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LOADING TESTS OF BUILDING STRUCTURES

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Increased attention is being paid to the modification of test procedures and to the development of the suitable criteria for the evaluation of loading tests of building structures and members. This topic is of interest to several organizations: Committee E-6 of ASTM (Field load testing of buildings), a common committee of ASCE/IABSE, and Committee 20-TBS, RILEM (Testing Building Structures In-Situ). Some years ago the author conducted a project which addressed fundamental standards for loading tests of building structures; during the course of the project he consulted many specialists and institutes in different countries. Thus, the project reflects, to a considerable degree, the opinions of specialists in this field. The project was used for the creation of Czechoslovak State Standard ČSN 732030, which became valid on January 1, 1969.

The author believes that the text of the mentioned Standard (which is comprised of the basic stipulations common to static and dynamic loading tests of all monolithic and prefabricated building structures and their parts and/or elements) can become a convenient supporting material for the work of specialists--both for preparing similar codes, standards or recommendations in other countries, and for practicing the tests. The author introduces the Standard in the fullest wording possible.

I. GENERAL

Purpose and Arrangement of a Loading Test

The purpose of a loading test is to assess the actual behaviour of a structure or an element through determination of its load-bearing capacity or usability in terms of magnitude of deflection, and cracking under external loads. The

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loading test must be so organized that it may correspond in all respects with the actual behaviour of the member or the structure, particularly with regard to the key factors for the state of stress at all critical points. The test load should simulate the actual dead and live loads, particularly with regard to their distribution, to ensure that the effects produced by the test coincide with the maximum effects applied to the structure, its part or element in actual performance, in the cross sections that are identical with reality.

Types of Loading Tests

Loading tests are classified as follows:

(1) Proof tests to demonstrate the ability of the member or structure to satisfy the given purpose in accordance with design requirements, the suitability of the construction method or the construction materials used (e.g. prototype test, approval tests, etc.).

(2) Control tests by means of which the ability of the member or the structure to satisfy the given purpose in accordance with design requirements is periodically or non-periodically followed (production control tests, acceptance tests, etc.).

(3) All other tests not intended exclusively for the assessment of a single member or structure.

Each loading test can be executed:

(1) to the very failure of the structure of its part or element, to determine its ultimate load-bearing capacity, or

(2) by test loads specified (if not directly stipulated by the respective standards) to prove the usability of the structure or its part with reference to its

    (a) load-bearing ability,
    (b) rigidity (deflection), or
    (c) cracks.

The assessment of the structure or its part or element according to the ultimate deformation limit or the crack limit is identical with the proof of usability from the viewpoint of rigidity. Loading tests which are proof tests are used particularly as prototype or approval tests.

Loading tests are used in extreme cases only, when all other possibilities have been exhausted (e.g. non-destructive strength tests, dimensions checks, control of the position of reinforcement, etc.) or if they are stipulated as the

proof of the ability of the structure or its part or element to satisfy the given purpose (e.g. in the case of bridges).

Authorization and Data for Loading Tests

Loading tests are carried out by a state-authorized testing laboratory or a testing laboratory authorized by the respective authority (owner) which stipulates also the extent and the manner of execution of the required test, if it is not stipulated by the respective standards, design of the structure, or the party ordering the test. Loading tests which can be carried out, in his own interest, by the contractor (producer of the structure) in the framework of his control of building operations (production control tests) are an exception to this rule.

The party who has ordered the execution of the loading test is bound to apply the testing laboratory which will execute the test with all technical data required for the assessment of the tested structure, including the supplements to structural analysis prepared on the basis of the latter's requirements.

Specialized staff, testing apparatuses, and equipment are provided by the testing laboratory to carry out the loading test. Auxiliary manpower, ancillary and safety facilities and measures (scaffolding, auxiliary galleries, etc.), and possibly the means of loading (which are indispensable for the execution of the test) are provided by the party who has ordered the test in accordance with the requirements of the testing laboratory.

When the loading tests are carried out by the contractor in the framework of the control of building operations, the contractor provides for himself all necessary testing apparatuses, equipment, and safety measures.

Safety Measures

The testing laboratory which carries out the loading test is responsible for the safety of people, property and other interests in the course of the test. Therefore, the laboratory must prepare and hand over to the owner or supervising authority, for approval, a list of all safety precautions and safety facilities supplemented with a sketch showing their arrangement and conditions which must

be complied with by the equipment with regard to the type of structure and the method of its testing. It must be particularly ensured that the safety scaffolding be situated as closely to the structure as possible, while simultaneously arranged so as not to hinder its deformation. In loading tests carried out by the contractor within the framework of the control of the building operations, the responsibility for the safety of people, property and other interests fall on the contractor.

If it is not possible to ensure sufficient safety measures and facilities, it is necessary to select such a method of loading and measuring of the tested building structure or its part or element that does not require the presence of people either above or below the tested structure or in its proximity (e.g. loading by means of water or air bags, remote control measuring, etc.). If, for objective reasons, even such measurer or facilities cannot be ensured (e.g. in the loading tests of bridges), the deformation increments and the general behaviour of the tested structure must be followed in suitable intervals and the loading procedure must be controlled.

II. PREPARATION OF A LOADING TEST

For every loading test a preliminary analysis is carried out. This analysis must elucidate the direction in which the test is to proceed and must convincingly prove the necessity and the desirability of the test execution. For this purpose the tested structure and all of its parts are inspected in detail to ascertain whether the design satisfies externally all requirements shown in the design or standard design of the structure or its part or element. In particular, the geometric dimensions, weight, deviations of shape and deformations, quality of materials, quantity, type and position of reinforcement, number and diameters of bolts, rivets and nails and their loosening, if any, are determined. Also the joint dimensions and dimensions and quality of welds are checked, and the strengths of high tension bolts are checked at random. Particular attention must be

afforded to all joints and nodes, transverse and wind bracings, as well as the slenderness of the individual compressed members. Also all data on the tests of building materials and the production control tests carried out during the execution of the structure are collected.

The manner in which the structures meets the assumptions of the structural analysis is checked; when required, it is necessary to verify the correct selection of the foundations, the correct estimate of the permissible stress of the foundation soil and whether the climatic, hydrogeological or other conditions, particularly the position of the ground water level, have not changed since the time of the design.

If cracks or any other visible faults can be found in the structure (e.g. aggregate pockets, voids, loose rivets or nails, faulty welds, corroded spots, in the case of timber structures, termites or rot, in the case of light weight concrete, excessive moisture content, etc.), they are marked visibly with pencil or chalk on the structure and recorded on the drawing.

The loading test may start only after the whole of its procedure has been thought out to the minutest detail and after thorough preliminary preparations, particularly with respect to the methodology of testing, have been made. The progress of the test must be so designed that a clear idea of the results obtained can be maintained at any moment during the test, so that it is possible to predict the possible further behaviour of the structure.

For this purpose a detailed working schedule must be prepared before every loading test, taking into account the specific features of every individual test. It is recommended that this schedule be divided into phases according to Annex I. A detailed specification of operations to be carried out in the individual phases may be stipulated by other standards or specifications.

III. EXECUTION OF A LOADING TEST

Selection and Preparation of Tested Structure

The selection of the part of the structure to be subjected to a loading test is based on the purpose of the test. Particular care must be taken that the influence of the adjoining parts of the tested structure on the deformation of the tested part be minimal or at least definable.

Individual members of the tested part of the structure must be secured against buckling during the test in the manner corresponding statically with the actual state during the performance of the structure. At the time of the test it must be ensured that other conditions decisive for the given structure (e.g. temperature, humidity, saturation with liquid) are identical with or very near the conditions prevailing at the time of the performance of the structure.

If the total permanent load is not applied to the structure or some of its parts at the time of the test (for technical or other reasons), an equivalent load must be placed on them in the case that its value may influence decisively the test results (e.g. if a tested part of the structure is involved, in the case of expected great settlement of statically indeterminate structures, etc.). Before the test begins, a preliminary loading test is carried out (in unclear cases) to determine the interaction of the tested part with adjoining parts (to determine the extent of trasverse distribution, continuity, etc.), and the further progress of the test, e.g. the extent or the magnitude of the load, are adjusted accordingly.

Age of the Structure

The test is carried out only after the structure has attained the required properties, particularly the full strength of the materials used, and/or after the termination of creep or settlement of the structure. In the case of concrete structures it is recommended that the tests begin after the elapse of 3 months. If it is necessary to begin with the loading test earlier, the date of the test is determined by the authorized testing laboratory entrusted with the execution

of the test, after an agreement has been made with the party who has ordered the test.

Methods of Measurements

In the course of the test all kinds of deformations necessary for an objective assessment of the behaviour of the tested structure are measured. In every case the following characteristics must be determined:

(1) deflections of the individual structural members including, in the case of cantilevers, their rotation at supports, and

(2) the time of origin of the first defect and the course of its development including, in the case of cracks, their widths in various loading stages, and possibly, the time of the first indications of the loss of stability of the individual members.

It is recommended that the relative deformations of the individual members of the [illegible]ndividual members of the structure be followed, particularly in the vicinity of their connections or other exacting places.

The permissible error of the apparatuses used for the measuring of deformations must not exceed the greater of the following values:

(1) 5% of the expected theoretical deformation under standard load,

(2) 0.05 mm

The measuring apparatuses are fitted in such a way as would ensure a safe determination of the relative change of the shape of the structure (or its cross section) due to the test load (with the exclusion of the settlement of the supports, effect of temperature changes, etc.). The measuring apparatuses and the structure supporting them as well as the tested structure should be protected from the weather, wind and direct insolation during the test. It is recommended that loading tests be carried out in the open air at the time of day when the effects of temperature changes are minimum (in the morning, in the evening, at [illegible]ight).

For a certain period preceding the beginning of the loading test, it is recommended that all measuring apparatuses be monitored, with the purpose of elucidating the influence of temperature changes on the deformations of the

structure and on the apparatuses. Should great changes in the readings of the apparatuses be ascertained, additional supplementary measures must be taken to ensure the protection of the tested structure, the apparatuses and their supporting structures. Alternatively, the values of temperature correction coefficients must be determined or a continuous temperature compensation for the measured data must be provided.

If the correct functioning (operation) of the apparatuses has not been proved in any other suitable way, the tested structure is loaded, prior to the beginning of the test proper, preliminarily with a load not exceeding, as a rule, 20% of the standard load.

When selecting the measuring apparatuses for dynamic tests of structures it must be borne in mind the frequency range of the apparatuses must ensure that all essential harmonic components of the motion are recorded. The natural frequencies of the tested structure or its part or element due to forced vibrations (on the basis of resonance curves) are investigated for more than one position of the vibration exciter, unless the actual vibration source is stationary. When investigating the vibrations due to the operation of machines, the vibrations of the principal parts of the machines are measured apart from the vibrations of the tested structure.

During the whole time of the measurements of deformations during the loading test, the course of ambient temperature and the temperature of directly insolated parts of the tested structure are recorded; in the case of concrete, masonry and timber structures, the course of the relative humidity of the surrounding environment is recorded.

Types of Test Loads

For static load testing of structures, loads of various types may be used, if the following conditions have been complied with:

(1) the load used for the test must not make an independent load-bearing structure (beams, slabs, etc.); if piece loads are used (bricks, bags, etc.) the arch effect must be prevented. For this reason the bricks or

blocks should be applied in the form of separate stacks sized 30 x 30 to 45 x 45 cm in plan, and spaced with 3 to 5 cm gaps; bags or other major piece materials are permitted to be placed in stacks whose length do not exceed 1/6 of the span of the tested member (not more, however, than 1 m) with a gap of 5 to 10 cm;

(2) the weight of the loading unit must be easy to ascertain (e.g. pieces of regular shape or of uniform dimensions);

(3) the load must be easy to transport and easy to remove;

(4) no hygroscopic materials may be used for loading on the sites with fluctuating humidity; and

(5) on slanting surfaces the load must be secured against sliding.

For dynamic load tests of structures, whenever possible, such sources of vibrations are used to produce the dynamic effect at the time of the actual performance of the structure. When these sources are replaced with any other sources of vibrations, care must be taken that all decisive dynamic as well as static characteristics (particularly the frequency range) which will originate during the actual performance of the structure, are preserved.

In static load tests of elements or parts of structures it is recommended that the test load be applied by means of hydraulic presses or cylinders, whose capacity and accuracy of measurement in relation to the load produced must satisfy the stipulations of ČSN 25 0251. When necessary, it is possible to use also other types of loads.

For test loads of up to 1500 kp/sq m it is recommended to use loading bags or flexible containers filled with water or loading bags with compressed air. When producing load by means of hydraulic cylinders or compressed air, care must be taken lest the tested structure be influenced by their reactions. It is not permitted to use any type of load which does not satisfy the above requirements, e.g. sand or any other loose material in bulk (with the exception of the cases when the structure is subjected to such loads in its actual performance). When uniform piece loads are used, the weight of the individual pieces may differ maximally by 5% from an arithmetic mean determined by weighing at least 10 pieces selected at random. When non-uniform piece loads are used every individual piece

must be weighed separately and visibly marked with the respective weight. The error in the magnitude of the total load must not exceed ± 5%.

Location of Test Loads

The location of the test loads on the tested structure must correspond with the load for which the structure has been designed or will be exposed to. If it is impossible to achieve this, for objective reasons, such equivalent loads must be used that will produce the same state of stress or strain as the actual load. An equivalent load may be used in cases when the function of the member or structure during the test is different from that in its actual performance conditions (e.g. because of the change of the manner of bearing). The use of the selected location and the magnitude of the equivalent load must be justified by analysis, preferably by limit design analysis methods.

The load must be placed into position as quickly as possible, without any impact or vibrations; as a rule, the load should be applied in several stages determined in accordance with the type of structure. For building structures the individual loading stages should not exceed 25% of the test load.

When testing simply supported or fully fixed and uniformly loaded slabs with a ratio of sides $l_1/l_2 \geq 3$, supported only in the longer direction of l_1, the slab is loaded in a zone 1.5 l_2 wide on both sides of the investigated point. When an equivalent load is used, it is possible to proceed according to Annex I. When testing slabs continuous in the direction of l_2 with the ratio of sides $l_1/l_2 < 3$, the load is applied to a zone 3 l_2 wide with the center in the investigated point in the measured span and at least in another 2 spans with a free span in between each two.

The distribution of the load in the tests of girders (floor beams, roof trusses, etc.) is selected in accordance with the structural pattern of the structure and the actual effectiveness of transverse connections, preferably by means of a preliminary loading test of transverse load distribution or spatial interaction.

In the case of structures consisting of main load-bearing members and transverse bracing, a preliminary loading test to ascertain transverse load distribution or spatial interaction is carried out. In the case of other structures the procedure is analogous, in accordance with the static behaviour of the tested structure. The test of transverse load distribution or spatial interaction is intended to determine the percentage of the applied load sustained by the investigated member. For this test the investigated member is loaded and the deformations of the adjoining cooperating load-bearing members are measured; alternatively only the deformation of the investigated member is ascertained under gradual loading of the adjoining cooperating members. In this test the stress of any cooperating member must not exceed 50% of the ultimate load stress. At the same time the stress of the investigated member must exceed 30% of the ultimate load stress, with the exception of the cases when the test load quota per one member would exceed 80% of the standard value of live load. In the test of transverse load distribution or spatial interaction it is possible to assume that the sum of deformations of the same type of measured members (e.g. deflections in the same place of the beams) equals the deformation which would originate under the same load applied to an independent member separated from the remainder of the structure. In this process, wherever possible, all members whose influence exceeds 2.5% should be considered (i.e. the members whose deformations exceed 2.5% of the sum of deformations of measured members). If the members are of different rigidity, the measured deformations of the individual members are reduced at the ratio of their rigidities.

According to the results of the transverse distribution tests all influencing members are loaded. However, if the strength of the transverse connection permits it, only the investigated member is loaded with the load increased at the ratio of the sum of deformations of the deformation of this member. In the tests of thin-walled structures the load is subsequently applied to all positions which can result in the loss of stability of the structure.

Magnitude of the Test Load

The magnitude of the test load for the test of the load-bearing capacity (the test load replacing the effect of live load) is not limited and is increased to an ultimate load causing the failure of the structure or its part.

If the load-bearing capacity of a single element of a structure is tested, the load is increased in stages until the element fails, even in the case when the purpose of the test is to assess the element also according to the ultimate deformation limit or the crack limit.

In the test of usability of the structure or its part or an element with reference to its load-bearing capacity, the value of the test load Z equals the respective (or the required) standard live load P_n multiplied by an average of one plus the load factor n*, i.e.:

$$Z = 0.5\ P_n\ (1 + n) \qquad (1)$$

In the test of the usability of the structure or its part with reference to its rigidity the value of the test load equals, on the one hand, the respective (required) standard live load P_n, on the other hand the test load Z according to Eqn. (1). In the test of the usability of the structure or its part with reference to cracks the value of the test load equals the respective (required) standard live load P_n.

In all cases it is assumed that the dead load is in place in its full extent before the beginning of the test. If any part of the dead load has not been applied before the beginning of the test, additional load must be applied to the structure amounting to the design value of the respective part of the dead load. Additional load is applied in one stage, in the case of concrete, masonry, timber, light alloy, plastics, glass and composite structures at least 72 hours before testing; in the case of steel structures at least 3 hours before the

*The load factor (>1) is defined in Czechoslovak Standard ČSN 73 0035 as a factor compensating the possible deviations from the design load, varying for different structural materials and purpose of the structure from 1.1 to 1.4.

beginning of the loading test, unless stipulated otherwise by other standards for the testing of building structures. This additional load is left on the structure until the very end of the loading test.

In dynamic load tests of structures the magnitude and the position of the dead load must correspond exactly with the performance conditions, otherwise the results of the test must be corrected with regard to the actual load. If the structure has been designed to withstand dead load only (e.g. a window lintel), the test load equals the design dead load minus the dead weight of the structure. In the case of members and structures used in moist environment or in an environment with increased air humidity the dead load for the test is increased by the value corresponding with the possible changes of moisture. If the value of the live load comprizes two or more short-time loads, the sum of the test loads is multiplied by the reduction coefficient of 0.9. However, if the reduced sum of the test loads is inferior to any individual test load, the maximum test load is used for the test without any reduction.

In dynamic tests of structures the influence of the live load on the natural frequences of structures, and the amplitudes of forced vibrations, are considered. When investigating the vibrations due to the operation of machines is it necessary to:

(1) evaluate the influence of the effect of the individual machines or groups of machines affecting the structure or its part or element by their gradual elimination;

(2) assess the state of the machines, particularly when the vibrations of the structure become excessive; and

(3) take into account the circumstance that the number of revolutions of some machines changes according to operational requirements, while in the case of some other machines the magnitude of exciting forces changes in dependence on the variable loading of the machine, while its number of revolutions remains constant.

Period of Application of the Test Load

In the course of the test individual loading stages are introduced only after the deformation due to the preceding loading stage has stablized. The deformation is considered stablized, in the meaning of this paragraph, if its increment in a

5 minute period is less than 15% of the preceding increment for the same period, or less than the permissible error of the measuring apparatuses used. The shortest period of application of the full test load in the usability test of the structure is selected by considering the type of material of the tested structure, as follows:

(1) for the structures of all types of concrete whose compressive modulus of elasticity exceeds 100,000 kp/sq cm and for reinforced concrete structures	24 hours
(2) for the structures of light weight concrete whose compressive modulus of elasticity is less than 100,000 kp/sq cm, and for masonry structures	48 hours
(3) for timber structures	72 hours
(4) for steel structures	1 hour
(5) for light alloy structures	3 hours
(6) for structures of plastics, glass and composites: until the stabilization of deformation, usually more than	72 hours.

These periods must be increased, if the deformation has not stabilized. If the actual loading period of the structure in actual performance conditions is less than the period stimpulated it is possible to reduce the period of load application during the test, accordingly. In no case, however, must the period of test load application be less than the actual loading period in actual performance conditions of the structure. The full test live load is relieved in one stage.

Period of Measurements Under Load

In the course of the whole period of application of the full test load, the deformation is measured continuously or in identical intervals which, as a rule, do not exceed one quarter of the periods stipulated above.

Period of Measurements After Load Removal

In the usability test of the structure the deformation is measured after the removal of the test load, as a rule during the same interval as that during which the full test live load is measured according to "period of measurements under load" (above). If the deformation is measured in intervals, the last interval may

be double. If the tested structure does not satisfy, in the first test, the criteria stipulated, the second test may be started: in the case of concrete, masonry, timber, light alloy, plastics and composites structures, after the elapse of 72 hours; in the case of steel structures, after the elapse of 3 hours after the load removal in the first test.

IV. EVALUATION OF THE TEST

Analysis of the Structure

The analysis of the limit states of the structure for the purpose of test evaluation is carried out with regard to all decisive influences in accordance with the following. If it is impossible to determine reliably the actual value of dead load, the analysis is based on the dead load values given in the respective standard. If part of the dead load is replaced, for the test period, by an additional load, its actual value is considered in the analysis. Live load is considered with its actual test value.

The degree of constraint considered in the analysis of elastically constrained or continuous structures is best determined by means of a preliminary loading test. In this test the stress of the investigated member should be, as a rule, between 30 and 50% of the design stress; however, the test load must not exceed 80% of the standard live load.

When determining the span, cooperating slab width, centroid fibre, etc. for the analysis the stipulations of the respective standards for the design of building structures are observed. The magnitude of transverse distribution or spatial behaviour considered in the calculation is best determined by means of a preliminary loading test.

For the numerical determination of the ultimate load limit of the tested structure the procedure stipulated by the individual standards for the design of building structures is used with the following changes:

(1) in the analysis the average of the actual decisive characteristics of the material of the structure are used whenever possible (compressive

strength of concrete, yield limit of steel, etc.), which are determined by non-destructive tests or some other suitable methods, and

(2) the analysis is carried out, whenever possible, with regard to the actual distribution of bending moments and forces ascertained during the loading test.

The analysis of the structure for the test load is carried out in accordance with the respective standards for the design of building structures. When determining the deformation the modulus of elasticity is considered with its actual value determined by a non-destructive test in the structure or some other suitable method.

Numerical and Graphic Evaluation of Measured Data

The progress of every loading test is recorded in detail in a test record which contains all ascertained data on the member or the structure before the test, the working schedule, and its fulfillment. The measured data are processed numerically and graphically so as to make a basis for obtaining a clear picture of the behaviour of the structure in the whole course of the loading test. In numerical evaluation the data are reduced with regard to the settlement of supports and/or the effect of temperature or moisture. The results are tabulated in a clear form and the calculation of permanent, elastic and total deformations from the basic readings is carried out. In this process the final values of the individual quantities measured during the whole duration of the test or during the whole period of measurements after the load removal are considered.

The principal relations elucidating objectively the behaviour of the structure under load and after its removal are expressed on the basis of numerical values, graphically, preferably by means of three-component, or multicomponent diagrams (e.g. load x deformation x time).

Criteria for Loading Test Evaluation

The criteria for loading test evaluation differ principally according to whether the evaluation concerns a test carried out to the failure of the structure or a test using the test load. The tested building structure is assessed

with regard to its

(1) load-bearing capacity (when loaded until it fails), or

(2) usability, viz:

(a) with reference to its load-bearing ability,

(b) with reference to its rigidity under the test load, and

(c) with reference to cracks under the test load.

Further supplementary criteria may be stipulated by the standards for the design or erection of the individual types of building structures of further standards for their testing. When using more detailed methods of loading test evaluation their suitability for the given case must be proved. The tested structure is considered satisfactory with regard to its load-bearing capacity if it complies with the condition that the actual load under which it has failed is higher than or at least equal to the ultimate design load, at the same time being:

(1) higher than 95% of the theoretical value determined by analysis, if the structure has failed due to the exhaustion of its strength, or

(2) higher than 100% of the theoretical values, if the structure has failed due to the exhaustion of its stability.

The load under which the structure has failed is such load under which the structure has lost its ability for further use due to one of the following causes:

(1) complete failure of the structure or its part or section or the rupture of reinforcement (in the case of reinforced concrete structures);

(2) loss of stability of the structure or its part or element;

(3) local failure which continues growing without any increase of the load;

(4) the deformation increments under the same load measured three times in succession at identical intervals do not decrease;

(5) the deformation increment due to the last loading stage equals the sum of the deformations due to the first five equally high loading stages or exceeds it;

(6) the deflection equals 1/50 of the span or exceeds it;

(7) in bent concrete structures the width of some crack or the sum of crack widths over 200 mm of the length of the tested member equals or exceeds 1.5 mm;

(8) the failure of concrete structures by slanting cracks in the proximity of supports or point loads; or

(9) loss of bond between reinforcement and concrete.

The tested building structure is considered usable with reference to its load-bearing ability, if it has fulfilled simultaneously the following conditions:

(1) the magnitude of permanent deformations does not exceed for:

(a) steel structures	15%
(b) prestressed concrete structures	20%
(c) reinforced concrete, masonry and composite (steel and concrete) structures	25%
(d) timber structures	30%
(e) plastics and composites structures	40%

of the total deformation under test load; and

(2) the state of failure due to the design load is stabilized, while the width of cracks in concrete structures does not exceed 0.3mm, if they are protected against weather, and 0.2 mm, if they are exposed to weather.

If the permanent deformation in the first test exceeds the above values, but does not attain for metal structures 40%, for reinforced concrete, composite, prestressed concrete, and masonry structures 50%, and for timber, plastics and composites structures 60% of the total deformation under test load, another loading test may be carried out during which the conditions must be complied with. If the structure does not appear satisfactory even after the second test, in especially justified cases it is possible to carry out the third loading test, in which the permanent deformations must not exceed 1/3 of the values given below. If the permanent deformations exceed the above stipulation, the structure is not satisfactory.

The tested building structure is considered usable with reference to its load-bearing ability on the basis of the second loading test if it satisfies the following conditions:

(1) the magnitude of permanent deformations does not exceed for the:

(a) metal structures 7.5%

(b) prestressed concrete structures 10.0%

(c) reinforced concrete, composite and masonry structures 12.5%

(d) timber structures 15.0%

(e) plastics and composites structures 20.0%

of the total deformation under the test load; and

(2) no new failures originate and the existing failures do not extend (in the case of reinforced concrete structures the cracks do not increase either in length or in width).

If the first test is discontinued for any reason and the full test load has been applied for at least one half of the stipulated period, the structure is assessed during the repeated test according to the above values; if not, then according to the preceding values.

The tested building structure is considered usable with reference to its rigidity (deformation), if it satisfies simultaneously the following conditions:

(1) the measured elastic deformations under test load must not exceed the k-multiple of the theoretically determined value where the value of k according to the following table depends on the mean load factor, deduced from its values n for live loads and on the material of the tested structure (see ČSN 73 0035 or further respective standards);

(2) the fulfillment of the above deformation conditions with the exception of precast reinforced concrete elements which will be tested earlier than after the elapse of 3 months and to which the stipulations of the special standard on the testing of precast reinforced concrete elements apply;

(3) total deflections or other total deformations under standard live load must not exceed the limit deflections or deformations given in the respective standards for the design and erection of building structures and reduced according to the magnitude (type) and period of application of the load; and

(4) total deflections or other total deformations under test load must not exceed the limit deflections or deformations more than k-times, the values of k being given in the following table:

Mean value of load factor n for the considred live loads	k				
	Steel	Reinforced concrete and masonry	Prestressed concrete	Timber	Plastics and composites
1.0	1.05	1.10	1.05	1.10	1.10
1.1	1.05	1.12	1.07	1.12	1.11
1.2	1.05	1.15	1.10	1.15	1.13
1.3	1.05	1.17	1.12	1.17	1.14
1.4	1.05	1.20	1.15	1.20	1.16

Note: Intermediate values may be linearly interpolated.

The tested structure of reinforced concrete is considered usable with reference to the origin and development of cracks, if it satisfies simultaneously the following conditions:

(1) the crack width under standard live load must not exceed the values stipulated by the standards for the design of structures;

(2) the distance between cracks under standard live load must not exceed the values stipulated by the standards for the design of structures;

(3) the cracks do not appear under loads less than 0.9 of the theoretically determined load for the origin of the first crack according to the theory of elasticity; and

(4) after the removal of the load the cracks close to a width inferior to 1/3 of the prescribed value.

The criteria for the evaluation of dynamic tests are determined individually, usually after a consultation with a specialized institution, unless they are stipulated by other standards for load testing of building structures.

Final Evaluation of a Loading Test

In the final evaluation of the loading test the conclusions drawn from the processing of the loading test results are given. The conclusions must be unambiguous. If the structure or its elements have not satisfied the stipulations

of the respective standards or specifications valid for the product, an explanation of the reasons must be given, within the given possibilities.

ANNEX I: WORKING SCHEDULE

It is recommended to divide the working schedule into the following phases:

(1) general stipulations

(2) methodology

(3) investigations proper

(4) processing of results

(5) conclusion

The general stipulations of the schedule are of a guiding character. They formulate the purpose of the test, determining the individual phases of investigations accordingly. In this respect it is decided according to which criteria the structure or its part will be assessed. According to the structural analysis comprizing also the calculation of deformations, the preparations of the test are so carried out that it would be possible to compare the obtained results or adjust the analysis according to the results obtained in the very course of the test. Moreover, the method of loading, the magnitude and the type of load or other effects are stipulated which must be known so that it is possible to assess the behaviour of the structure. Finally the considerations of the expected results are given.

The methodology of work is governed by the characteristics accepted as the basis of the assessment of the load-bearing ability and usability of the structure according to the individual criteria. A working program is compiled, stipulating the loading procedure and the duration of the individual stages, type and mounting of the individual apparatuses, the methods and the required accuracy of measurements, etc. Also the procedure which will ensure the uniformity of reading of the individual apparatuses and eliminate the influence of such factors as would distort the measurements (temperature, humidity, etc.) is stipulated;

justification should be given here for the recording of special, unusual deformation characteristics of the structure.

Before the investigation proper the testing apparatuses and their mounting, as well as their proper functioning after thier mounting, are checked first. Furthermore, all other ancillary plant is checked together with the load (ballast) of loading plant; also the accuracy of the testing apparatuses may be verified. The loading test proper, which proceeds according to a previously prepared time schedule, is recorded in detail, the record forming an annex to the final report on the test. The results of the measurements are preliminarily processed in the course of the test to enable the checking of the assumptions of the analysis and, should it be necessary, an adjustment of the analysis and/or the further progress of the test on the basis of the results obtained.

The processing of the results of the investigation (measurements and evaluation of the loading test) is carried out in accordance with this standard. Whenever possible the results are processed by the methods of mathematical statistics and anomalous results are explained.

In the conclusion, all deductions drawn from the processing of the results of the loading test are given.