# Discussion on two related papers published in the

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## Testing concrete in tension and in compression*

by C. D. Johnston, BSc, PhD and E. H. Sidwell, MSc, FICE

### Contribution by L. J. Parrott, BSc(Eng)

*Cement and Concrete Association: Materials Research Department*

The authors are to be commended for attempting to provide a tensile loading method in which standard prisms can be tested without special preparation. There is, however, a point arising from Figure 5 which suggests that the specimen might not be stressed with uniaxial tension: the curves for relative lateral compressive stress approach the abscissa so steeply at 10 and 13 inches that it seems possible that the middle of the specimen is in biaxial tension. It might be useful if the authors could provide some data on the response of gauge C1 to compare with the data of Figure 5. The application of a lateral uniformly distributed compressive stress over part of the side of a slab is shown in Figure 1 to produce a tensile stress in the direction of the compressive load. The experimental data were produced mainly to investigate the stresses beneath the loaded section, so details of the strains outside the loaded section are mainly along the centre-line B-B. It seems likely that tensile stresses will also develop away from the centre-line. The standard solution for a lateral point load similarly predicts tensile stress along the centre-line, in the direction of compressive loading.

### Contribution by M. S. Marathe, PhD

*University of Manitoba*

The writer has read the paper by Dr Johnston and Mr Sidwell with great interest and agrees with the authors that there is a need for a simple technique to determine the tensile strength of concrete more accurately, and for a closer correlation between various types of test for concrete. The writer has done some work on tensile testing of concrete(1) at the University of Leeds and would like to comment on a few points in the paper.

Evans(2) has shown that the performance of the direct tension test for concrete is largely affected by the load being eccentric. Therefore care should be taken to equalize strains on opposite faces of the specimen and to maintain this condition at least up to the first crack, beyond which strain values are misleading owing to the presence of a microcrack either inside or outside the gauge length. The writer attached sensitive strain gauges (either roller mirror gauges or e.r.s. gauges) on the opposite faces of the specimen and, by trial and error, equalized the strains. Usually, a few trials were necessary in each test before the eccentricity could be removed.

The authors have stated that up to 3% eccentricity could be present in a test. This eccentricity would amount to $\frac{1}{8}$ in. for a 4 × 4 in. specimen and presumably up to 30% difference in the strains on the opposite faces of the specimen. The writer feels that a better accuracy would be needed to obtain a true tensile strength of concrete.

*Pages 221–228 of *Magazine* No. 65.

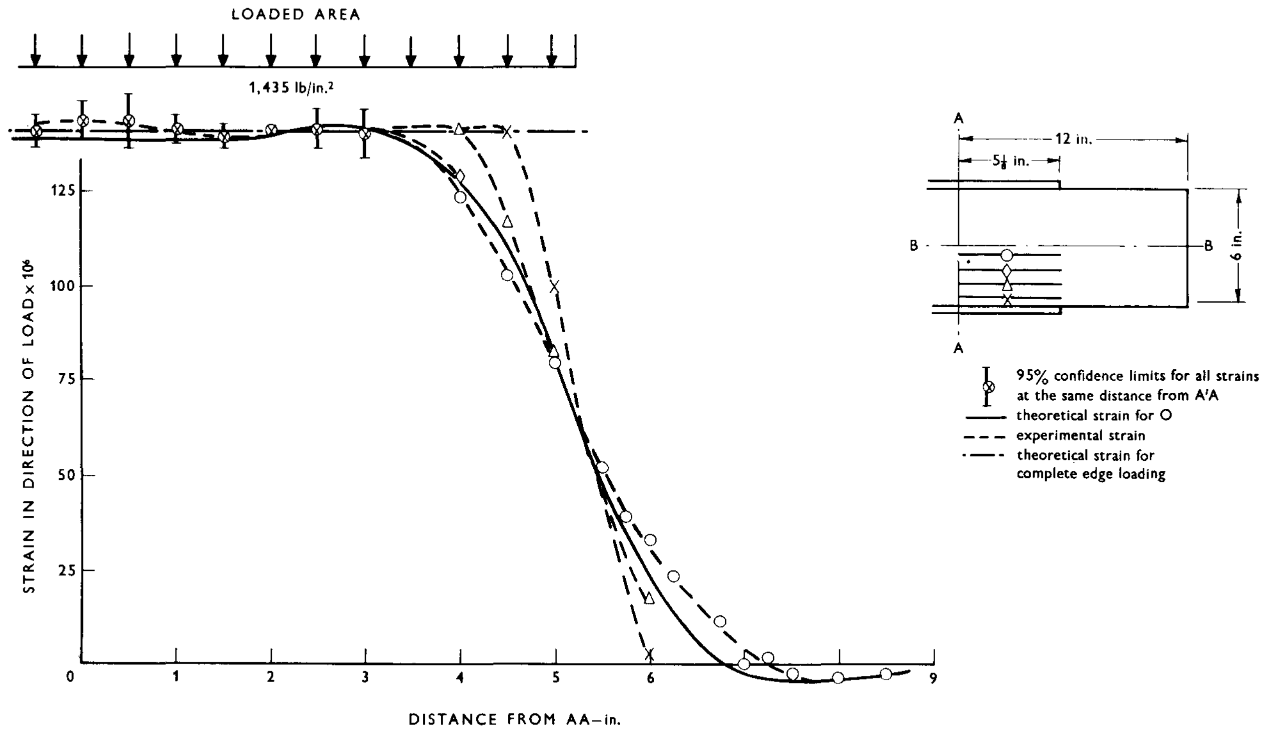


*Figure 1: Strain distribution for a slab loaded over part of its edge.*

## **Contribution** by D. A. Stewart, MBE, FICE, AMIEE, MConsE

*Cowdell & Stewart, Consulting Engineers*

This paper has raised a number of interesting points quite apart from the test results in their application to the behaviour of concrete in structural members. The predominance of failures at the lower end of the specimen as cast may well be related to concentration of the coarse aggregate during compaction of an over-sanded mix, as would be the case if Road Note 4 gradings were used with the exception, perhaps, of grading No. 1, for both ¾ and 1½ in. maximum sized aggregate. Against this suggestion it must be accepted that there would be a tendency to increase the water/cement ratio at the top of the specimen. This condition might normally be expepted to reduce the resistance of the concrete to both tensile and compressive forces.

Another interesting point is the apparent relationship existing between maximum aggregate size and variability in failure, as disclosed in Table 2. What this Table does, in fact, indicate very clearly is that there is a likelihood of greater variation of a ⅜ in. aggregate in a 4 × 4 in. mould than there is for the same aggregate and mix in a 6 × 6 in. mould. This, surely, is a matter of the packing characteristics of the aggregates and the perturbation caused in their assemblies by the wall effect of the mould. There is no reason to suppose that, in normal construction work, concrete made with 1½ in. aggregate is more subject to erratic response to stresses than are ¾ in. and ⅜ in. materials. The shape and size of test specimens have an important bearing upon many experimental results, as, for instance, shrinkage and creep, and it is therefore most unsafe to argue from the particular to the general.

A further matter of interest, which the authors have failed to mention, is the workability of these various concretes. If their research is to be referred to the field, the engineer will be anxious to know whether the compacting factors of these mixes were of constant value or not.

## **Reply** by the authors

In response to Mr Parrott's query, the authors would like to refer to the data given here in Table I. As the relative lateral compressive strain is slightly less at the location C2 than at C1, tensile stress, if present, will occur at C2. However, values of the relative lateral compressive stress, calculated by using the formulae relating stress $\sigma$, strain $\varepsilon$ and Poisson's ratio in three dimensions and assuming Poisson's ratio to be

TABLE 1: **Extracts from relative lateral strain measurements on 4 in. and 6 in. square specimens.**

| Parameter | 4 in. specimen | | | | 6 in. specimen | | | |
|---|---|---|---|---|---|---|---|---|
| | C1 | C2 | C3 | C4 | C1 | C2 | C3 | C4 |
| $\varepsilon_c$ | 0·198 | 0·185 | 0·538 | 0·860 | 0·203 | 0·196 | 0·219 | 1·110 |
| $\sigma_c$ | 0·000 | −0·005 | 0·375 | 0·733 | 0·000 | −0·003 | 0·029 | 0·965 |

equal to the C1 strain value, show that the magnitude of the lateral tensile stress at C2 is less than 1% of the applied uniaxial tensile stress. This stress combination cannot be construed as significantly biaxial. In addition, the location where Mr Parrott obtains the maximum lateral tensile strain, about two inches from the end of the loading strip, corresponds almost exactly to our location C2, so it appears that this location is subject to the worst possible biaxial conditions.

In response to Dr Marathe's remarks, the authors would like to point out that eccentricity in this case was calculated as (individual strain − average strain)/(average strain). This rather loose use of the term eccentricity has led to his misunderstanding the text, so the difference between strains on opposite faces, suggested as being up to 30%, is actually 6% or less.

In response to Mr Stewart's remarks, it is interesting to note that he, like the authors, cannot explain the slight tendency for failure to occur in the deeper part of the concrete. With regard to Table 2 of the paper, it does, of course, show the well-known effect of size of aggregate in relation to size of specimen, but its primary purpose is to present comparable values of coefficient of variation in tension and compression. The effect of size of aggregate, more clearly illustrated in Table 4, is that standard 4 in. ($\frac{3}{4}$ in. aggregate) and 6 in. ($1\frac{1}{2}$ in. aggregate) specimens are subject to an increase in coefficient of variation, but not standard deviation, as the size of aggregate increases and the ratio (size of aggregate to size of specimen) remains almost constant. The authors have not argued from the test specimen to the structural unit, as Mr Stewart suggests, but have emphasized that assessment of the strength of the unit from standard test specimens is subject to the above effects. Finally, the significance Mr Stewart attaches to the maintenance of a constant compacting factor is not made clear but, in answer to his specific query, it should be pointed out that the mixes were designed within the very low and low workability ranges defined in Road Note No. 4 (reference 18 of the original paper).

## *REFERENCES*

1. EVANS, R. H. and MARATHE, M. S. Microcracking and stress curves for concrete in tension. *Materials and Structures.* Vol. 1, No. 1. January–February 1968. pp. 61–64.
2. EVANS, R. H. Extensibility and modulus of rupture of concrete. *The Structural Engineer.* Vol. 24, No. 12. December 1946. pp. 636–659.