DEVICE WITH ADVANCED FACILITIES FOR NON-DESTRUCTIVE TESTING OF MECHANICAL PROPERTIES OF CONCRETE

MATSULEVICH O.V., KREN A.P., RUDNITSKY V.A.
INSTITUTE OF APPLIED PHYSICS
OF NATIONAL ACADEMY OF SCIENCES OF BELARUS
Minsk, Belarus

At present the volume of nondestructive testing of strength of concrete constructions increases considerably. Nondestructive methods are used both at building of constructions and at their following monitoring, assessment of damage caused by natural or technogeneous factors (floods, fires, etc.). Sclerometric methods based on determination of material properties from its response to impact penetration of rigid indenter are widely used in NDT of concrete strength. The main advantages of the methods are efficiency of measurements; possibility of testing without decreasing of load-carrying capacity of constructions; sufficiently high energy of effect upon material that allows increasing reliability of testing.

Withal the methods have some shortcomings, the main one is their low informativity. The quantity of impact parameters used as the indirect characteristic of concrete strength is limited. It increases a measurement uncertainty when selected parameters are subjected to influence of factors which have no unequivocal relationship with concrete strength. Besides, the shortage of information about interaction between indenter and tested material makes separate determination of elastic and plastic characteristics of material practically impossible.

Informativity of the testing may be considerably increased when the whole process of indenter penetration is recorded. Such testing method called as a dynamic indentation method, is developed in Institute of Applied Physics of National Academy of Sciences of Belarus. A principle of the method [1] is based on local impact loading of material and continuous recording of analog signal of indenter velocity. This signal is an initial information about tested material. The velocity is registered by the use of magnetic gauge which includes a permanent magnet attached to the indenter and stationary inductance coil.

A typical curve of relationship between indenter velocity and time is shown in Fig. 1, a. Point O conforms to the moment when indenter touches to tested material and velocity of the indenter reaches its maximum (V_{max}). From this moment the indenter velocity dramatically decreases, becoming equal to zero at point A. Then due to restitution of material elastic deformation the indenter begins reverse movement, reaching rebound velocity (V_{end}) at point A'. Segment AA' conforms to a passive stage of impact. Differentiation of velocity $V(t)$ with following multiplication by indenter mass allows obtaining current values of contact force $P(t)$. Integration of velocity $V(t)$ allows obtaining current values of displacement $P(t)$. Relation of contact force versus penetration depth (Fig. 1, b) is most useful for analysis of material properties.

Thus from single measurement the method allows obtaining several indentation parameters from $V(t)$ and $P(\alpha)$ curves. The main characteristics of mechanical properties of tested material are duration of impact active stage t_a, maximum depth of indenter penetration α_{max}, maximum contact force P_{max}, contact force at maximum penetration $P_{V=0}$, velocity restitution coefficient e (ratio of V_{end} to V_{max}) and dynamic hardness HM. Latter is calculated as a ratio of contact force at maximum penetration to area of unreduced impression projection which is determined from α_{max} using geometric relations in the impression [1]. Listed indentation parameters may be used both for determination of concrete compression strength using preliminary ascertained calibration curves and for calculation of the material mechanical properties (elastic modulus, viscosity, etc.) in accordance with accepted model of the material deformation.

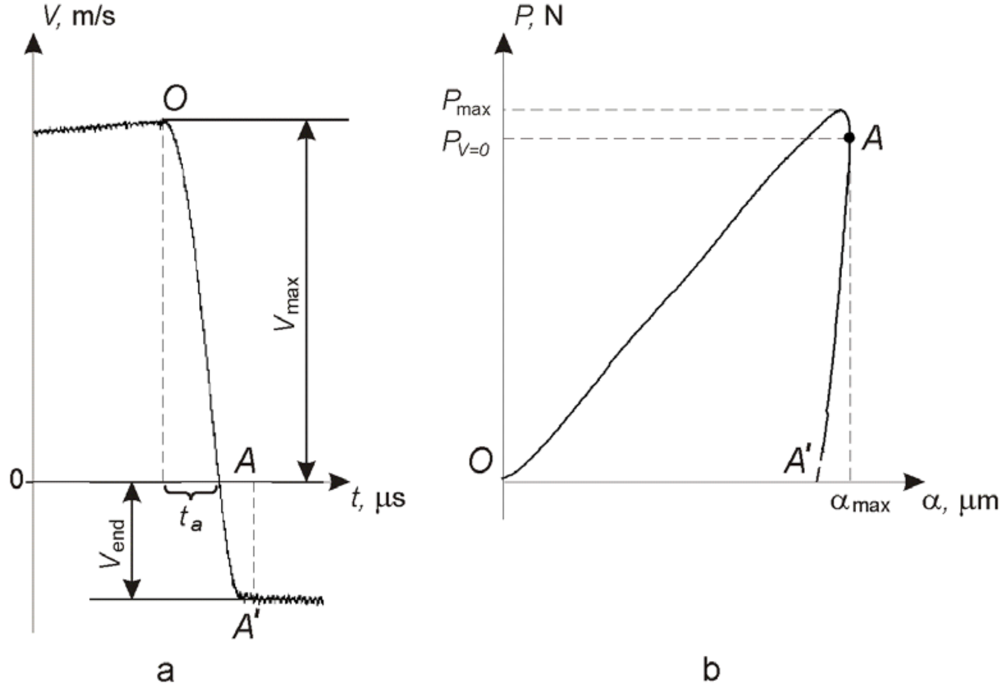

Fig. 1. Curves of the indenter penetration into material:
a – dependence of the indenter velocity on time, b – dependence of contact force on penetration depth

To estimate an efficiency of using of various indentation parameters as indirect characteristic of concrete strength a number of experiments was carried out. The experiments consisted in testing of concrete samples with different strength by the dynamic indentation method and following compression tests of the same samples. As a result of performed tests a calibration relations between concrete compression strength R_{press} and indentation parameters were obtained. Coefficient of variation ν_R of strength values R_{dyn} calculated from different indentation parameters using corresponding relations was used as a major criterion for comparison of the relations. It was found out that determining of strength from duration of impact active stage allows getting a minimum dispersion of R_{dyn} values. For the various samples a values of ν_R coefficient calculated from 10 measurements, was about (4–10) %. As a result of the experiments was also discovered that indentation parameters have different relative sensitivity to a change of concrete strength. This phenomenon makes possible developing techniques of multiple parameters testing of strength. An aim of such techniques is minimization of negative influence of factors which have no unequivocal relationship with concrete strength.

A distinctive feature of the dynamic indentation method is a possibility of determination of elastic modulus. Elastic modulus is one of the most important characteristics determining operational properties of concrete and asphalt. The measurement of change of the elastic modulus allows estimation of the current condition of a material and prediction of its behavior in the future. As it is known the dependence between stresses σ and strains ε arising in object under test should be obtained for determination of the elastic modulus. In case of dynamic impact tests a basis for finding of dependence σ(ε) is the dependence $P(\alpha)$, given on a fig. 1, b. Our investigations have shown that useful information about material properties may be obtained, not considering intermediate values of the impact parameters, but using only final quantities of penetration depth ($\alpha_{\max}$), contact force ($P_{V=0}$) and rebound velocity (V_{end}). So the following expression was derived for the elastic modulus:

$$E = (1-\mu^2)\left(\frac{2+n}{2}\right)^{\frac{3}{8}} \frac{D^{\frac{3}{4}}}{W^{\frac{1}{4}}} \left(\frac{P_{V=0}}{\pi D \alpha_{\max}}\right)^{\frac{5}{4}} \left(\frac{V_{\max}}{V_{\text{end}}}\right)^{2} \qquad (1)$$

where μ – Poisson's ratio of the tested material;

n – coefficient dependent on hardness of the tested material (for concrete *n* is accepted equal 2);

D – diameter of spherical tip of the indenter;

W – kinetic energy of the falling indenter.

Our experiments have shown that the values of the elastic modulus obtained by the dynamic indentation method under the formula (1) are in a good accordance to the results of determination of the module on speed of distribution of ultrasound.

Application of the method for concrete properties testing was realized in device IPM-1 which is produced in two modifications:

Portable device IPM-1B. It is made as the one-piece unit, which includes impact gauge, electronic module of analog-digital converter, processor, display and self-contained power supply. The three main parameters (strength, hardness and dynamic elastic modulus) are calculated at each measurement. Transferring of measurement results to a personal computer, its storage and statistical treatment are realized by special software, which is included in the delivery set.

Installation IPM-1A. It is made as the two separate units: impact gauge and electronic module, which must be connected to personal computer. Using of personal computer for data processing allows obtaining more detailed information about the material deformation process. User receives not only calculated values of material properties, but also directly impact parameters (both as the maximal values, and as graphic dependences of the parameters on time).

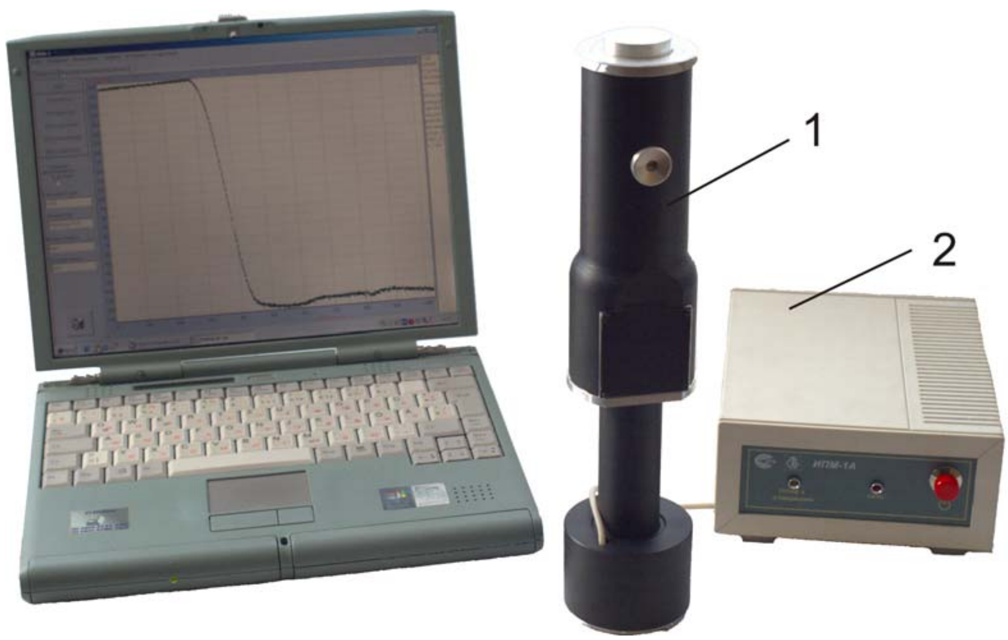

Fig. 2. Installation IPM-1A: 1 – impact gauge, 2 – electronic module

Specification of the device IPM-1

Impact energy, J	1,5
Strength measurement range, MPa	0,1-100
Strength measurement accuracy, %	±8
Measuring time, s	5

REFERENCE

1. V.A. Rudnitsky, V.V. Djakovich. Material tasting by the method of dynamic indentation. Nondestruct. Test. Eval. 1996, Vol. 12, p. 253–261.