Discussion

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The practical use of ultrasonic pulse velocity measurements in the assessment of concrete quality*

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Mr Tomsett must be congratulated on his paper which emphasizes the use of ultrasonic pulse velocity measurements for assessing the quality of concrete, particularly its application to the testing of prototype structures. The use of the ultrasonic pulse measurement technique is quite effective when the purpose of testing the concrete is of a comparative nature and pulse velocity is the only means of discriminating between the qualities of different parts of the concrete in a given structure. Hence Mr Tomsett's efforts in bringing out the usefulness of this technique for assessing the quality of concrete in situ should be appreciated.

However, he did not indicate the frequency of the transducers he used. Our experience in India while testing the quality of the concrete in a number of prototype structures such as frame-type turbo-generator foundations, large block-type gas compressor foundations etc. has shown that a frequency range of 20 to 100 kHz is most suitable for testing non-homogeneous materials like concrete. Frequencies higher than 100 kHz become scattered and absorbed easily in such materials and thus are not useful for effective testing of concrete of considerable thickness in situ. Low-frequency sonic waves (< 20 kHz), although they have higher penetration power

due to less absorption and scattering, do not give detailed information regarding smaller flaws or inhomogeneities in concrete. Hence the choice of ultrasonic frequency to be used plays an important role in arriving at reasonable conclusions with regard to quality of concrete in situ⁽¹⁾. Perhaps Mr Tomsett could throw some light on this aspect of choice of frequency based on his experience.

Ultrasonic pulse velocity surveys for the assessment of the in situ quality of concrete of a large number of mass concrete foundations with compressive strengths varying from 15 to 30 N/mm² have been undertaken in India during the last decade or so. This evaluation was necessitated for various reasons, such as observed surface cracks, effect of heat upon concrete due to fire, suspected honeycombing and cold joints in beams and columns, deterioration due to ageing etc. and over-all assessment of quality in situ before erection of large machines, including the efficacy of strengthening measures suggested in some specific cases.

Judicious use was made of commercially available ultrasonic equipment such as the Ultrasonic Materials Tester (UCT) developed in UK with transducers of frequencies ranging from 60 to 150 kHz and the Soniscope developed in Canada with transducers of 20 kHz, keeping in view the purpose of test and thickness of concrete to be probed. However, the Soniscope was the more commonly used because of

*Pages 7–16 of MCR 110.

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TABLE I: Pulse velocity criteria for the quality of concrete having a design compressive strength of 30 N/mm² cast under Indian conditions.

Pulse velocity (km/s)	In situ quality of concrete
1. 4.0 and above	Very good
2. 3.5 to 4.0	Good
3. 3.0 to 3.5	Medium
4. 3.0 and below	Poor

its low frequency and better probing capability. In the initial stages, pulse velocity criteria, as suggested by Mr Tomsett, were used to assess the quality of concrete at each point on a 300 × 300 mm grid marked on the opposite faces of the concrete structure under test. The criteria given in Table I were broadly adopted for assessing quality of concrete in foundations having a design compressive strength of 30 N/mm² cast under Indian conditions.

Zones of low pulse velocity (3.5 km/s and below) corresponding to Medium and Poor quality of concrete were demarcated and strengthening measures such as cement or epoxy grouting were suggested for them. A velocity survey conducted after such measures found an increase in the velocity of about 25 to 30%, indicating an improvement in the quality of concrete almost to the accepted level. Thus ultrasonic

pulse velocity measurement was found to be extremely useful for assessing the quality of concrete in a very short time and is the only technique presently available for such tests in situ, as Mr Tomsett has also rightly emphasized.

With the experience of testing a large number of concrete foundations, it was observed later that, in some cases, even though observed pulse velocities may correspond to Good to Very Good quality of concrete (velocity above 3.5 km/s), ultrasonic energy is absorbed considerably, owing to the presence of limited internal inhomogeneities in the form of honeycombing, small flaws etc. through which ultrasonic waves having wavelengths larger than the size of flaw do pass, but with diminished intensity. An acceptable velocity accompanied by high absorption indicates that the size or extent of the flaw is very limited; it has not changed the velocity substantially, but has only affected energy of transmission considerably by reflection and scattering of ultrasonic waves.

The use of still lower-frequency ultrasonic waves may result in higher transmission but without indication of such limited flaws – a fact which requires judicious selection of the correct ultrasonic frequency. Normally very high electronic gain (amplification) is required to obtain a readable transmitted pulse on the Soniscope screen through such inhomogeneities (flaws).

Figure 1: Pulse velocities with absorption of ultrasonic energy in portions of columns of turbogenerator foundations of a 210 MW set, Parli Thermal Power Station, Maharashtra (India). Measurement grid 300 mm square, figures at grid points are compressive wave velocities (km/s). P, VP = Poor, Very Poor reception of waves.

Figure II: Pulse velocities showing improved reception of ultrasonic energy after epoxy grouting at the same portions of columns as shown in Figure I. G, VG = Good, Very Good reception of waves. NP = reading not possible at grid points.

Such a situation, viz. acceptable velocities accompanied by high absorption of ultrasonic energy designated qualitatively as Poor (P) or Very Poor (VP), is shown in Figure I for some portions of columns of a frame-type turbogenerator foundation of a 210 MW set. Portions of concrete showing high absorption were recommended for strengthening measures which were subsequently carried out by epoxy grouting and it was reported that a sufficient amount of grout was satisfactorily accepted by such portions. Ultrasonic measurements repeated after epoxy treatment revealed that, with the pulse velocities almost of the same order as before grouting, reception of ultrasonic waves improved considerably, as shown in Figure II. Thus, in addition to estimation of pulse velocities, the relative amount of transmitted energy must be taken into account for the estimation of the quality of concrete in situ⁽²⁾.

Further, attempts were made to establish correlation between pulse velocity and compressive strength from large numbers of velocity data on various concrete foundations having design compressive strengths in the working range 15 to 30 N/mm². It is well known that pulse velocity depends upon many factors such as age, mix, water/cement ratio, type of aggregate etc. Nevertheless, experience gained up till now has shown that ultrasonic pulse transmission technique could be used with considerable reliability for quick estimation of quality of concrete in situ and provides a broad correlation

between pulse velocity and design compressive strength, as shown in Figure III. This correlation could be useful in predicting the order of compressive strength of concrete based on estimated pulse velocities with an accuracy adequate for engineering purposes.

As Mr Tomsett mentions, apart from the correlation between pulse velocity and compressive

Figure III: Variation of pulse velocity with design compressive strength of concrete.

strength, ultrasonic pulse velocity measurement on its own can be satisfactorily used for assessing the quality of concrete of a structure. But the measurement of pulse velocity should also be accompanied by assessment of transmission characteristics of the ultrasonic waves (amplitude of received pulse) for proper evaluation of quality of concrete in situ. In addition, small flaws which are situated at some depth in concrete can only be effectively tackled by simultaneous

measurements of velocity and transmitted energy as suggested above. Perhaps probing concrete with a broad spectrum of ultrasonic waves using probes of different frequencies (20 to 100 kHz) may be suggested as an exhaustive method for the estimation of flaws of various sizes located inside thick beams and columns, instead of just using a single frequency as per present practice.

Reply by the author

I am most grateful to Dr Guha and Mr Wedpathak for their comments on my paper.

Almost invariably I use the standard 54 kHz transducers supplied with the Pundit apparatus. I have found that the exponential receiving transducer is of great assistance in obtaining readings in locations where surface contact presents a problem, although even in such situations I use the 54 kHz transducer as transmitter.

The principle of using the additional parameter of wave attenuation to give further information about defects in the concrete is a very interesting technique and, I am sure, most effective. My sole reservation in

accepting it for general use would be the slowing down of the data-gathering process and the necessarily larger piece of apparatus which would be required. The instrument I use is about $200 \times 200 \times 150$ mm and is easily carried up and down ladders and into situations of difficult access. Readings may be taken at the rate of over 100 per hour under suitable circumstances. If required, an add-on cathode-ray oscilloscope unit is available for the Pundit and it may well be that a secondary inspection of suspect areas using attenuation measurements would provide additional information of considerable value.

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