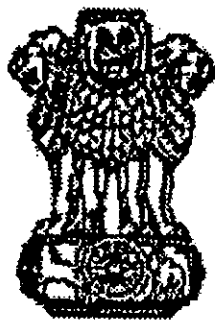


65

C - 1379



सत्यमेव जयते

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS



**GUIDELINES ON USE OF ULTRASONIC INSTRUMENT FOR MONITORING OF
CONCRETE STRUCTURES.**

**BS - 53
(Provisional)**

April, 2003

**RESEARCH DESIGNS & STANDARDS ORGANISATION
MANAK NAGAR, LUCKNOW. 226011**

INDEX

S.N.	Description	Page no.
1.	Introduction	1
2.	Objectives	2
3.	Main features of Ultrasonic Instruments	2
4.	Principle	3
5.	General Applications	3
6.	Methodology	4
7.	Determination of pulse velocity	7
8.	Interpretation of results	7
9.	Factors influencing pulse velocity measurements	8
10.	Other uses of Ultrasonic instrument	10
11.	Combination of methods	12
12.	Limitations	12
13.	Conclusions	13
14.	Sources	13
15.	References	14

GUIDELINES ON USE OF ULTRASONIC INSTRUMENT FOR MONITORING OF CONCRETE STRUCTURES

1. INTRODUCTION

1.1 Concrete structures are becoming more and more common in construction of various types of structures including bridge constructions. Concrete is a heterogeneous material. The strength of concrete structures depend upon many factors such as amount of cement, type of aggregates, water cement ratio, temperature, humidity, curing, environmental condition etc. Beside this, the control exercised during construction also contributes a lot to achieve the desired quality. Conventional method of cube testing to assess strength of concrete can not be considered to be the representative strength as cube testing results do not represent actual strength of structure due to differential treatment of cubes vis a vis actual structure as a whole. Methods such as load testing and core testing for assessing the actual compressive strength of hardened concrete are relatively cumbersome, time consuming and difficult to perform. Sometimes, it requires repair to structure due to minor damage suffered during testing in some cases.

1.2 It is often worthwhile to perform Non-Destructive Testing(NDT) techniques as compared to other methods involving greater expense, preparation or damage. An NDT survey is relatively quick, easy to use, cheap and give a general indication of the required property of the concrete. This approach will enable us to find suspected zones, thereby reducing the time and cost of examining a large mass of concrete. The choice of a particular NDT method depends upon the property of concrete to be observed such as strength, corrosion, crack monitoring etc including the limitations of the test method. The subsequent testing of structure will largely depend upon the results of preliminary testing done with the appropriate NDT technique.

1.3 NDT techniques not only provide fair idea about the relative strength and overall quality of concrete in structure but also help in deciding whether more rigorous tests like load testing, core drilling etc. at selected location are required or not. The objective of a non-destructive test is to obtain an estimate of the required property of material by measuring certain parameters which are empirically related to its strength.

1.4 Variety of NDT equipments have been developed and are available for investigation and evaluation of different parameters related to the strength, durability and overall quality of concrete. Ultrasonic Pulse Velocity measurement, rebound hammer, Windsor probe, Pull-Off Tester etc. are some of them.

1.5 Ultrasonic pulse velocity test determines the velocity of a ultrasonic pulse through a concrete member which can be related with quality of concrete. It is based on the principle that denser the material, more will be the velocity of the ultrasonic pulse passing through it. Furthermore, denser the material, more will be its strength. As such, by measuring the ultrasonic pulse velocity in any structure, its strength can be predicted to certain extent. The method is already standardized and covered by various codes such as BS-1881



Part 203, ASTM-C597, NF P18 - 418, UNI 7997 - 9524, IS-13311 (Part 1)-1992, etc.

RDSO has also procured Tico-Ultrasonic Instrument manufactured and supplied by M/s Proceq, SA, Zurich, Switzerland. These guidelines are based on study, tests and trials conducted with the help of this equipment.

2.0 OBJECTIVE

2.1 The guidelines contained in this report will provide an understanding about use of Ultrasonic Instrument for condition assessment of concrete in PSC/RCC structures.

3.0 MAIN FEATURES OF ULTRASONIC INSTRUMENT

3.1 Ultrasonic Instrument is a handy, battery operated and portable instrument used for assessing elastic properties of concrete quality. The recorded data is displayed on graphic LCD screen. The instrument can store large number of measured value in its non-volatile memory.

Now-a-days instruments are available in which the stored data can be down loaded to Personal Computer for further analysis using RS 232-C interface and integrated software loaded on it. Variety of Ultrasonic Concrete Instruments are available in the market. An ultrasonic instrument normally consists of Ultrasonic pulse generator, One pair of Transducers, Amplifier, Electronic Timing device, Connecting cables, etc. The equipment procured by RDSO has following features:-



- a) Display Unit with 128x128 graphic LCD for display.
- b) Memory:- The equipment is having non-volatile memory for storing about 250 measured values.
- c) Transducer:- The nominal working frequency for normal concrete should lie between 24 to 150 kHz. The standard tester uses frequency of 54 kHz.
 - Measuring range : approx. 15 to 6550 μ s
 - Resolution: 0.1 μ s
 - Voltage pulse: 1 kV
 - Pulse rate : 3/s
 - Impedance at input: 1 Mega Ω
- d) Transit Time:- The apparatus is capable of measuring transit time to an accuracy of within ± 10 % over a range of 20 micro second to one millisecond to ensure that transit time are measured correctly.
- e) Pulse Transmitter:- The pulse generator causes the transmitting transducer to be shock excited by a peak voltage of 1000 volts. Pulses are generated at frequency of either 10 or 3 operating for 1.5 microseconds.



- f) Calibration Rod:- Ultrasonic Instrument should have a system for checking the accuracy of pulse transit time measurement either by internal or external reliable electronic device. This is ensured by using a standard calibration rod supplied by the supplier on which the transit time is marked with an accuracy of ± 0.2 micro second.
- g) Operating Temperature :-The pulse velocity meter should maintain its performance over the range of an ambient temperature (up to 60°C).
- h) PC Compatibility:-Instrument is provided with RS 232-C interface & Integrated software for transmission of the measured value to PC for further analysis.
- j) Other accessories such as batteries , connecting cables, carrying strap, and carrying case

4.0 PRINCIPLE

4.1 The underlying principal of assessing the quality of concrete using this instrument is that comparatively higher velocities of pulses are obtained when the quality of concrete is good in terms of density, homogeneity and uniformity. Lower velocities are obtained incase of poorer quality of concrete.

4.2 Ultrasonic frequency pulse is used to give sharp leading edge and to generate maximum energy in the direction of its propagation. It is generated by an electro-acoustical transducer. When it is induced in to the concrete, it undergoes multiple phases within the concrete. A Complex system of stress waves is developed which include longitudinal (compressional), shear (transverse) and surface waves. The receiving transducer detects the onset of the longitudinal waves, which are the fastest. The velocity of the pulse is independent of the geometry of the material through which it passes, but depends upon the materials and mix proportions of concrete. Density and modulus of elasticity of aggregate also significantly affect the pulse velocity.

4.3 If there is crack, void or flaw inside the concrete which comes in the way of transmission of pulse, the pulse strength is attenuated and it has to traverse around the discontinuity, there by making its path length longer which in-turn increase the transit time, consequently, lower velocities are obtained.

5.0 GENERAL APPLICATIONS

5.1 Ultrasonic instrument can be used for many applications as explained below :

- a) Determination of concrete uniformity: This can be most reliably achieved by taking measurements on a regular grid on a member, or at comparable locations on similar members.
- b) Detection of cracking and honeycombing: Honeycombing or voids may be identified by taking a series of measurements through a member on a regular grid.. The minimum size of detectable defect depends upon the transducer size and the distance between them. Cracking and honeycombing will increase the effective

path length of pulse resulting in a higher measured transit time. If such defects lie between the transducers, a higher measured transit time will not necessarily occur if the crack or voids are water filled or bridged by reinforcement.

- c) In situ strength estimations: It can be estimated with confidence if calibration charts for the concrete are specifically prepared. It may be possible to improve this value if the density is known, or by combination of this test with measured rebound numbers.
- d) Strength development monitoring: This is possible with appropriate calibration charts for the given concrete. In this case results can be compared with predetermined limits for acceptance. This method may be used for quality control, formwork removal, stressing operations, etc.
- e) Assessment of concrete deterioration: Pulse velocity testing can be used as a general comparative survey to locate the suspected areas. Techniques are also available to estimate the depth of surface fire damage or chemical attack. Long term performance of concrete may also be monitored by conducting repetitive tests at selected locations.
- f) Estimation of layer thickness: This may be possible where a surface layer of inferior quality which may be due to weathering or other damages, existing in the body of concrete.

6.0 METHODOLOGY

6.1 Initial Investigations - Visual inspection is the first step in any investigation. Its aim is to get first indication of what is wrong and how extensive the damage is. The main equipment is obviously the human eye and brain, aided with a note book, proforma or and a camera. A close inspection is better if access can be arranged. Systematic visual survey should be planned in advance. It should start as a casual "Look over" that spots a problem and critical locations for subsequent surveys. Old records regarding problems, if any, should also be gone through. Every effort is made to identify proper locations for subsequent detailed investigations. Based on information collected by visual inspection, further course of action is decided which may include proper selection & use of suitable NDT equipments.

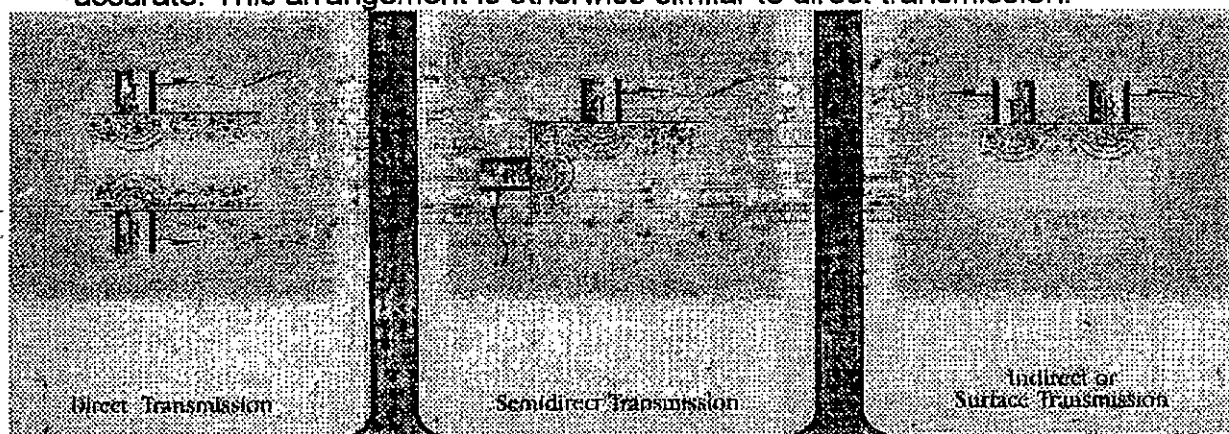
6.2 For proper and effective use of equipment, it is essential that the person carrying out tests should be conversant and have proper knowledge of operational procedure of the equipment.

6.3 The equipment should be calibrated before starting the observation and at the end of test to ensure accuracy of the measurement and performance of the equipment. It is done by measuring transit time on a standard calibration rod supplied along with the equipment.

6.4 A platform of suitable height should be made to have an access of the measuring locations. The locations of measurement should be marked and numbered with chalk or similar thing prior to actual measurement (pre decided locations). The same is also recorded in note book .

6.5 Mounting of Transducers The direction in which the maximum energy is propagated is normally at right angles to the face of the transmitting transducer, it is also possible to detect pulses which have traveled through the concrete in some other direction. The receiving transducer detects the arrival of component of the pulse which arrives earliest. This is generally the leading edge of the longitudinal vibration. It is possible, therefore, to make measurements of pulse velocity by placing the two transducers in the following manners:

- a) Direct Transmission (on opposite faces) This arrangement is the most preferred arrangement in which transducers are kept directly opposite to each other on opposite faces of the concrete. The transfer of energy between transducers is maximum in this arrangement. The accuracy of velocity determination is governed by the accuracy of the path length measurement. Utmost care should be taken for accurate measurement for the same. The couplant used should be spread as thinly as possible to avoid any end effects resulting from the different velocities of pulse in couplant and concrete.
- b) Semi-Direct Transmission This arrangement is used when it is not possible to have Direct Transmission (may be due to limited access). It is less sensitive as compared to direct transmission arrangement. There may be some reduction in the accuracy of path-length measurement. Still it is found to be sufficiently accurate. This arrangement is otherwise similar to direct transmission.



- c) Indirect or Surface Transmission: Indirect Transmission should be used when only one face of the concrete is accessible (when other two arrangements are not possible). It is the least sensitive out of the three arrangements. For a given path length, the receiving transducer get signal of only about 2% or 3% of amplitude that produced by direct transmission. Furthermore, this arrangement gives pulse velocity measurements which are usually influenced by the surface concrete which is often having different composition from that below surface concrete. Therefore, the test results may not be correct representative of whole mass concrete. The indirect velocity is invariably lower than the direct velocity on the same concrete element. This difference may vary from 5% to 20% depending on the quality of the concrete. Wherever practicable, site measurements should be made to determine this difference.

6.6 There should be adequate acoustical coupling between concrete and the face of each transducer to ensure that the ultrasonic pulses generated at the transmitting transducer should be able to pass into the concrete and detected by the receiving transducer with minimum losses. It is important to ensure that the layer of smoothing

medium should be as thin as possible. Couplant like petroleum jelly, grease, soft soap and kaolin/glycerol paste are used as a coupling medium between transducer and concrete.

6.7 Special transducers have been developed which impart or pick up the pulse through integral probes having 6 mm diameter tips. A receiving transducer with a hemispherical tip has been found to be very successful. Other transducer configurations have also been developed to deal with special circumstances. It should be noted that a zero adjustment will almost certainly be required when special transducers are used.

6.8 Most of the concrete surfaces are sufficiently smooth. Uneven or rough surfaces, should be smoothened using carborandom stone before placing of transducers. Alternatively, a smoothing medium such as quick setting epoxy resin or plaster can also be used, but good adhesion between concrete surface and smoothing medium has to be ensured so that the pulse is propagated with minimum losses into the concrete.

6.9 Transducer are then pressed against the concrete surface and held manually (the mounting of sensors is explained in subsequent paras) . It is important that only a very thin layer of coupling medium separates the surface of the concrete from its contacting transducer. The distance between the measuring points should be accurately measured

6.10 Repeated readings of the transit time should be observed until a minimum value is obtained .

6.11 Once the ultrasonic pulse impinges on the surface of the material, the maximum energy is propagated at right angle to the face of the transmitting transducers and best results are, therefore, obtained when the receiving transducer is placed on the opposite face of the concrete member known as Direct Transmission.

6.12 The pulse velocity can be measured by Direct Transmission, Semi-Direct Transmission & Indirect or Surface Transmission. Normally, Direct Transmission is preferred being more reliable and standardized. (various codes gives correlation between concrete quality and pulse velocity for Direct Transmission only) . The size of aggregates influences the pulse velocity measurement. The minimum path length should be 100 mm for concrete in which the nominal maximum size of aggregate is 20 mm or less and 150 mm for aggregate size between 20 mm and 40 mm.

6.13 Reinforcement, if present, should be avoided during pulse velocity measurements, because the pulse velocity in the reinforcing bars is usually higher than in plain concrete. This is because the pulse velocity in steel is 1.2 to 1.9 times of that in concrete. In certain conditions, the first pulse to arrive at the receiving transducer travels partly in concrete and partly in steel. The apparent increases in pulse velocity depends upon the proximity of the measurements to the reinforcing bars, the diameter and number of bars and their orientation with respect to the path of propagation. It is reported that the influence of reinforcement is generally small if the bar runs in the direction right angle to the pulse path for diameter of the bar is less than 12 mm. But if percentage of a steel is quite high; or the axis of the bars are parallel to direction of propagation; then the correction factor has to be applied to the measured values.

7.0 DETERMINATION OF PULSE VELOCITY

7.1 A pulse of longitudinal vibration is produced by an electro-acoustical transducer, which is held in contact with one surface of the concrete member under test. After traversing a known path length (L) in the concrete, the pulse of vibration is converted in to an electrical signal by a second electro-acoustical transducer, and electronic timing circuit enable the transit time (T) of the pulse to be measured. The pulse velocity is given by

$$V=L/T$$

Where,

V= Pulse velocity

L= Path length

T= Time taken by the pulse to traverse the path length.

8.0 INTERPRETATION OF RESULTS

8.1 The ultrasonic pulse velocity of concrete can be related to its density and modulus of elasticity. It depends upon the materials and mix proportions used in making concrete as well as the method of placing compaction and curing of concrete. If the concrete is not compacted thoroughly & having segregation, cracks or flaws, the pulse velocity will be lower as compare to good concrete, although the same materials and mix proportions are used. The quality of concrete in terms of uniformity, can be assessed using the guidelines given in table below.

Table: Criterion for Concrete Quality Grading.
(For Direct Transmission)

S No	Pulse velocity in km/sec	Concrete quality grading
1	Above 4.5	Excellent
2	3.5 to 4.5	good
3	3.0 to 3.5	Medium
4	Below 3.0	Doubtful*

AS per IS 13311 (Part I) :1992

*Note - in case of doubtful quality, it will be desirable to carry out more tests.

8.2 Since actual values of the pulse velocity in concrete depends on a number of parameters, so criterion for assessing the quality of concrete on the basis of pulse velocity is valid to the general extent. However, when tests are conducted on different parts of the structure, which have been built at the same time with similar materials; construction practices & supervision and subsequently compared, the assessment of quality becomes more meaningful and reliable.

8.3 The quality of concrete is usually specified in terms of strength and it is, therefore, sometimes helpful to use ultrasonic pulse velocity measurements to give an estimate of strength. The relationship between ultrasonic pulse velocity and strength is affected by a number of factor including age, curing conditions, moisture condition, mix proportions, type of aggregate and type of cement.

8.4 The assessment of compressive strength of concrete from ultrasonic pulse velocity values is not accurate because the correlation between ultrasonic pulse velocity and compressive strength of concrete is not very clear. Because there are large number of parameters involved, which influence the pulse velocity and compressive strength of concrete to different extents. However, if details of material and mix proportions adopted in the particular structure are available, then estimate of concrete strength can be made by establishing suitable correlation between the pulse velocity and the compressive strength of concrete specimens made with such material and mix proportions, under environmental conditions similar to that in the structure. The estimated strength may vary from the actual strength by ± 20 per cent. The correlation so obtained may not be applicable for concrete of another grade or made with different types of material.

9.0 FACTORS INFLUENCING PULSE VELOCITY MEASUREMENTS

The pulse velocity depends on the properties of the concrete under test. Various factors which can influence pulse velocity and its correlation with various physical properties of the concrete are as under:

9.1 Moisture Content : The moisture content has chemical and physical effects on the pulse velocity. These effects are important to establish the correlation for the estimation of concrete strength. There may be a significant difference in pulse velocity between a properly cured standard cube and a structural element made from the same concrete. This difference is due to the effect of different curing conditions and presence of free water in the voids. It is important that these effects are carefully considered when estimating strength.

9.2 Temperature of Concrete: No significant changes in pulse velocity in strength or elastic properties occur due to variations of the concrete temperature between 10°C and 30°C have been found. Corrections to pulse velocity measurements should be made for temperatures outside this range, as given in table below:

Table - Effect of temperature on pulse transmission

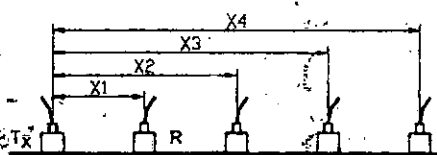
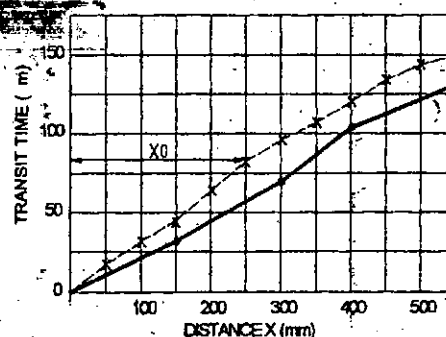
Temperature $^{\circ}\text{C}$	Correction to the measured pulse velocity in %	
	Air dried concrete	Water saturated concrete
60	+5	+4
40	+2	+1.7
20	0	0

0	-0.5	-1
-4	-1.5	-7.5

Figures taken from BS 1881 (Pt 203 Year 1986)

9.3 Path Length: The path length (the distance between two transducers) should be long enough not to be significantly influenced by the heterogeneous nature of the concrete. It is recommended that the minimum path length should be 100 mm for concrete with 20 mm or less nominal maximum size of aggregate and 150 mm for concrete with 20 mm and 40 mm nominal maximum size of aggregate. The pulse velocity is not generally influenced by changes in path length, although the electronic timing apparatus may indicate a tendency for slight reduction in velocity with increased path length. This is because the higher frequency components of the pulse are attenuated more than the lower frequency components and the shapes of the onset of the pulses becomes more rounded with increased distance traveled. This apparent reduction in velocity is usually small and well within the tolerance of time measurement accuracy.

9.3.1 With indirect transmission, there is some uncertainty regarding the exact length of the transmission path. It is, therefore, preferable to make a series of measurements with placing transducers at varying distances to eliminate this uncertainty. To do this, the transmitting transducer should be placed in contact with the concrete surface at a fixed point 'X' and the receiving transducer should be moved at fixed increments 'X_n' along a chosen line on the surface. The transmission times recorded should be plotted as points on a graph showing their relation to the distance separating the transducers.



9.3.2 The slope of the best fitted straight line drawn through the points should be measured and recorded as the mean pulse velocity along the chosen line on the concrete surface. Where the points measured and recorded in this way indicate a discontinuity, it is likely that a surface crack or surface layer of inferior quality is present and the pulse velocity measured in such case is unreliable.

9.4 Shape and Size of Specimen: The velocity of pulses of vibrations is independent of the size and shape of specimen, unless its least lateral dimension is less than a certain minimum value. Below this value, the pulse velocity may be reduced appreciably. The extent of this reduction depends mainly on the ratio of the wavelength of the pulse vibrations to the least lateral dimension of the specimen but it is insignificant if the ratio is less than unity; Table given below shows the relationship between the pulse velocity in the concrete, the transducer frequency and the minimum permissible lateral dimension of the specimen.

Table : Effect of specimen dimension on pulse transmission

Transducer Frequency in kHz	Minimum lateral dimension of specimen in mm for Pulse velocity in concrete in (km/s)		
	$V_c = 3.5$	$V_c = 4.0$	$V_c = 4.5$
24	146	167	188
54	65	74	83
82	43	49	55
150	23	27	30

(Figures taken from BS 1881 (Pt 203 Year 1986)

9.4.1 This is particularly important in cases where concrete elements of significantly different size are being compared.

9.5 Effect Of Reinforcing Bars: The pulse velocity in reinforced concrete in vicinity of rebars is usually higher than in plain concrete of the same composition because the pulse velocity in steel is almost twice to that in plain concrete. The apparent increase depends upon the proximity of measurement to rebars, their numbers, diameter and their orientation. Whenever possible, measurement should be made in such a way that steel does not lie in or closed to the direct path between the transducers. If the same is not possible , necessary corrections needs to be applied. The correction factors for this purpose are enumerated in different codes.

10.0 OTHER USES OF ULTRASONIC INSTRUMENTS

10.1 Determination Of Concrete Uniformity Heterogeneities in the concrete cause variation in pulse velocity which, in turn, are related to variation in quality. Measurements of pulse velocity provide means of studying the homogeneity and ,for this purpose, a system of measuring points which covers uniformly the appropriate volume of concrete in the structure has to be chosen. The number of individual test points depends upon the size of the structure , the accuracy required and the variability of the concrete .

10.1.1 In a large unit of fairly uniform concrete, testing of 1m grid is usually adequate but, on small units or variable concrete a finer grid may be necessary. It should be noted that, in cases where the path length is same throughout the survey, the measured time should be considered to assess the concrete uniformity without converting it into velocity. This technique is particularly suitable for surveys where all the measurements are made by In-direct transmission.

10.1.2 It is possible to express homogeneity in the form of a statistical parameter such as the standard deviation or coefficient of variation of the pulse velocity measurements made over the grid. However, such parameters can only be properly used to compare variations in concrete units of broadly similar dimensions.

10.1.3 Variations in pulse velocity are influenced by magnitude of the path length because this determines the effective area of concrete sample during each measurements. The variations should be considered in relation to the effect which can be expected on the required performance of the structural member being tested. This generally means that the tolerance allowed for quality distribution within members should be related either to the stress distribution within them under critical working load conditions or to exposure conditions.

10.2 **Detecting Large Voids Or Cavities** A grid should be drawn on the concrete member approximately of the size of cavity. A survey of measurement at the grid points enables a large cavity to be investigated by measuring the transit times of pulses passing between the transducers when they are placed so that the cavity lies in the direct path between them. The size of such cavities may be estimated by assuming that the pulses pass along the shortest path between the transducers and around the cavity. Such estimates are valid only when the concrete around the cavity is uniformly dense and the pulse velocity can be measured in that concrete.

10.3 **Detection Of Defects** The use of the ultrasonic pulse velocity technique to detect and define the extent of internal defects should be restricted to well qualified personnel with previous experience in the interpretation of survey results. It is important that ultrasonic pulse velocity measurements are made and interpreted by persons with experience and training in the technique. Attention is drawn to the potential risk of drawing conclusions from single result. When an ultrasonic pulse traveling through concrete meets a concrete-air interface, there is negligible transmission of energy across the surface. Thus, any air-filled crack or void lying immediately between two transducers will obstruct the direct ultrasonic beam when the projected length of the void is greater than the width of the transducers. When this happens, the first pulse to arrive at the receiving transducer will have been diffracted around the periphery of the defect and the transit time will be longer than a similar concrete with no defect.

10.3.1 It is possible to make use of this effect for locating flaws, voids or other defects more than the width of the transducers. Relatively small defects have little or no effect on transmission times and are of minor engineering importance. Plotting contours of equal velocity often gives significant information regarding the quality of a concrete unit.

10.3.2 In cracked members, where a broken faces of the members are held tightly together in close contact with compression forces, the pulse energy may pass unimpeded across the crack. As an example, this may occur in cracked vertical piles. If the crack is filled with liquid which transmits the ultrasonic energy, e.g. in marine structures, the crack is undetectable using digital reading equipment. Measurements of attenuation may give valuable information in these cases.

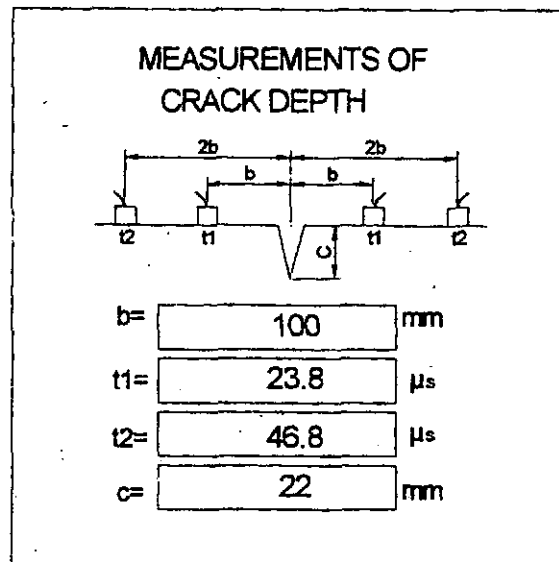


10.4 **Estimation of The Thickness of Inferior Quality Concrete Layer** Ultrasonic instrument can be used to estimate thickness of suspected poor quality of Concrete layer. Poor quality layer may occur during manufacture or arise as a result of damage by sulphate attack, fire, frost, poor quality control etc. The thickness of such a layer of

concrete can be estimated from ultrasonic measurements of transit times along the surface. If the distance between transducers is small, the pulse travels through the surface layer of concrete. Beyond a certain distance between transducers, the first pulse received has passed along the surface of the underlying higher/poor quality concrete. The slope of these experimental points gives the velocity in that concrete. Localized areas of damaged or honeycombed concrete are more difficult to test but it is possible to derive an approximate thickness of such localized poor quality material if both direct transmission and surface propagation measurements are made.

10.5 Estimation Of Crack Depth

An estimate of the depth of a crack visible at the surface may be obtained by measuring the transit times across the crack for two different arrangements of the transducers placed on the surface. One suitable arrangement is shown in fig. in which the transmitting and receiving transducers are placed at a distance "b" and "2 b" on opposite sides of the crack. Transit times corresponding to these locations are measured. The analyses of this data by inbuilt software gives directly the depth of the crack. The depth may not be accurate due to number of assumptions taken into account for arriving at the results.



11.0 COMBINATION OF METHODS

11.1 The accuracy achieved can be improved by using the combination of two or more test methods. The use of rebound hammer and ultrasonic pulse velocity may be the most appropriate combination for near-to-surface testing. In other circumstances it may be necessary to combine one or the other of these methods. The patterns of results obtained should be compared directly, and results should not be converted to some other property before comparison. Confidence will be gained if similar patterns emerge. In situations where the volume of concrete is relatively small, and where a specific property, e.g. strength, is of primary interest, it may be worthwhile to compare two or more estimates of that property using different methods. Surface probing in general gives lower pulse velocity than in case of cross probing and depending on number of parameters, the difference could be of the order of about 1 km/sec.

12.0 LIMITATIONS

Ultrasonic pulse velocity method has following limitations:

- i) The pulse velocities for most practical concrete mixes lie within a narrow range and it is therefore necessary to measure both the transit time and path length to an accuracy of the order of $\pm 1\%$ if the results are to be of greatest value.
- ii) Measured values may be affected by surface texture, moisture content, temperature, specimen size, reinforcement and stress.

- iii) Correlations with strength are difficult to make and will be influenced considerably by the types and proportions of mix constituents and maturity.
- iv) For comparative surveys, readings may be made with both transducer placed on the same surface but when it is necessary to measure pulse velocity accurately, e.g. for strength estimation, it will be necessary to place the transducers on opposite faces of the concrete element.

13.0 CONCLUSION

13.1 Ultrasonic instrument provide an excellent means for establishing uniformity of concrete and thereby quality control operations. It can measure the internal flaws as well as surface and internal cracks in the concrete. The equipment should be handled by an experienced engineer and the analysis and interpretation of test data should be carried out by a specialist in the field of concrete technology and concrete structures otherwise results may be misleading.

13.2 With the fast changing technology, advancement in the field of software and electronics, more and more varieties of NDT equipments including ultrasonic instruments are available with latest features. Detailed market survey is essential before going for actual procurement of equipment.

The use of Non-Destructive Testing (NDT) Equipment of bridges is still at a primitive stage in India. But it is the time to make beginning. Therefore, Monitoring of some of the bridges using these can be adopted as a trial, to pave way for future.

14.0 SOURCES

14.1 Now-a-days, number of firms are manufacturing these equipments. The equipment is yet to be Indianised and hence needs to be imported. Some of the Indian firms are working as Indian agents to its manufacturers. The addresses of the some of the firms dealing with supplying of ultrasonic instruments are as under:

SN	Address of firm
i)	M/s James Instruments Luc. 3727 North Aedzie Averic, Chicago, ILLINOIS 60618 USA
ii)	PROSEQ USA, Rieshash Strasses, CH -8034 Zurich, Switzerland
iii)	M/s Colebrand Ltd. Colebrand house, 18-20, Warwide Street Regent Street, London SIR 6 BE, England.
iv)	Koelectic Ltd. International House, Thane Station Industrial Estationxon, Ox92py, England.
v)	M/s Ultra Technologies Pvt. Ltd., B-85 Kalka Ji, New Delhi - 19
vi)	M/s AIMIL Ltd., A-8, Mohan Cooperative Ind. State, Mathura Road, New Delhi-110044
vii)	Controls Testing Equipments Ltd., Ickniel Way, England

15.0 REFERENCES

- i) IS 13311 (part 1) -1992.
- ii) BS 1881 (part 203) -1986.
- iii) BS 1881 (part 201) - 1986.
- iv) ASTM C 597- 1983
- v) Catalogue of Tico - Ultrasonic Concrete Tester supplied by M/s PROCEQ – SA, Zurich, Switzerland
- vi) Catalogue of Ultrasonic Concrete Tester supplied by M/s Control Testing Equipments Ltd., UK

~~RB-2~~

File No - RB/misc Vol II