September 1985

CRI TECHNOLOGY DIGEST

NON-DESTRUCTIVE TESTING OF CONCRETE

PART II

National Council for Cement and Building Materials

NON-DESTRUCTIVE TESTING OF CONCRETE
Part II*

INTRODUCTION

National Council for Cement and Building Materials (NCB) has been extending the facilities of non-destructive testing of concrete structures and judicious interpretation of results to the entire construction industry in India and in neighbouring countries. This technology digest (Part II) briefly discusses the approach NCB has adopted in tackling various problems it was called upon to handle involving non-destructive testing of concrete structures and gives substance of such case studies undertaken. The basic principles and applications of various methods have already been dealt with in Part 1.

NCB's APPROACH

NCB's approach to the non-destructive testing of concrete structures has been as follows:

a) Combination of UPV and rebound hammer methods are used for the assessment of the quality and likely compressive strength of *in-situ* concrete.

b) The quality of concrete in terms of uniformity, incidence or absence of internal flaws, cracks and segregation, etc, indicative of the level of workmanship employed, is assessed by the UPV method. Depending upon the pulse velocity measured and by using the guidelines given in Table 1, the quality of concrete is characterised in terms of 'good', 'medium' or 'poor'. These guidelines have been evolved on the basis of very large amount of data on reinforced and prestressed concrete constructions in the country, ranging from heavily reinforced turbogenerator foundations or other types of industrial structures to moderately reinforced RCC beams, slabs and columns of residential, hospital and office buildings.

c) Assessment of likely compressive strength of concrete is made from the rebound indices with the help of calibration curve of the nature shown (*see* Fig 2 Part I). Realising that the rebound indices are indicative of the strength of concrete only to a limited depth from the surface of the order of 30 mm or so, and that the rebound indices are insensitive to internal micro-cracking, flaws or heterogeneity that may or may not exist within the mass of concrete, the compressive strength of concrete

*Reprint of September 1983 issue

so obtained is taken to be indicative of the entire mass only when overall quality judged by the UPV is good. When the quality assessed is medium, the estimation of compressive strength by rebound indices is extended to the entire mass only on the basis of other colateral measurements, eg, strength of site concrete cubes, cement content in the concrete or core testing. When the quality of concrete is poor, no assessment of concrete strength is made from rebound indices.

d) In most of the situations, the records of the original materials or mix proportions used in the structure are not available. Therefore, considerable improvisation has to be done in evolving the testing scheme and use is made of comparative measurements made on adjoining portions of the structures or even other structures in the vicinity of the one in question. In doing so, an approach is taken that if the same materials and similar mix proportions and level of workmanship were employed for the two situations, any significant difference in the UPV or rebound indices between them must be due to some inherent differences in the overall quality. If the nominal grades of concrete (mix proportions) are known to be different in either case, suitable allowance is made for the same in interpretation of results.

TABLE 1 VELOCITY CRITERION FOR CONCRETE QUALITY GRADING

Sl No	Pulse Velocity* (km/sec)	Condition of Concrete
1	Above 3·5	Good
2	3·0 to 3·5	Medium
3	Below 3·0	Poor

*Cross probing (see Fig 1 of Part 1)

e) In view of the inherent variability in the test results, sufficient number of readings is taken by dividing the entire structure in suitable grid of 30 × 30 cm or even smaller. The results are analysed statistically and plotted as histograms and the lower fractiles of results are taken for assessing the quality or 'characteristic' strength of concrete, in line with current limit state concepts of design.

f) Around each grid point atleast six readings of rebound indices are taken. The rebound hammer is regularly calibrated to check its accuracy. The data obtained in a particular structure are also compared with previous data on other similar structures to arrive at the best possible estimates.

g) A structure is classified to be of satisfactory quality only when both the UPV and the rebound indices obtained are satisfactory for the type of concrete structure and the grade of concrete. When either or both of these measurements are unsatisfactory, the structure or portions of it are characterised to be of doubtful quality, where further remedial actions may be needed.

CASE STUDIES

NCB has carried out non-destructive testing in a large number of concrete structures for evaluation of characteristics of concrete related to its overall quality and/or compressive strength. Some of the case studies are highlighted below:

Assessment of Overall Quality of an RCC Raft Foundation

The RCC raft foundation of a tower structure in a fertiliser plant 5·0 x 6·6 metres in plan was investigated to assess the overall quality and likely compressive strength of concrete. By the combined use of UPV and rebound hammer methods, the compressive strength of concrete was assessed to be of the order of 100 kg/cm^2 which was much lower than M20 grade specified. The entire foundation area was categorised in terms of its overall quality and compressive strength (Fig 1). The results were further corroborated by subsequent laboratory tests on the cement and concrete samples made with the material and mix proportions adopted in the works. Suitable remedial solutions were thereafter adopted.

Detection of Cold Joints in Monolithic Construction

The RCC columns, beams and slabs of the turbo-generator foundation of a 2×110 MW thermal power plant were examined for detection of cold joints which were suspected to have taken place due to an inadvertent interruption during concreting, which was supposed to be continuous. From the relative values of UPV obtained in different locations in the structure by surface and cross-probings, presence of cold joints were detected in the foundation mat. Weak spots were identified, in addition, elsewhere in the frame structure, which are often noticed in such constructions, because of difficulties of uniform pouring and thorough compaction of concrete due to the presence of heavy reinforcements. The compressive strength of concrete in the two units were estimated to be satisfactory for the grade of concrete specified. The cold joints and other discontinuities were subsequently grouted.

Assessment of Load Carrying Capacity of an RCC Framed Structure

The ground floor columns of a three-storey building in a neighbouring

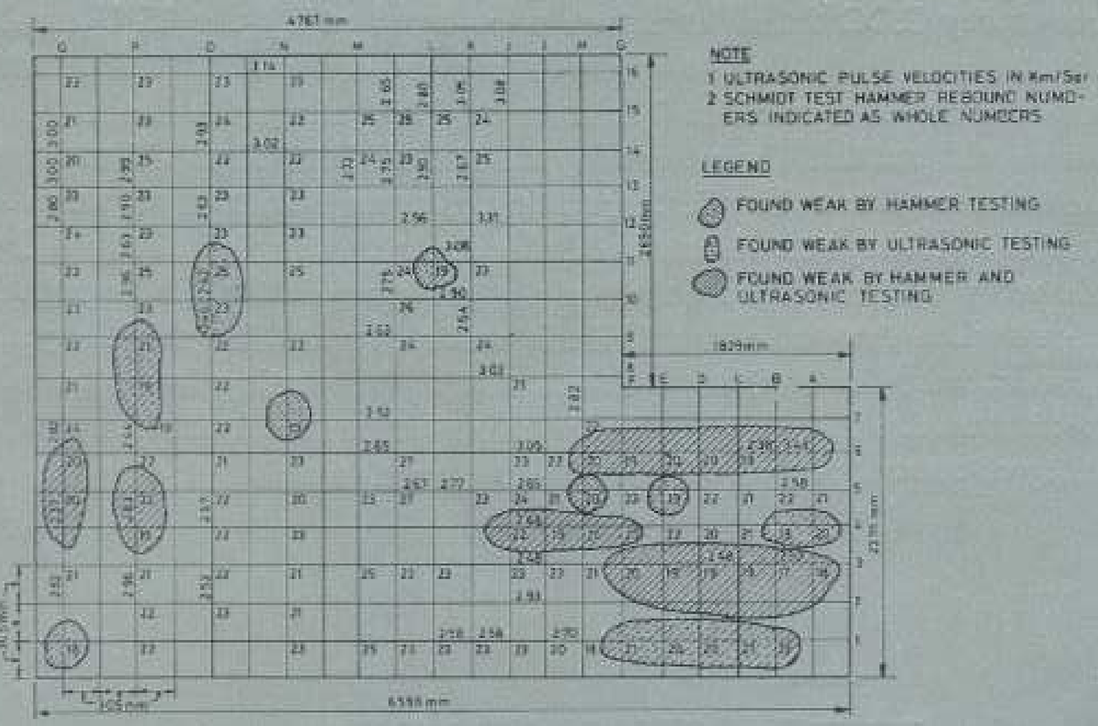

Fig 1 Assessment of overall quality of concrete in an RCC raft foundation

country were assessed for their structural adequacy to carry the loads of additional two storeys proposed to be added nearly 15 years after the original construction. Although the rebound hammer indices were satisfactory, the UPV values were found to be generally lower than those encountered for similar grades of concrete in India. The overall condition of the structure was satisfactory and no signs of distress due to load or weathering were noticed. In absence of records of the original materials (specifically aggregates), mix proportions and level of workmanship obtainable at the time of construction, comparative tests were done on the ground floor columns of an adjacent five storey block constructed to similar specifications by the same agency at the same time. A comparison of histograms of the rebound hammer indices and pulse velocity values (Fig 2) led to the conclusion that concrete in ground floor columns of both the buildings was more or less of similar quality except a few columns which were of suspect quality. Analysis of cement content in columns chosen at random from both the buildings gave comparable values. It led to the conclusion that additional two storeys can be added on the buildings after strengthening the suspected columns.

Investigations of Corrosion Damage in RCC Columns

The overall quality and uniformity of RCC beams and columns of three-storey RCC frame structure were assessed by the UPV method were the columns had developed severe corrosion cracks within a short time after its construction. Variation in UPV along the height of the columns showed that the concreting was not uniform (Fig 3). This conclusion was corroborated by further testing of cement content, *pH* value and chloride and sulphate contents of the concrete samples obtained from different portions of the columns as well as considerable segregation noticed when the outer mosaic dado was removed. The overall quality of concrete in the columns was assessed to be ranging from 'poor' to 'questionable'. Along with other possible causes, such variation in the quality of concrete may itself give rise to corrosion cells.

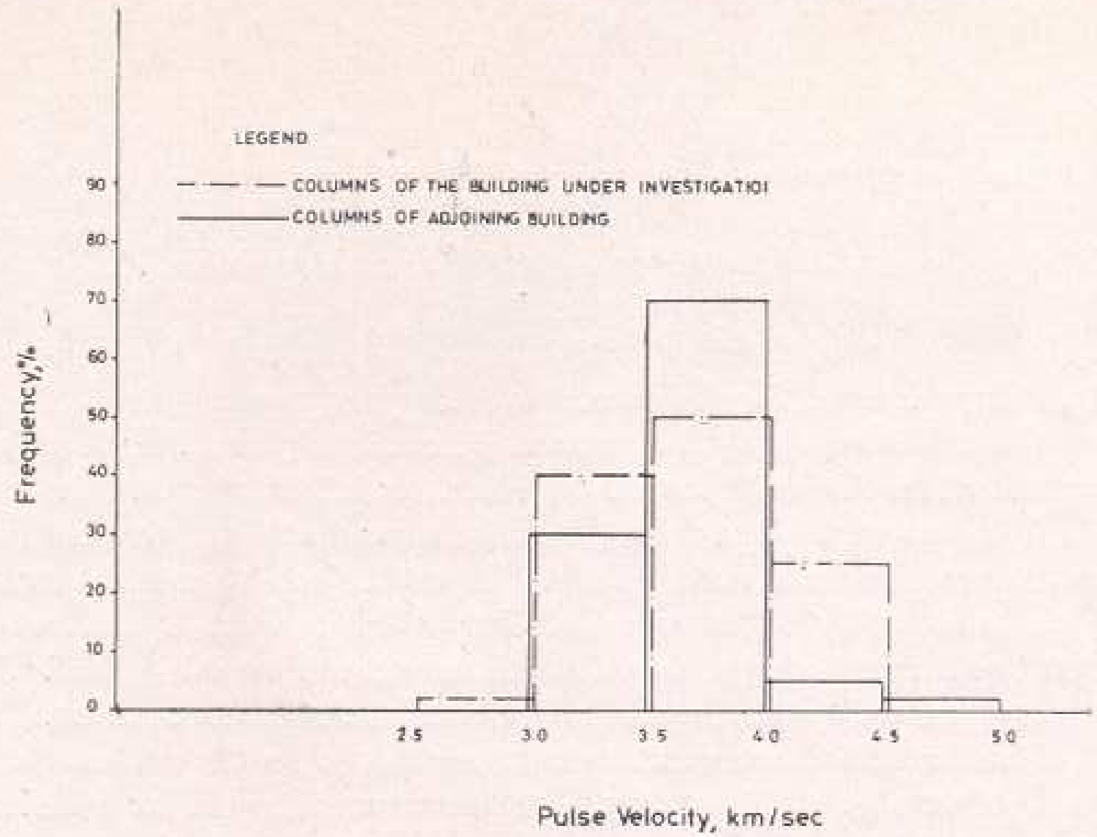

Fig 2 Comparison of pulse velocities in RCC columns

Detection of Depth of Cracks

The horton sphere foundation of a fertiliser plant was damaged during construction as a derrick fell suddenly on the pedestals. There were some visible cracks on the top surface and it was suspected that cracks had penetrated inside to various depths. The extent of damage to pedestals was investigated by UPV method. On comparison of the UPV values obtained within different portions of the affected pedestals as well as on other pedestals which were not affected, the depth of cracks could

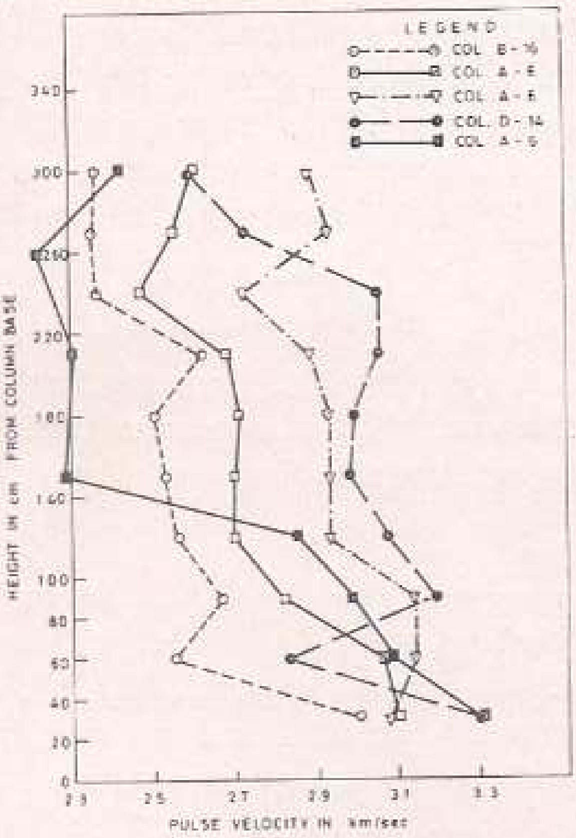

Fig 3 Variation of pulse velocity along the height of columns

be assessed as shown in Fig 4. During reconstruction of these foundations, the depth of cracks so assessed was found to be close to the actual.

Assessment of Fire Damage

In an RCC tower structure damaged due to fire while under construction, the residual compressive strength of concrete at various locations was assessed by rebound hammer method. The loss in strength was estimated by comparison with the results of control cube tests, after making necessary corrections for strengths of concrete in control cubes and in the actual structure. From the retrogression of strength so estimated, it was assessed that the maximum temperature reached during the fire was not more than 500°C, which was corroborated by further thermo-gravemetric and XRD studies on concrete samples obtained from different locations of the structure. By combined use of these methods the extent of damage due to fire could be estimated to a reliable degree and suitable repair measures were carried out. The structure has been in satisfactory service since then.

Use in Quality Control

The variation in compressive strength across the cross-section of prefabricated prestressed concrete railway sleepers was investigated by rebound hammer method. It was found that the rebound numbers (and therefore, the compressive strength) of concrete was lower at the bottom surface of the sleepers as cast than at the top, indicating that the compaction of concrete by shutter vibrators was not adequate and effective. The estimated compressive strengths of concrete were of the order of 390 kg/cm² at the bottom and 560 kg/cm² at the top. On the basis of this investigation, the choice of the vibrators as well as the scheme of their locations and mounting on the forms were revised, which along with

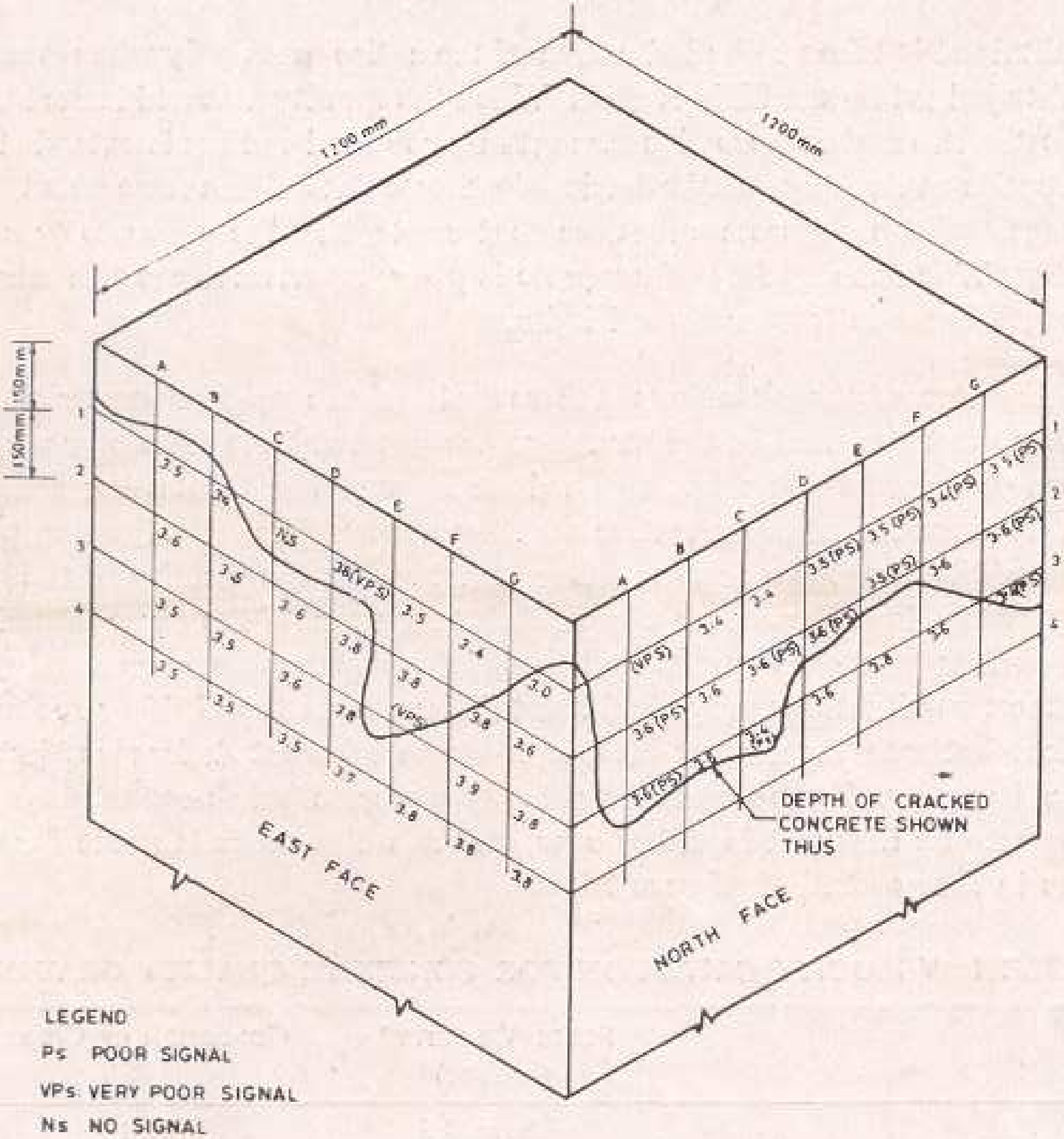

Fig 4 Depth of crack in concrete pedestal as assessed by the ultrasonic pulse velocity measurement

other measures suggested, brought down the rejection rate of the sleepers considerably.

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Published by Shri S K Khanna on behalf of National Council for Cement and Building Materials, M 10 South Extension II, New Delhi 110 049 and Printed at Indraprastha Press (CBT), Nehru House, New Delhi 110 002 **Regd. No. R.N. 40434/82**