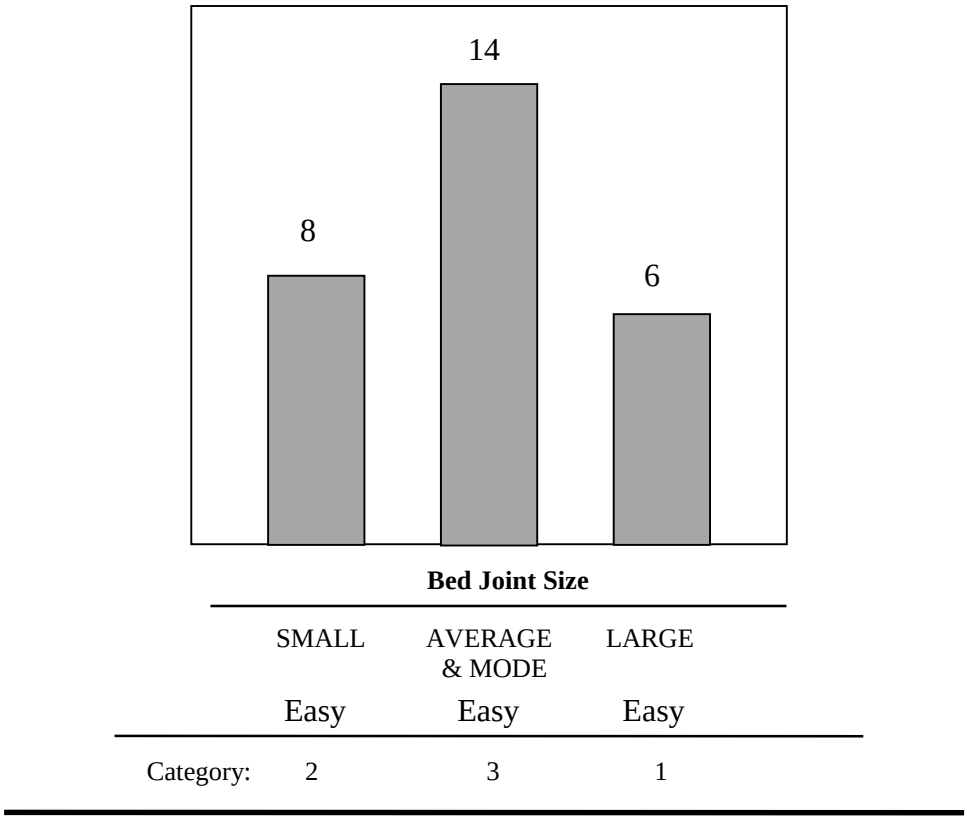

Figure 3: Buildability diagram for bricklayers who differentiate size with ease of building a wall

Table 4: Types of bricklayers

Category	Description
FIRST CATEGORY	The square in the top left corner shows that 5 considered that it is easy to use large joints whilst considering that it difficult to use small joints; An exclusive preference of large joints.
SECOND CATEGORY	The square on the bottom right shows that 6 considered that it is easy to use small joints whilst considering that it difficult to use large joints; An exclusive preference of small joints.
THIRD CATEGORY	The square on the bottom left shows that it is difficult to lay bricks either with small or large bricks, thus moving towards a joint that is neither small nor large.
FOURTH CATEGORY	The last category of bricklayers (i.e. Category 4), do not differentiate 'ease of construction' with either large or small joints. (See top right square.)

The number of bricklayers in Category 3 is much larger than the number in Categories 1 and 2, (14 against 8 and 6). This suggests a distribution with a central tendency as shown in Fig. 3 and is similar to the frequency distribution of the bed joint sizes shown in Fig.1. Given this similarity, buildability explains to a considerable extent the wide variations in field observations made on sites where the use of a particular joint size was not imposed.

7. SIGNIFICANCE OF THE FINDINGS

7.1 Degree of Control and Joint Size

This research has shown that not all bricklayers share a common view on the ease of constructing a wall given a particular joint size. They differ with a central tendency as shown in Fig. 3. Most bricklayers (i.e. category 3) prefer to use an intermediate size – a size that is neither small nor large. Thus to get them to use a size that is either large or small would need some control. Similarly, getting bricklayers of Categories 1 and 2 to adopt a size neither small nor large, or to a choice that they consider difficult, would need control as well. In contrast, controlling the actions of a Category 4 bricklayer should be relatively easier as size is not an issue with them. However, there may be times that there isn't a need for any control of the joint size! Bricklayers may be allowed to use a uniform size of their choice without an impact on costs as explained in 7.2.

7.2 Optimising Cost of Brickwork

The adoption of a particular size from a cost perspective depends on the 'cost polarity' or the 'cost homogeneity' of bricks and mortar. If the cost densities are significantly different then there is cost polarity; if not, there is cost homogeneity (Abeysekera, 2001). Technically, any size within the range of sizes shown in Fig. 1 could be built. If cost polarity is defined as the ratio of cost density of bricks to mortar, a value greater than 1 indicates that the use of more mortar would result in a reduction in costs. Thus, the strategy should be to use a bed joint size as large as possible. If however, the cost polarity is equal to 1, then there is clearly no opportunity to minimise costs. But, this means that there is no need to exercise any control of the joint sizes from the perspective of costs; bricklayers may be given the opportunity to use a size of their choice.

7.3 The Threat to the Standardised Approach to Joint Size

According to the findings of this survey, bricklayers are capable of building walls with a wide variety of joint sizes and they do not consider a particular size as being easier to build with. Given that the bed joint holds a large percentage of mortar, it was shown in 7.2 that it is possible to select a joint size, which would minimise the cost of brickwork. In most cases, it is likely that the cost effective joint size would be different to the unique size of 10mm. Clearly, on this basis, there is no grounds to argue for a standard bed joint size for that matter a standard size for any joint.

8. CONCLUSIONS

Sizes larger than the universally prescribed metric size of 10mm are currently being used in many countries. Whilst there could be many reasons for this practice, this study shows that most Sri Lankan bricklayers finds it easier to lay bricks with a size larger than 10mm opting for a size neither small nor large. Yet, there are others who prefer to work with sizes at the two extremes of the spectrum of bed joint sizes. In contrast, there are some who do not differentiate size with buildability at all. Accordingly, four categories of bricklayers could be identified depending on how they perceive buildability of the joint with respect to its size. This means that the adoption of a particular size calls for control. However, the achievement of an intermediate size, i.e. a size that is neither small nor large should be much easier than an extreme size.

These discoveries have much significance. Given that it is possible to find a joint size that would minimise costs, the case for a standard joint size cannot be upheld. Additionally, bricklayers can build with a range of sizes. Thus, from this perspective, the standardisation approach to the bed joint has cost society immensely given the magnitude of brickwork operations carried out world over. Billions of dollars, if not more, could have been saved provided an attempt was made to select a non-standard joint size that is cost effective! A 'dynamic', as against a 'static' approach to the selection of the bed joint size is advocated. Any decision related to this process could be made without much difficulty through the application of the principles embodied in 'cost polarity' and 'cost homogeneity'.

The ignorance of the fact that cost and productivity could be optimised through the manipulation of the bed joint size has by and large curbed any enterprising developments. Clearly, there are plenty of opportunities both in the developing and the developed world to adopt the approaches suggested herein, and thereby reap the benefits.

As mentioned before, it appears that brickwork has developed more as a craft than by a process of scientific investigation and reasoning. Even the knowledge gathered thus far scientific inquiry appears to be incomplete, and sometimes

distorted as evidenced by the shortcomings in the standardisation approach to bed joint size. It is time that an attempt is made to lay the foundations for a 'theory of brickwork' drawing upon the existing body of knowledge.

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