STATISTISCHE AUSWERTUNG VON DRUCKVERSUCHEN AN MAUERWERK AUS GASBETONSTEINEN

ZUSAMMENFASSUNG. Die Ergebnisse von 172 Druckversuchen an Mauerwerk aus Gasbetonsteinen werden statistisch ausgewertet. Hierbei wird zwischen 3 Ausführungsarten unterschieden: Fugen aus Normalmörtel mit der üblichen Fugendicke von 12 mm, Fugen aus Dünnbettmörtel, der handwerksüblich aufgetragen wurde, und Fugen aus Dünnbettmörtel, in glatter und vollflächiger Ausführung. Die statistischen Mittelwerte und die Fraktilwerte der Wanddruckfestigkeit werden in geschlossener Form dargestellt. Die Auswertung erfolgt mit Hilfe eines Verfahrens nach [1] auf der Grundlage von Potenzfunktionen. Die Ergebnisse für die 3 Ausführungsarten werden vergleichend gegenübergestellt, wobei der Einfluß der Fugenausführung auf die Wandfestigkeit deutlich wird.

STATISTICAL EVALUATION OF COMPRESSION TESTS ON MASONRY WALLS CONSTRUCTED IN GAS-CONCRETE BLOCKS

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ABSTRACT. The results of 172 compression tests on masonry walls constructed in gas-concrete blocks are statistically evaluated. 3 types of construction are used: joints in normal mortar with a standard joint thickness of 12 mm, joints in a thin mortar bed applied in the normal workmanlike manner, and joints in a thin mortar bed applied smoothly and over the complete bed joint face. The statistical mean values and the characteristic values of the compressive strength of the wall are shown in a closed order. The evaluation is carried out with the aid of a method according to [1] based on the exponential functions. The results for the 3 methods of construction are compared, whereby the influence of the joint construction on the wall stability becomes apparent.

TERMS

$\beta_S$ compressive strength of the blocks (mean value)

$\beta_M$ compressive strength of the mortar (mean value)

$\beta_W$ mean compressive strength value of the blockwork wall

$\beta_{W,5\%}$ characteristic value of the compressive strength of the blockwork wall

## 1. INTRODUCTION

Masonry walls of gas-concrete blocks are either constructed with 12 mm thick bed joints of normal mortar or using a thin mortar bed. In order to show the various influences of joint construction on the compressive strength of this masonry walling, the results of compression tests have been compiled and statistically evaluated. The objective of the evaluation is to formulate the compressive strength of the walling as a mean value as well as a characteristic value in dependence of block and mortar strength, which are then shown separately for the various methods of construction.

## 2. INITIAL DATA FOR THE RANDOM TESTS

In total, the results of 172 compression tests were available. Some were taken from [4] , further results were obtained from the authors of [4] and from the 'Forschungsvereinigung Gasbeton e. V.' (Research Association for Gas Concrete) in Wiesbaden, Federal Republic of Germany. These tests were compiled in the following 3 groups:

Group A: 105 tests on gas-concrete blockwork walling constructed with normal mortar with bed joints of a standard thickness of 12 mm.

Group B: 58 tests on gas-concrete blockwork walling constructed with a thin mortar bed, i.e. with bed joints with a thickness of approximately 1 to 3 mm. The thin mortar bed was applied in the normal manner using a toothed trowel.

Group C: 9 tests on walling constructed as described for group B but with the thin mortar bed not applied with a toothed trowel but smoothly and flat over the full bed joint face.

These 3 groups were individually statistically evaluated.

## 3. THEORETICAL BASIS FOR THE STATISTICAL EVALUATION

The statistical evaluation of the random tests was carried out according to a method that was introduced in 1982 at the IBMaC in Rome [1] . Here the statistical characteristic values for wall strength, namely mean value, deviation and characteristic value, were not given as numerical values but as mathematical functions of closed order, dependent on block and mortar strength. This has the advantage that one can not only statistically evaluate samples of equal initial materials as random samples, but also that all available random samples with the greatest variation in blockwork and mortar strength can be compiled together to a single random test. The thus possible large number of samples increases the accuracy of the evaluation, the representation of the results as a mathematical function acts in a compensatory manner and allows the clear perception of the correlationships.

As the method is described in detail in [1] and [2] , it is not repeated here. It is based on the use of an exponential function for the mean value of the compressive strength of the masonry wall $\beta_W$, dependent on the compressive strength of the blocks $\beta_S$ and the compressive strength of the mortar $\beta_M$:

$$\beta_W = a \cdot \beta_S^b \cdot \beta_M^c \qquad (1)$$

The values a, b, and c are determined by optimisation, whereby logarithmic normal distribution, as is normal in the testing of building materials, is an assumption. The characteristic values $\beta_{W,5\%}$ of the compressive strength of the wall are given as a 5% characteristic with a statement probability W = 95 %. As the test samples possessed varying slenderness ratios, all test results were converted to a slenderness ratio h/d = 5 in accordance with the RILEM sample test.

## 4. STATISTICAL EVALUATION OF THE RANDOM TESTS

The evaluation was carried out using an individual electronic programme for each of the 3 groups A to C.

Group A: masonry wall with normal mortar
The mean value function for the compressive strength of the wall is given by:

$$\beta_W = 1.01 \cdot \beta_S^{0.674} \cdot \beta_M^{0.061} \qquad (2\ A)$$

This function as well as the characteristic value $\beta_{W,5\%}$ is given in Figure 1 for the three common mortar strengths $\beta_M$ = 2.5, 5 and 10 N/mm².

The relationship of characteristic value to mean value $\beta_{W,5\%} / \beta_W$ decreases with increasing compressive strength of the blocks, and lies between 0.82 for $\beta_S$ = 2.5 and 0.73 for $\beta_S$ = 7.5 N/mm². The function of the characteristic value can be formulated in a simplified form as follows:

$$\beta_{W,5\%} = (0.74 \div 0.83) \cdot \beta_S^{0.674} \cdot \beta_M^{0.061} \qquad (3\ A)$$

The equations (2 A) and (3 A) are valid for the range of the random test $2.5 \leq \beta_S \leq 7.5$. Comparing the equations (2 A) or (3 A) with the relationships often used and given by Bröcker in [3]

$$\beta_W = a \cdot \sqrt{\beta_S} \cdot \sqrt[3]{\beta_M} = a \cdot \beta_S^{0.5} \cdot \beta_M^{0.33} \qquad (4)$$

it can be seen that the influence of the block strength $\beta_S$ is larger and the influence of the mortar strength $\beta_M$ is much smaller than given in (4). Evidently it is of consequence that the strength of blocks and mortar are of the same order of magnitude and that the transverse strain behaviour of both components in the masonry is similar.

Group B: masonry wall with thin mortar bed of standard quality
The statistical evaluation showed that the exponent c in (1) lay in the vicinity of zero, i.e. the mortar strength has hardly any influence on the wall strength. However it must be taken into consideration that the strength of the thin mortar beds in all tests was greater than the strength of the blocks. It is easily understood that the strength of the mortar in the very thin mortar joint can be of no great importance for the strength of the wall: The result of the statistic evaluation can be explained mechanically. For this reason the mortar strength was always inserted with the same value as that for the block strength in a further computer run, thus simplifying (1).

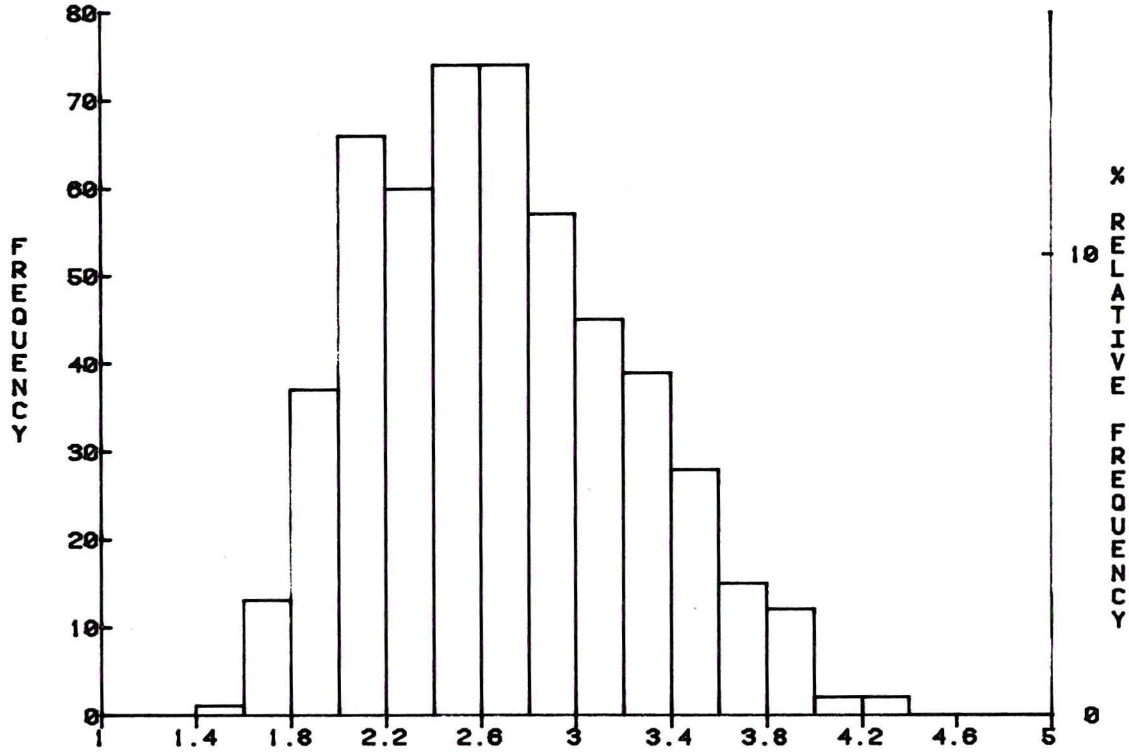


FIGURE 4. MORTAR COMPRESSIVE STRENGTH - HISTOGRAM

## 4. SUMMARY

Consideration of the random variation in various flexural and shear properties of brickwork has shown similar patterns. Results for the elastic modulus of vertical beams have been presented in detail to indicate these patterns. For the modulus of rupture of bricks and for mortar compressive strength the patterns are different from those for flexural and shear properties and these results have also been presented.

In general it was found that the sample variances for each of the properties are homogeneous where the samples correspond to separate wall tests, and the differences between these samples are significant in some cases but not in all. It was concluded that when these differences are statistically significant it is due to factors beyond the control of the experiments, but factors which would nevertheless be expected to occur in a practical situation. The examination of results pooled across these test groups therefore indicates the pattern of variation likely to be encountered in the field. Differences between groups by brick batch were more significant than differences between test groups. However, even this variation between batches of seemingly identical bricks could occur in practical construction, and the overall distribution of results pooled across these batch groups was therefore examined.

These functions are also shown in Figure 1.

The equations (2 C) and (3 C) are valid for the range of the random test $2.5 \leq \beta_S \leq 5$, as no test results were available for larger compressive strength values for gas-concrete blocks.

The equations (3 A), (3 B), (3 C) give the characteristic values $\beta_{W,5\%}$ in the form of limits.

The exact mathematical function of these characteristic values has a relatively complicated form. It can be approximated fairly accurately by the following simpler equations:

Group A:

$$\beta_M = 2.5 \text{ N/mm}^2 \qquad \beta_{W,5\%} = 0.92 \cdot \beta_S^{0.6}$$

$$\beta_M = 5 \text{ N/mm}^2 \qquad \beta_{W,5\%} = 0.95 \cdot \beta_S^{0.6} \tag{6 A}$$

$$\beta_M = 10 \text{ N/mm}^2 \qquad \beta_{W,5\%} = 0.99 \cdot \beta_S^{0.6}$$

Group B:

$$\beta_{W,5\%} = 0.68 \cdot \beta_W^{0.9} \tag{6 B}$$

Group C:

$$\beta_{W,5\%} = 0.77 \cdot \beta_W^{0.9} \tag{6 C}$$

## 5. DISCUSSION OF RESULTS

For better comprehension, the functions of the mean values and the characteristic values shown in Figure 1 are compared again in Figures 2 and 3. The following conclusions can be drawn:

a) For blockwork masonry walling constructed using a thin mortar bed, the compressive strength of the mortar $\beta_M$ has no influence on the wall strength $\beta_W$, if it is larger than the block strength $\beta_S$.

b) Using standard mortar, the mortar strength is of relatively small influence on the wall strength. This is expressed by the exponent c = 0.061 according to (2 A). An improvement of the mortar quality in order to improve the compressive strength of the wall is therefore of little consequence.

c) The use of a thin mortar bed with equal quality of the blocks leads to a greater compressive strength of the wall than with standard mortar. The very thin joint is apparently less of an impairment compared to the thick joint of standard mortar.

d) Thin bed mortar applied smoothly and flat over the full bed joint face results in a larger compressive strength of the wall compared to the normal application as carried out in the workmanlike manner using a toothed trowel. The quality of the joint is then an influencing factor, to a small degree for the mean value, to a greater degree however for the deviation and for the characteristic values of the compressive strength of the wall.

e) The deviation of the wall strength is less using a thin mortar bed, thus the characteristic value function more favourable than when using standard mortar. Evidently here the deviation of the strength of the mortar and the quality of the joint are of consequence.

The described results of the statistical evaluation correspond with the mechanical model of the failure mechanism of masonry walling subjected to compressive load.

## Literature:


[1] Mann, W.: Statistische Auswertung von Druckversuchen an Mauerwerkskörpern in geschlossener Darstellung mit Hilfe von Potenzfunktionen, 6. Internationale Mauerwerkskonferenz IBMaC 1982, Rome, page 86

[2] Mann, W.: Druckfestigkeit im Mauerwerk - Eine statistische Auswertung von Versuchsergebnissen in geschlossener Darstellung mit Hilfe von Potenzfunktionen, Mauerwerk-Kalender 1983, page 687

[3] Bröcker, O.: Steinfestigkeit und Wandfestigkeit, Betonstein-Zeitung 1961, page 120

[4] Kirtschig and Kasten: Auswertung von Versuchsergebnissen ..., Heft 43, Institut für Baustoffkunde und Materialprüfung der Universität Hannover, 1979

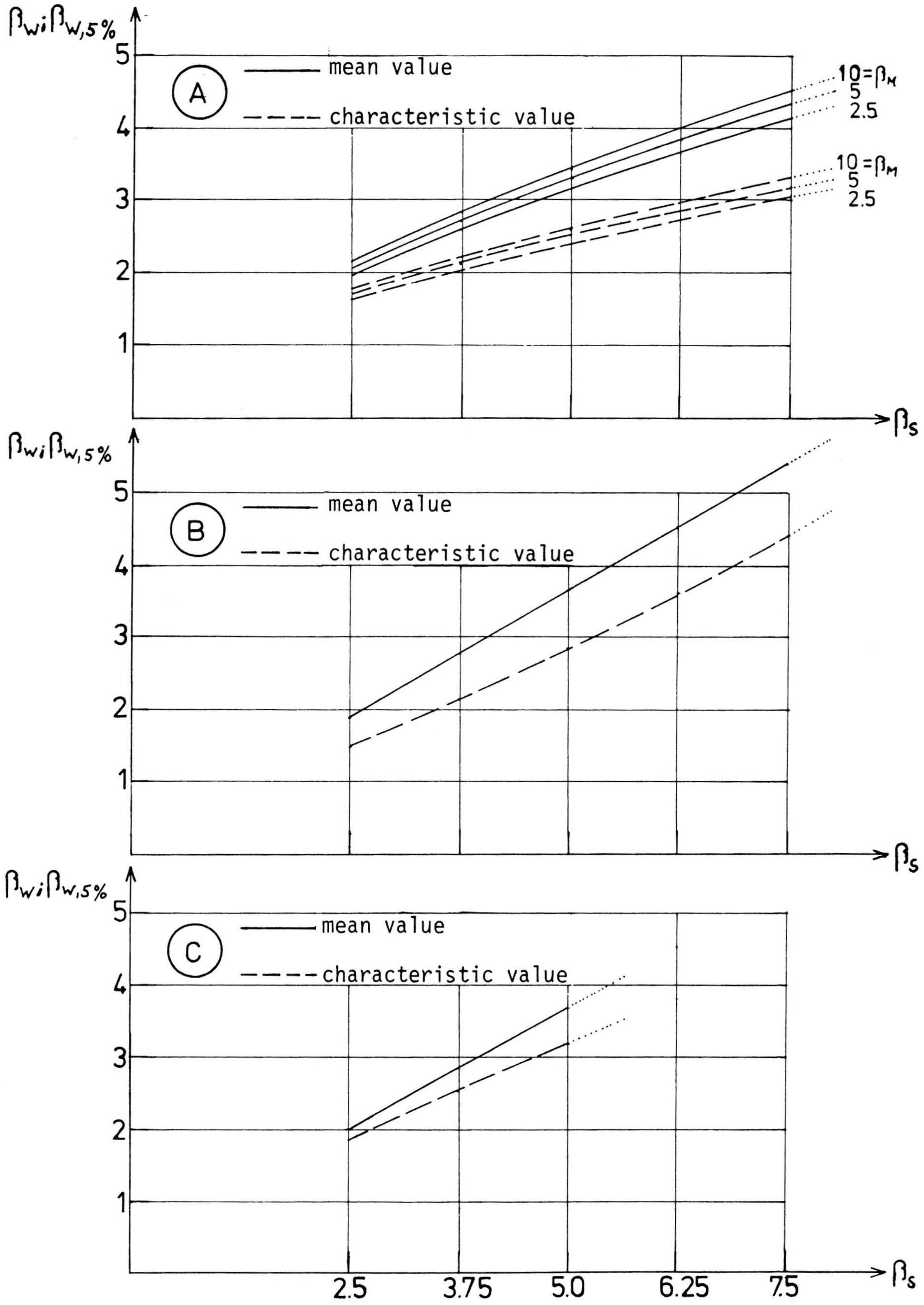


Figure 1 Mean value $\beta_W$ and characteristic value $\beta_{W,5\%}$ for the compressive strength of the wall dependent on the compressive strength of the blocks $\beta_S$ for construction methods A, B, and C of the bed joint [ $N/mm^2$ ]

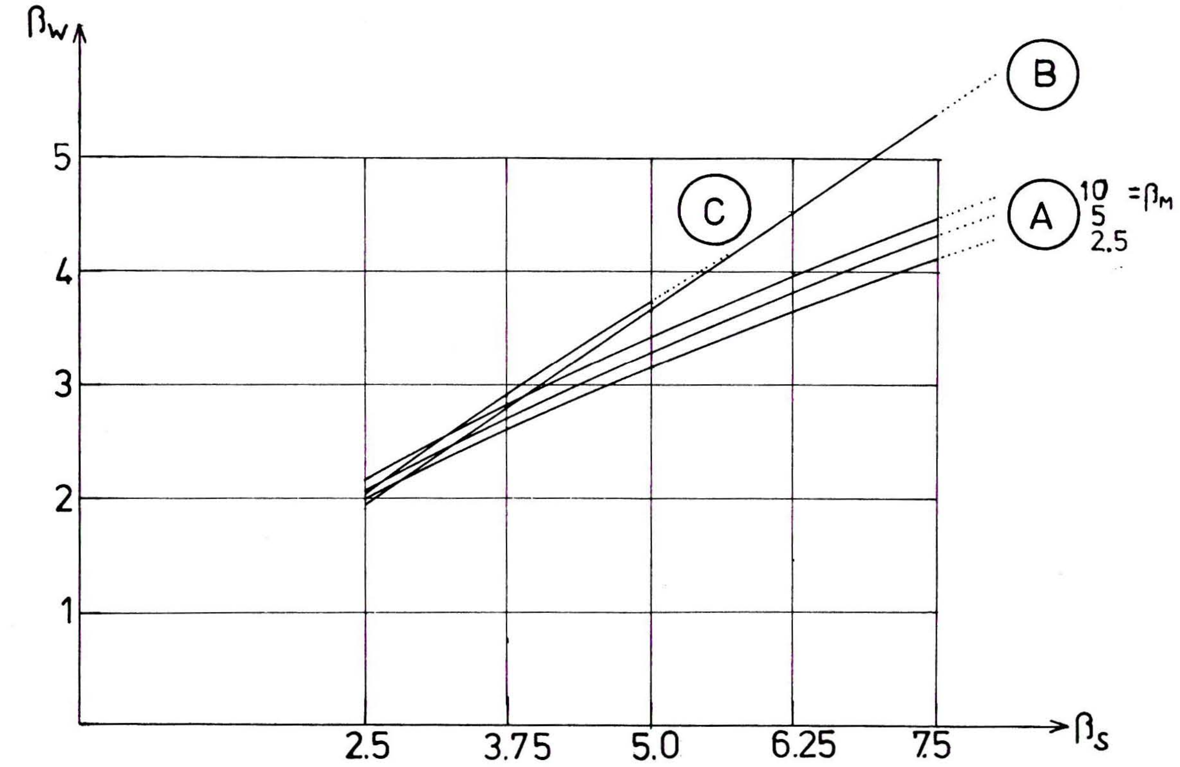


Figure 2 Comparison of the mean values $\beta_W$ dependent on $\beta_S$ and the construction method used for the bed joint [ N/mm$^2$ ]

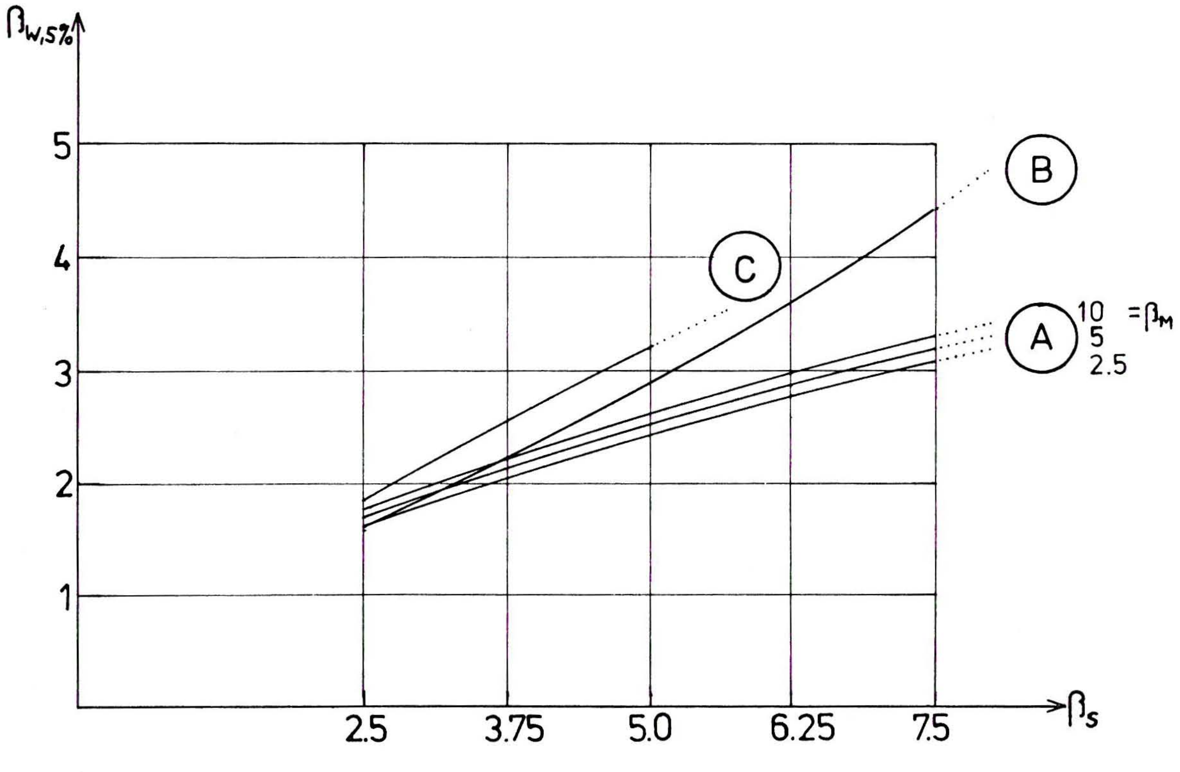


Figure 3 Comparison of the characteristic values $\beta_{W,5\%}$ dependent on $\beta_S$ and the construction method used for the bed joint [ N/mm$^2$ ]