The influence of water gain upon the tensile strength of concrete*

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The fact that the rise of bleed water through freshly placed concrete induces anisotropic properties in concrete to a significant degree as a result of water gain on the bottom surfaces of the aggregate particles often tends to be ignored and may indeed not be widely recognized. Dr Fenwick and Mr Sue are to be commended for adding to the relatively small body of available data indicating quantitatively the effects of this anisotropy upon concrete strength. However, in their survey of the rather limited data available on the subject, it appears that they did not have access to a 1973 U.S. Transportation Research Board publication⁽¹⁾ in which I gave relevant data (Figure I) with which they might wish to compare their own results.

Figure I: Comparative tensile strengths of specimens cast vertically and horizontally.

The scope of the investigation included 23 mixes with aggregate maximum size, slump and water/cement ratio as the variables. As in the case of the paper under discussion, the results indicate no particular relationship between the magnitude of the strength differential associated with the two different directions of casting and mix variables such as slump, water/cement ratio and aggregate characteristics. However, the average differential reported in my work was of the order of 8% for both tension and compression, considerably less than the 20% or so reported in the paper under discussion. The reasons for this fairly substantial discrepancy are not immediately obvious, and may well be associated with the bleeding characteristics of the mixes used in each investigation, so measurements of bleeding rate and bleeding capacity might usefully be included in future work of this type. Certainly, the discrepancy is unlikely to be due to differences in experimental technique, because very similar techniques were used to determine tensile strength in both investigations, a circumstance from which I derive some considerable satisfaction in view of my involvement in the original development of the scissor grip many years ago. It is encouraging to see this technique being used in New Zealand following its use in several research programmes in the United Kingdom and Canada.

If I may offer some small criticism of the paper under discussion, it is that the representation of effects in tension by the ratio of tensile strength to the square root of compressive strength, instead of by tensile strength alone, may mask some of the effects of water gain upon tensile strength because the effects upon compressive strength are of opposite sense⁽¹⁾ (Figure II). In addition, I have always been adamantly opposed to any graphical or tabular data which imply that there is a constant relationship or ratio between tensile strength and compressive strength. This has been clearly illustrated in a previous discussion⁽²⁾.

* Pages 146 to 154 of MCR 120.

Figure II: Comparative compressive strengths of specimens cast vertically and horizontally.

Reply by the authors

We would like to thank Professor Johnston for his contribution as it adds considerably to the value of the paper. The ratio of the tensile strength of the specimens cast vertically to those cast horizontally in our tests was 0.8. This lies between the figures of 0.92 observed by Professor Johnston⁽¹⁾ and the lower value of about a half found in the limited number of direct tensile tests carried out by Hughes and Ash (reference 4 of our paper).

Professor Johnston suggests that the bleeding characteristics of the mix may account for the observed difference in these tensile strength ratios. However, our test results indicate that this phenomenon could only have a small effect for the normal range of concrete mixes. When the sand proportion was changed in our test series II, a marked difference was apparent in the bleeding from the mixes, but the tensile strength ratio was not altered. However, we

On the whole, a clearer picture of the anisotropic behaviour of concrete in tension is obtained by comparing tensile strengths associated with different directions of casting (Figure I) as in Table 1 of the paper. However, this Table appears to contain a minor error which may confuse some readers because, although the values of the columns headed f_{th} and f_{tv} are consistent with what would be expected from the influence of water gain, the numbers in the column headed f_{th}/f_{tv} do not correspond to the column heading. Apparently, the heading should read f_{tv}/f_{th} , a very minor error in an interesting paper.

support his suggestion that bleeding rate and capacity measurements should be included in future work.

It is difficult to obtain equivalent compaction in the horizontally and vertically cast tension specimens, as in one case the specimen is less than a 100 mm deep, and in the other it is 600 mm. It may well be that part of the difference arises from differences in compaction. However, we feel that the major factors are likely to be:

- (1) the tensile strength of the larger aggregate particles, in that a low strength will mask any directional strength reductions due to watergain effects, and
- (2) the surface characteristics of the larger aggregate particles, in that these may influence the sensitivity of the bond strength to watergain.

The column heading f_{th}/f_{tv} in Table 1 is incorrect as Professor Johnston pointed out. It should read f_{tv}/f_{th} .

REFERENCES

1. JOHNSTON, C. D. Anisotropy of concrete and its practical implications. *Concrete properties and performance*. Washington, D.C., Highway Research Board 1973. Highway Research Record No. 423.
2. JOHNSTON, C. D. and WARD, M. A. Discussion on: The long-term tensile strength of plain concrete. *Magazine of Concrete Research* Vol. 23, No. 77. December 1971. pp. 198-199.