IS 14893 (2001): Non-destructive integrity testing of piles (NDT) - Guidelines [CED 43: Soil and Foundation Engineering]

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भारतीय मानक

स्थूण्य (पाइल) की अविनाशी अखण्डता परीक्षण (एनडीटी) — मार्गनिर्देश

Indian Standard

NON-DESTRUCTIVE INTEGRITY TESTING OF PILES (NDT) — GUIDELINES

ICS 19.100, 91.080.01, 91.080.40

BUREAU OF INDIAN STANDARDS
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Soil and Foundation Engineering Sectional Committee, CED 43

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Soil and Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

For a successful pile foundation it is imperative that the piles constructed are of sound quality and of design shape and dimensions that is 'structural integrity'. The routine vertical load tests carried out on working piles do not provide direct information on structural integrity of piles. Also, in view of the very limited number of tests (0.5 to 2 percent) carried out at a particular project site, it is not possible to reliably testify structural quality of piles. However, it is also true that all the piles cannot be tested in this way because of both economic and time constraints.

It is a firm belief that *cast-in-situ* piles in majority of cases fail because of defective pile shaft necking, discontinuity of concrete, intrusion of foreign matter and improper toe formation due to contamination of concrete at base with soil particles, washing of concrete due to high water current, adoption of improper construction method, poor quality control on concreting or any other reason. Cracks developed while handling and installing precast piles can also be a cause of failure. If pile integrity can be assessed before completion of pile caps then this will go a long way to certification of pile integrity.

Over the last twenty to twenty five years Non-Destructive Integrity Testing techniques have been in use world over. Today, this is commonly acknowledged as a useful tool for the evaluation of the quality and acceptance of pile foundations. Although, this is a very economical method even for assessing the total number of piles at a site, it is limited in scope to testing the integrity of the shaft and is not intended to replace the use of static load testing.

Integrity testing is relatively simple and quick and enables number of piles to be examined in a single working day. The method does not identify all imperfections in a pile, but provides information about continuity, defects such as cracks, necking, soil incursions, changes in cross section and approximate pile lengths (unless the pile is very long or skin friction is too high).

Integrity testing result for a particular area may not be necessarily valid for another area. Detailed results in a particular area for a number of sites have to be collected and evaluated before interpretation of tests results of a new site in that area. Integrity tests provide an indication of the soundness of concrete but they should be undertaken by persons experienced in the method and capable of interpreting the results with specific regard to piling.

It is for the engineers to decide whether results of the tests point to the likelihood of defects being present of such significance as to affect materially the long term load carrying capacity of the pile. The engineer should then decide whether to carry out further examination of the pile or to take remedial action for which a sound engineering judgement is called for.

Final rejection of the pile should not be based on Integrity Testing alone and may be confirmed by static load tests and where possible examined by excavation.

The composition of the committee responsible for the formulation of this standard is given at Annex A.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

NON-DESTRUCTIVE INTEGRITY TESTING OF PILES (NDT) — GUIDELINES

1 SCOPE

This standard covers the methods on non-destructive testing of all types of concrete piles covered in IS 2911 (Part 1/Sections 1, 2, 3 and 4 and Part III). The manner in which 'Integrity Testing or Non-Destructive Testing (NDT)' is currently used in this country is outlined in this standard.

2 NORMATIVE REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards:

IS No.	*Title*
2911	Code of practice for design and construction of pile foundations:
(Part 1/Sec 1) : 1979	Concrete piles, Section 1 Driven *cast-in-situ* concrete piles (*first revision*)
(Part 1/Sec 2) : 1979	Concrete piles, Section 2 Bored *cast-in-situ* piles (*first revision*)
(Part 1/Sec 3) : 1979	Concrete piles, Section 3 Driven precast concrete piles (*first revision*)
(Part 1/Sec 4) : 1984	Concrete piles, Section 4 Bored precast concrete piles (*first revision*)
Part 3 : 1980	Under-reamed piles (*first revision*)
Part 4 : 1985	Load test on piles (*first revision*)

3 TERMINOLOGY

For the purpose of this standard the following definitions shall apply.

3.1 Integrity Testing

A method of qualitative evaluation of the physical dimensions (cross sectional variation), soundness or defects of the piles concrete with respect to its continuity.

3.2 Shaft

The material forming the pile, generally concrete.

3.3 Laitance

The materials which rise to the top of the concreted pile, consisting of cement, fines and water, having very low density.

3.4 Low Stress Wave

A low energy non-destructive wave.

3.5 Low Strain

This is defined as strain < 0.01.

3.6 Secondary Reflections

Reflections added to the primary shock wave due to imperfections in the pile shaft.

3.7 Captured Signal

A recording of the signal produced by a hammer blow and stored in the digital form by the computer.

3.8 Particle Velocity

The velocity of pile particles resulted on account of stress wave passing through the pile.

3.9 Stress Wave Velocity

The velocity of impact wave which travels down the pile.

3.10 Transducer

A device used to monitor accelerations of pile particles also known as accelerometer.

3.11 Disk/Diskette

Storage device for computer data.

3.12 Ultrasonic

Vibrations above human hearing (typically above 20 kHz).

3.13 Damping

The resistance to motion.

3.14 Sonic Emitter

A device for generating high frequency waves.

4 SITE INFORMATION REQUIRED FOR THE TESTS

The following information are generally required to carry out integrity tests:

a) Location of site;
b) Pile types including size, material and reinforcement;
c) Layout of piles;
d) Details of pile installation (including construction and driving sequence and rest periods);
e) Number of piles to be tested;
f) Subsurface profile/driving details of the piles (more if variations are noted);
g) Depth of water table and soil investigation report, if any;
h) Density of concrete;
j) Strength of concrete;
k) Abnormal conditions noted while driving/boring or concreting of piles. The normal daily report produced by the piling site should contain this information. In addition, any other information concerning planning and conducting the tests including relevant past experiences covering similar test(s) in the area; and
m) Details of test piles(s), if any.

5 TYPES OF TESTS

5.1 Various methods are available for checking the integrity of concrete piles after installation. In the most widely used method, impulses or vibrations are applied to the pile and measurements made of timings and attenuation of reflected signals.

The commonly used sonic methods, vibration methods, sonic logging techniques, etc, have been tried within the last 15-20 years in different parts of the world. However, the methods based on One Dimensional Stress Wave approach known as Sonic Integrity Testing, a Low Strain Integrity testing or Sonic Echo Testing have been used successfully in various parts of the world. The method is simple and quick enabling dozens of piles to be examined in a single working day without much interference in site activities.

The work carried out on sonic integrity testing of pile in the country has shown its efficiency; in assessing the structural quality of piles and therefore it is appropriate to frame in this code the salient features of this method.

5.1.1 *The Low Strain Integrity Testing*

This is a system of assessing the integrity of piles by the use of low stress wave imparted to the pile shaft and is also known as Sonic Integrity or Sonic Echo Test.

A small metal/hard rubber hammer is used to produce a light tap on top of the pile. The shock travelling down the length of the pile is reflected back from the toe of the pile and recorded through a suitable transducer/accelerometer (also held on top of the pile close to the point of impact) in a computer disk or diskette for subsequent analysis.

The primary shock wave which travels down the length of the shaft is reflected from the toe by the change in density between the concrete and sub-strata. However, if the pile has any imperfections or discontinuities within its length these will set up secondary reflections which will be added to the return signal (*see* Fig. 1).

By a careful analysis of the captured signal and a knowledge of the conditions of the ground, age of concrete, etc, a picture of the locations of such problems can be built up. The reflected stress wave can be monitored using either processing technique, the observed signals are amplified and converted into digital display as velocity versus length or frequency versus mobility records, providing information on structural integrity of piles.

The stress wave velocity and approximate pile lengths are provided as input for the integrity testing. The stress wave velocity is dependent on the Young's modulus and mass density of pile concrete. This value generally lies between 3 000-4 000 metre per second depending on the grade of concrete used (M15-M25).

5.1.2 Normally more than one recording of signals is done until repeatability of signals is achieved. If necessary, averaging of signals is also done to achieve more informative signals. In a suspected pile the test should be repeated at more than one location on top of the pile.

5.1.3 In case of large diameter piles, the tests shall be conducted at 5-6 places to cover the entire section of the pile.

5.1.4 The tests shall be conducted on piles whose length is correctly recorded or on test piles where available, to determine the value of stress wave velocity and characteristic or reference signal for comparing the signals for testing subsequent piles.

5.1.5 The method of testing involves high skill and use of computerized equipment. Therefore, the tests should be performed and interpreted by trained and experienced personnel.

5.2 Other Methods

Other methods such as Frequency Response also

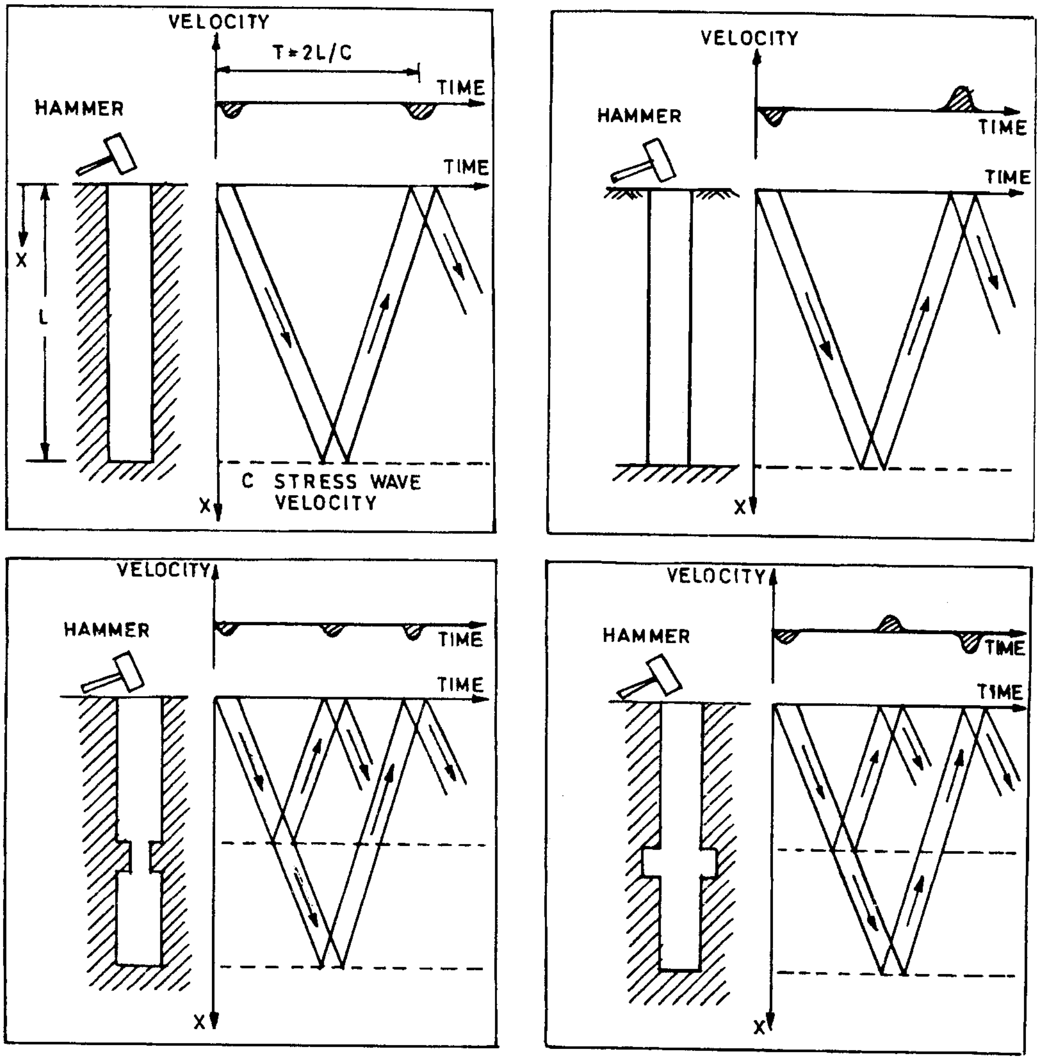

FIG. 1 PATTERN OF STRESS WAVE REFLECTIONS

known as vibration method (pile head is vibrated at high frequencies and responses analysed by computer aided technologies). Sonic Coring (where measuring of signal between sonic emitter and receiver placed in adjacent tubes in the pile in advance). Seismic Resistivity which also requires an adjacent bore hole, etc, have been used to a varying degree of success. However, these are not commonly used because of economic and time considerations.

5.3 High Strain Integrity Testing

In a few cases where piles are too long or skin fiction is high, low strain method does not provide sufficient information particularly the toe reflection. In such cases high strain method can be used by giving higher impact energies and additional measurements of the pile top acceleration and strain observed. However, the high strain method is used basically to monitor the performance of piles during driving and to estimate bearing capacity and are not covered in this guidelines.

6 DATA AND REPORTING

6.1 The assessment of structural integrity is based on two equally important aspects:

a) Quality of signals, and

b) Accurate analysis and interpretation of signal.

6.2 Piles requiring remedial measures should be so marked immediately on completion of the field integrity testing, and rectification, measures selected.

6.3 The final report should include signals of each integrity test and reflect on the structural condition of piles.

7 GENERAL REQUIREMENTS OF THE TESTS

7.1 Piles shall be trimmed to cut off level or sound concrete level before the test with all laitance removed. No pile cap blindage work should be undertaken prior to the test.

7.2 The area surrounding the pile should be free from standing water and kept dewatered during the tests.

7.3 The pile head should be accessible.

7.4 Testing should be free of work likely to cause disturbance.

7.5 The *cast-in-situ* piles should not be tested normally before 14 days of casting.

7.6 The test piles, if available at site, can be used to determine the pulse velocity and characteristic or reference signal generated. Where no test pile is available information can be obtained from cast piles whose length is accurately recorded.

8 LIMITATIONS OF NDT METHODS

8.1 Non-Destructive Testing of piles does not provide the load carrying capacity of piles.

8.2 It does not provide information regarding verticality or displacement in position of piles.

8.3 Minor deficiencies like local loss of cover, small intrusions or type of conditions of materials at the base of piles are undetectable. Integrity testing may not identify all imperfections, but it can be useful tool in identifying major defects within the effective lengths. The test may identify minor impedance variations that may not affect the bearing capacity of piles. In such cases, the engineer should use judgement as to the acceptability of these piles considering other factors such as load redistribution to adjacent pile, load transfer to the soil above the defect, applied safety factors and structural load requirements.

8.4 Based on the latest information available, the limitations relating to the depths up to which the integrity tests can be carried on piles, depends on the surrounding strata and damping within the concrete.

8.5 The present experience of Non-Destructive Testing of piles is up to a diameter of 1 500 mm.

8.6 Soil stiffness or founding on rock of similar density as the pile will attenuate the signals such that there will be little or no toe reflection.

8.7 The low strain integrity method is applicable to *cast-in-situ* concrete bored and driven piles. Conclusive results are rarely obtained in case of segmented precast reinforced concrete driven piles or precast piles in prebored holes.

9 COMPLEMENTARY TESTS

If required, assistance may be taken of the following complementary tests to the integrity test method described.

a) *Ultrasonic Pulse Velocity Test* — This test is carried out at the head of the pile in order to arrive at the speed of sound propagation through the cast concrete of the pile.

b) *Penetration Test* — This test is used to assess the strength of the concrete at the pile head to ensure that the pile is sufficiently cured and ready for NDT.

c) *Density Testing of Cast Cubes* — In order to determine the density of concrete used each cube should be measured for density by weighing in air and water and using the following calculation:

$$\frac{\text{Weight in air in kg}}{[\text{Weight in air} - \text{Weight in water}]\ \text{kg}} \times 1\,000 = \text{Density in kg/m}^3$$

All the above supporting tests can be used to check soundness of concrete at the test level and to assess the stress wave velocity of pile concrete depending on concrete density and its *in-situ* condition.

ANNEX A

(Foreword)

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