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Determining concrete strength by using small-diameter cores*

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The Australian Standard for the securing and testing of cores from hardened concrete⁽¹⁾ requires that the diameter of the core shall be not less than 75 mm. I believe that this limitation is justified and agree with Mr Bungey when he says, "... the variability of results is likely to be so large that the use of such cores [44 mm diameter] to assess the strength of in situ concrete is of doubtful value in many practical situations". Nevertheless, there are times when cores having a diameter less than 75 mm must be taken and the work by Bungey will be of value in interpreting the results.

The Australian Standard also places a limitation on the ratio of the core diameter to the nominal maximum size of the aggregate at a value of 3. This follows the work of Rechart⁽²⁾, who plotted the increase in standard deviation of cores over the dispersion in strength of separately cast cubes, against the ratio of the core diameter to the maximum particle size. Little difference in the dispersion of the standard deviation occurred, provided the ratio was greater than 3. Bungey states that the 20 mm aggregate cores ($d/A_{\max} = 2.2$) exhibit a greater variability than the 10 mm aggregate ($d/A_{\max} = 4.4$), although this is not proved conclusively. It would appear there-

fore that the limitation of the ratio to be not less than 3 should still apply.

In our study at the Division of Building Research on the compressive strength of cores⁽³⁾, we noted that the core strengths were always less than the strength obtained from standard cylinders, even when good curing was provided. Also that the smaller the core diameter, the lower the compressive strength. To estimate the strength of 150 mm diameter cores from smaller cores, it was necessary to multiply the 100 mm diameter core by 1.07 and the 75 mm diameter core by 1.11.

In subsequent work⁽⁴⁾ it was shown that these strength differences from cores of various sizes were not due to the effect of the diameter, but rather they were related to a strength gradient through the concrete test slab. Where a strength gradient between top and bottom portions of the slab existed, small-diameter core specimens taken from the top surface reflected the strength at the top, whilst larger-diameter cores reflected the concrete strength at a lower level - all cores being secured from the top surface. Where no gradient existed, the observed strengths of the cores of different diameters were not significantly different, which supports the findings by Petersons⁽⁵⁾.

The above is an important factor when small-diameter cores are taken in practice. Under these circumstances, it is necessary to give due consider-

*Pages 91 to 98 of *MCR* 107.

ation to the location of the core. If we are interested in the surface strength of a slab, smaller-diameter cores will give a better estimate than larger cores. If

we persist with small-diameter cores for an estimate of the strength of the concrete mass, they should be taken near the centre of that mass.

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Contribution by S. A. W. Bowman

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The specification for a foundation contract in Tsuen Wan, one of the Hong Kong new towns, included a requirement for small-diameter cores to be taken from large cast-in-place piles after casting. The cores were to be checked visually for evidence of flaws, and crushed to confirm the strengths achieved by concrete test cubes. Objections were raised to the use of small-diameter cores for strength testing, on the grounds that they would not give a reliable indication of strength, and that to penalize the contractor on such unreliable evidence would not be proper.

At the same time, a proposal to widen a flyover in Kowloon led to cores of 150 mm diameter being taken to assess the actual strength of the concrete in the flyover. In order to compare the variability of results from large- and small-diameter cores taken from an actual structure, 50 mm diameter cores were taken as well, from positions as near as possible to the 150 mm cores.

Twenty-five 50 mm cores and twenty-four 150 mm cores were taken. Results from the 50 mm cores gave a mean strength of 44.7 N/mm² and a coefficient of variation of 28.9%. The mean strength of the 150 mm cores was 41.4 N/mm², and the coefficient of variation was 19.5%. The greater variability of results from small-diameter cores was thus confirmed.

In spite of this, it was concluded that 50 mm cores, being relatively cheap and quick to obtain, should continue to be used, not only for visual checks, but also for strength tests on the concrete in cast-in-place piles. To allow for the variability of such tests, it was laid down that, if the measured compressive strength of any section of a 50 mm core fell below 87% of the characteristic strength of the concrete, the contractor should be given the option either of carrying out remedial works specified by the engineer, or of taking a confirmatory 150 mm core.

Reply by the author

I thank Mr Lewis and Mr Bowman for their interesting contributions.

Mr Lewis confirms the need for small cores in some circumstances and emphasizes the importance of the core-diameter/aggregate-size ratio. He also provides a number of useful references relating to this and

other aspects of core performance. I would agree with him that ideally a limiting core-diameter/aggregate-size ratio of 3 should be maintained in order to contain the variability of results, but unfortunately this may not always be possible in practice.

Mr Lewis also highlights the particularly critical

problem of strength variation throughout members, which affects not only cores but other methods of non-destructive strength evaluation, such as internal fracture and Windsor probe testing. I have recently observed a situation similar to that which he described when examining laboratory cast beams in which strength variations within the member dominated other variables.

An interesting example of a practical situation in which small core strength testing was found to be

worth while is given by Mr Bowman. Although he does not indicate the size of aggregate, his figures for strength and coefficients of variation follow the pattern suggested by my work, and the difference in variability of results between site and laboratory work is well illustrated.

Both contributions confirm the importance of very careful planning and interpretation of any site core tests, and that this consideration is increased when the diameter is small.