IS 7317 (1993): Code of practice for uniaxial jacking test for deformation modulus of rock [CED 48: Rock Mechanics]

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IS 7317 : 1993
Reaffirmed 2010

भारतीय मानक

चट्टान के विरूपण के मापांक के लिये एक अक्षीय जैकिंग परीक्षण की रीति संहिता

(पहला पुनरीक्षण)

Indian Standard

CODE OF PRACTICE FOR UNIAXIAL JACKING TEST FOR MODULUS OF DEFORMATION OF ROCK

(First Revision)

UDC 624·121·54 : 006·76

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

December 1993 Price Group 5

AMENDMENT NO. 1 JULY 1994
TO
IS 7317 : 1993 CODE OF PRACTICE FOR UNIAXIAL JACKING TEST FOR MODULUS OF DEFORMATION OF WORK

(First Revision)

(*Page* 5, *clause* **6.1**, *line* 19) — Substitute the word 'elastic' for the existing word 'delastic'.

(*Page* 7, *clause* **6.4**, *line* 2) — Substitute the word 'modulus' for the existing word 'mudulus'.

(*Page* 7, *clause* **6.5**, *line for the symbol* 'δ') — Substitute the word 'plate' for the existing word 'slate'.

(*Page* 7, *clause* **6.6**, *line* 2) — Substitute the word 'any' for the existing word 'and'.

(*Page* 7, *clause* **6.6**, *Formula after line* 3) — Substitute the following formula:

$$\delta = \frac{2p(1-\gamma^2)}{Ed}\left[\sqrt{R^2+Z^2}-Z\right] - \frac{pZ(1+\gamma)}{Ed}\left[\frac{Z}{\sqrt{R^2+Z^2}}-1\right]$$

(*Page* 7, *clause* **6.6**, *Formula after line 3, and at all other places where capital* 'P' *is written*, — Substitute small 'p' for the existing letter capital 'P' at all places in *clause* **6.6**.

(*Page* 7, *clause* **6.6**, *line for the symbol* 'δ') — Add the following after the word loading 'in one loading cycle'.

(*Page* 7, *clause* **6.6** *line for the symbol* 'E') — Substitute 'Ed = modulus of deformation' for the existing line.

(*Page* 9, *clause* **6.6**, *second para*) — Insert the word 'if' after the word '......in question'.

(*Page* 9, *clause* **6.6**, *second formula*) — Substitute the following for the existing formula:

$$\delta = \frac{2p(1-\gamma^2)}{Ed}\left[\sqrt{R_2+Z^2}-\sqrt{R_1^2+Z^2}\right] + \frac{pZ^2(1+\gamma)}{Ed}\left[\frac{1}{\sqrt{R_1^2+Z^2}}-\frac{1}{\sqrt{R_2^2+Z^2}}\right]$$

[*Page* 9, *clause* **8.1** (d), *last line*] – Substitute 'if' for the existing word 'of'.

(CED 48)

Printed at Printwell Printers, Aligarh, India

Rock Mechanics Sectional Committee, CED 48

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Rock Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

In general rock mass is heterogeneous, anisotropic and discontinuous; and its mechanical behaviour is governed by the existence and orientation of discontinuities such as bedding planes, joints, fracture zones, and the degree of weathering etc. These discontinuities may be clean or filled with fine grained material, rough or smooth, and may be continuous or discontinuous. As such, the mechanical properties of rock mass differ greatly from the laboratory test results carried out on small samples of intact rock. The parameters actually needed in design are the *in-situ* properties of rock mass and not that of intact rock. In designing and constructing engineering structures over or inside the rock mass, the main parameters of importance are its deformability, shear and other strength characteristics. Out of these three parameters, the dispersion in the test results of shear characteristics and the strength of a particular rock mass has been observed to be small as compared to the deformability values of the same. The deformation characteristics of *in-situ* rock is one such property which needs utmost care in its evaluation. It depends largely on the adopted technique of testing, the loaded area, the loading system, and the methodology by which the results are interpreted.

Modulus of deformation is an essential parameter for the design of tunnels, underground chambers, mines and dam foundations. The deformability of the rock mass will govern the strain conditions that develop around an excavation during its initial changes. When designing a structure in or on a rock mass, it is important to know the deformability characteristics of the same for following two reasons:

a) To assess expected displacements during excavation and relate these to subsequent monitoring to check stability; and

b) To permit the correct design of any rock support measures that must be able to accomodate the expected deformation without failure.

Deformation modulus of rock mass may be determined by bore hole jack test, uniaxial jacking test, pressure chamber test and radial jacking test etc. In case of uniaxial jacking tests, the loading of a jointed rock mass has to be arranged in the direction conforming to design requirement. Alternatively, it may be determined in two perpendicular directions and the value in required direction computed according to normal practice.

The results of bore hole jack tests may be used only as an index of rock mass deformability and there is strong dependence on jack-rock interaction and moreover the corrections are uncertain. Flat jack tests are severely limited by access problems, and only shallow rock in a disturbed state can be used to measure deformability adjacent to exposed surface and the results do not provide the deformability of the rock mass. Radial jacking tests and pressure chamber tests are better as they cause deformation of much larger volume of rock mass around the drift/tunnel and hence are most representative. But these tests are difficult to conduct and are very expensive.

The main disadvantage of all the above methods except in the bore hole jack tests, is that the results are influenced by blast damage and stress relief and therefore controlled excavation methods are required. The bore hole jack tests have the advantage that large number of locations can be tested rapidly and hence the test is sometimes used without recognition of its limitations. On the other hand Uniaxial Jacking tests are easy to conduct, relatively cheaper, and are much simpler. This test determines how *in-situ* rock reacts to controlled loading and unloading cycles and provide data on deformation moduli, creep and rebound. The modulus of deformation of rock mass is lower than the elastic modulus of intact rock material as determined in the laboratory.

This standard was first published in 1974. This revision provides a general discussion of the Uniaxial jacking test procedures. The revised code updates the information and explains in more detail the procedures utilised to accomplish the test. This also gives recommended interpretation of the modulus of deformation for use in technical analysis.

In the formulation of this standard, due weightage has been given to international coordination among the standards and practices in different countries in addition to relating it to the practices in the field in this country.

In reporting the result of a test or analysis, made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounned off value should be the same as that of the specified value in this standard.

Indian Standard

CODE OF PRACTICE FOR UNIAXIAL JACKING TEST FOR MODULUS OF DEFORMATION OF ROCK

(First Revision)

1 SCOPE

1.1 This standard covers the method for the determination of modulus of deformation of rock mass by uniaxial loading technique in which pressures are exerted on two parallel flat rock faces on the two opposite sides of a section of a drift, gallery or tunnel by means of hydraulic jacks. The applied stress and the resulting displacements are used for the determination of the modulus of deformation by the help of the appropriate elastic theory. The modulus of deformation is not a constant parameter, its value depends upon the stress level also. The choice of the design value for the *in-situ* modolus of deformation or elastic modulus thus becomes a matter of engineering judgement.

1.2 The creep characteristics of the rock mass may be computed from the graphs of displacement versus time.

1.3 The effects of anisotropy may be determined by applying the load in any desired direction. However, in jointed rocks, the test shall be conducted in the direction conforming to design requirement.

2 SELECTION OF TEST SITE

2.1 Prior to selecting a test site location, all available surface and sub-surface geological data of the exploratory drift shall be complied and analysed by the geologist. A three dimensional portrayal of these data shall also be prepared in plotted form.

2.2 After detailed exploration, sufficient geological mapping, and reviewing all available information in the exploratory drifts, the zone of the influence of the structure (dam, tunnel, under-ground openings, etc), may be divided into different lythological units and then sub-divided further into various structural zones. In each of these similar zones, a minimum of about four tests may be carried out. If large variations are found in the obtained results, additional confirmatory tests should be carried out to be able to choose design values for each zone.

2.3 The test site shall be selected such that the geology at the test location is representative of the geology of the area loaded by the structure to be built.

2.4 Testing in drifts, tunnels or any other underground openings is preferred for convenience. In the absence of such facility, the test may be located close to the sides of open excavations for foundation or abutments.

2.5 After selecting the test site, the geologist shall prepare a three dimensional map showing the micro geology of the *in-situ* rock mass falling under the influence of test. The following information pertaining to the test location may preferably be collected and jointly recorded by a team of geologists and engineers:

a) Rock quality designation (RQD);
b) Point load strength index of the rock material;
c) Number of joint sets, their dip and strike;
d) Spacing and condition of joints:
e) Ground water condition: dry/damp/wet/dripping/flowing;
f) Rock mass rating (RMR) and rock mass quality (Q);
g) Modulus of elasticity of rock material;
h) Special features that is, presence of shear or fault zones etc;
j) Method adopted for excavation of the drift that is by controlled blasting, hand chiselled or by any other means; and
k) Description of damages due to blasting.

3 PREPARATION OF TEST SITE

3.1 The size of the drift or gallery in which tests are to be carried out shall be kept as small as required for testing, so as to reduce the number of packing plates or the size of the intervening truss placed across the tunnel. The size of the exploratory drift shall be such that the distance between the loaded area and a restraining tunnel surface shall be at least equal to the radius of the loaded area so that any restraint would not effect the calculated moduli significantly, as shown in Fig. 1.

The minimum size of the opening convenient for the test being about 1·25 m wide and about 2·2 m high. The excavation of the drift shall be made in such a manner as to cause minimum disturbance of rock to be tested. Blasting shall not be allowed during final preparation of the test site.

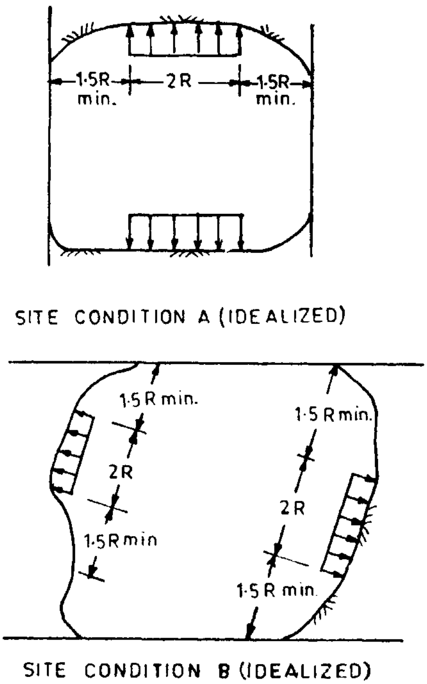

FIG. 1 DISTANCE BETWEEN THE LOADED AREA AND THE RESTRAINING SURFACE

3.2 After site selection, the area selected for testing shall be carefully prepared as quickly as possible, preferably within 15 days of the test site selection. In case of rocks being susceptible to loosening and weathering, tests should be conducted within thirty days of excavation of drift to obtain properties of fresh rock mass.

3.2.1 All loose rock material shall be removed by using chipping hammers and drills. The final trimming of rock to provide two parallel, concentric and smooth rock faces, about 5 cm larger than the test plate shall be done by means of chisel and hammer. The areas shall be finally ground smooth. There shall be an understanding between the field engineers and test engineers on the importance of careful treatment of rock during all excavation phases.

4 TEST SET UP

4.1 The test set up depends upon various conditions of testing, that is, whether the test is carried out in a small drift or in a wider tunnel or in an open trench; whether the test is carried out in a vertical or horizontal or inclined direction; and whether the resulting deformations are measured with respect to the bearing plate, or outside the loaded area or inside the rock mass along the centre line of the loaded surface.

4.2 For some typical test set ups Fig. 2, 3 and 4 may be referred.

4.2.1 Figure 2 A/Fig. 2 B depicts the arrangement for vertical/horizontal test set up in small drifts and galleries where the deformations are measured with respect to the bearing plates.

4.2.2 Figure 3 shows a similar test set up in a wider tunnel. However, for inclined tests, suitable supporting structures may be designed.

4.2.3 Figure 4 indicates an inclined test set up in a small drift where the deformations are measured inside the rock mass along the centre line of the loaded area.

4.3 Set Up for Narrow Drifts and Galleries

4.3.1 The minimum size of the steel bearing plate shall be 25 mm thick and 600 mm diameter. The size of the plate to be used at a given test site shall however not be less than 3 to 4 times the average spacing of joint or crack pattern subject to the limitations of the testing capacity available. Two such circular or square rigid steel plates shall be placed in contact with the rock surface with an intervening layer of 1 : 1 cement mortar or plaster of paris. The maximum thickness of the intervening layer shall be about 5 mm. The test location shall be saturated with water to simulate seepage at site. The mortar shall be allowed to cure sufficiently to obtain adequate strength prior to commencement of test. The space between the steel plate and the mortar layer and between the steel plate and the packing plate should be filled with teflon sheet of sufficient thickness in order to have a uniform transfer of load.

4.3.2 The loading apparatus shall be such that it is capable of applying simultaneous uniform pressures to two test areas on the opposite rock faces prepared. A calibrated hydraulic jack of capacity commensurate with the required stress or a minimum of 200T and capable of maintaining the desired pressure to within 2 percent of a selected value throughout the duration of the test shall be used for load application. The hydraulic pump system with necessary fittings, valves, gauges and hoses shall also have sufficient pressure capacity and volume for applying the desired loads. Generally it shall be preferred to use a pump with plungers of two sizes, the larger one for the lower pressure range and the smaller one for the higher pressure range. Cast iron packing plates of 75 mm thickness or material of equivalent rigidity, shall be placed in between the hydraulic jack and the steel plates in contact with the rock faces. Two of the packing plates should be of special design and should be provided with four equally spaced holes through which micrometer dial gauges are attached to measure independently the displacement or deformation of rock at the top and the bottom. The final gap, if any, between the plates should be closed by moving the plunger forward by operating the pump. A small initial load, about 0·5 kg/cm² should be applied and allowed to remain for a minimum period of 24 h to allow for the setting of cement mortar or 6 h for setting of plaster of paris before starting the test. Before applying the initial load it should be ensured that all the packing plates are concentric with the plunger of the jack, and in turn concentric with the plates.

4.3.3 The dial gauges capable of reading up to 0·002 mm with a minimum travel of 10 mm should be set up to give deformations of the four corners of each bearing plate. By moving the brass screws, the gauges should be adjusted to show initial reading nearly three fourths of the entire range of travel of the gauge.

Deformations of the two plates should be measured independently as the type and condition of the rock may be different at the two faces because of loosening or stress relief in the rock mass in the roof or sides of the drift.

4.4 Set Up for Wider Tunnel Locations

4.4.1 The set up is shown in Fig. 3 and it is suitable for horizontal loading for locations in wider tunnels. In this case also the deflections of each face are measured separately with respect to independent datums located at a distance of about 3 to 4 times the size of the plate, along the axis of the tunnel. The deflection is recorded by the help of four dial gauges at one face.

4.5 Set Up for Drifts where the Deformations are Measured Inside the Rock Mass

4.5.1 The typical set up has been shown in Fig. 4. In this case, 600-1 000 mm diameter flat jacks shall be used in place of bearing plates at the two ends. In the set up, the deformations shall be measured at the centre of the loaded area both at the surface and at different depths using multiple point extensometers located in central NX-76 mm diameter bore hole and with reference to a datum fixed at a depth of 6 times plate diameters.

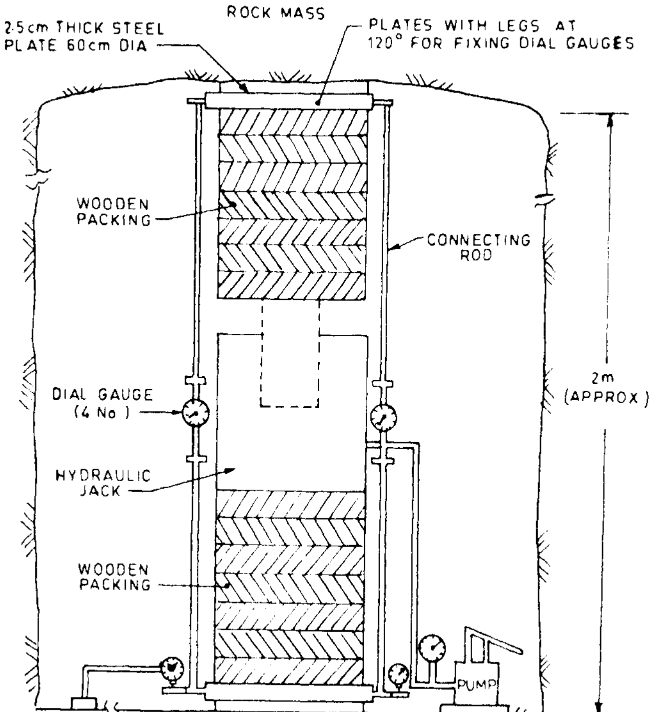

FIG. 2A SET UP OF EQUIPMENT FOR UNIAXIAL JACKING TEST IN VERTICAL DIRECTION IN NARROW DRIFTS OR GALLARIES

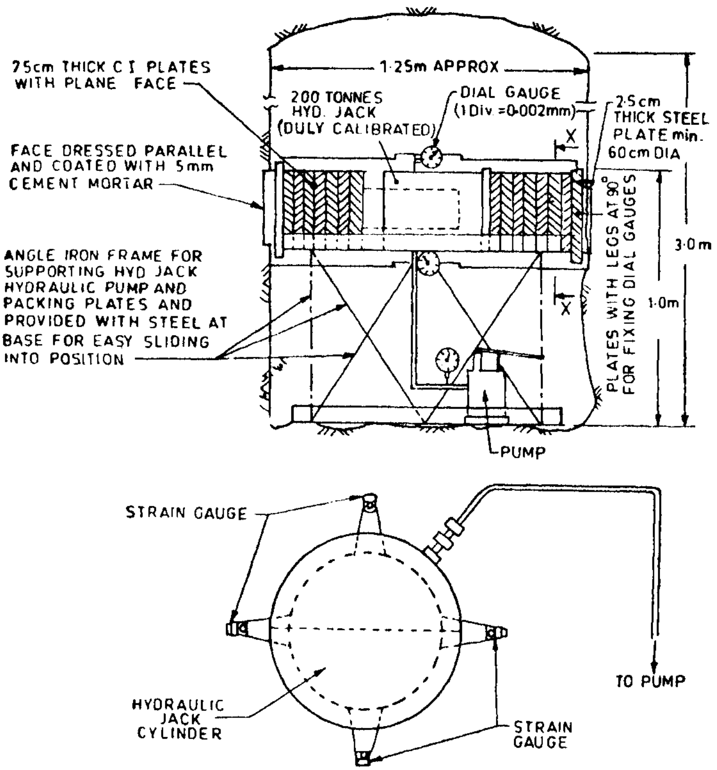

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FIG. 2B SET UP FOR UNIAXIAL JACKING EQUIPMENT FOR NARROW DRIFTS AND GALLARIES

5 TEST PROCEDURE

5.1 As far as possible, preference shall be given to the testing technique shown in Fig. 4. However, if it is not possible to deploy this test set up, then the set up shown in Fig. 2 or 3 may be used.

5.2 After all components of the test set are installed, they shall be checked jointly by the field and test engineers. A final check of all mechanical, hydraulic and electronic components (if any) shall be made after the mortar pads are placed and again before the first load increment is applied.

5.3 Test shall be conducted continually on a 24 hours a day basis utilising load ranges and increments compatible with the particular design considerations.

5.4 The test shall be started after allowing sufficient time for setting of cement mortar provided between the steel plates and pressed rock faces. The initial load applied shall be reduced to bare minimum to hold the steel plates in position, say about 0·5 kg/cm^2.

5.5 Rock deformation shall be recorded at sufficient intervals and a minimum of six readings during the first hour of each load increment or decrement is recommended.

5.6 The maximum load at which the test is to be conducted shall correspond to 1·2 to 1·5 time the anticipated maximum stress liable to be developed because of the proposed structure. Care shall be taken to check that the rock mass is not stressed beyond its strength. The test shall be conducted in a total number of five cycles. Each cycle shall consist of 20 percent of maximum test stress. In each cycle of loading, the load increments may be at least one fifth to one tenth of the test load involved in each cycle; the unloading, may be done in three steps. The test being a cyclic loading test, the load shall be brought down to the initial load applied to hold the plates in position, each time before reloading for another cycle. Deflection given by dial gauges and the corresponding loan (or stress) shall be noted. The dial gauge readings should be continued till it is less than one division over a period of thirty minutes. Besides, the duration of each pressure increment may be determined by the creep characteristics of the rock mass. Plot of deformation versus time shall be prepared by conducting separate test. This plot is useful for studying the creep characteristics of the rock. In uniaxial jacking test the duration of load increment for each cycle shall be fixed up to one hour in general and may be increased up to five hours depending upon the rock mass condition. However, experience of the test party and critical examination of observations during the first pressure increment can be used to modify time requirements for successive increments. The results shall be plotted in the stress deformation diagram which forms the basis of interpretation for analysing the behaviour of the rock mass under imposed load and for determining the values of the deformation and elastic moduli, and the magnitude of irreversible deformations.

5.7 After the test is completed, the installation procedure is reversed and the entire set up is retrieved for subsequent use. The concrete pads shall be removed so as not to create a safety hazard by having them fallen by the action of gravity at some later date.

5.8 The data observed during the test may be plotted to give deformation versus stress, time and depth below the surface curves (*see* Fig. 5, 6 and 7) to calculate moduli of deformation/elasticity at various stress levels, creep factors and the variation of moduli with respect to depth.

5.9 The creep test as shown in Fig. 6 is essential for weak/soft rocks.

6 INTERPRETATION OF THE TEST DATA

6.1 Because rock mass is not truely an elastic material, there is considerable latitude available in selecting the type of modulus to be computed for the design purpose. All moduli are computed from Baussinesq formula for a homogeneous elastic half space; the only difference is the portion of the curve used by the designer to obtain the deformation and stress changes. In the cyclic loading tests, it is usually found that large deformation occur in the first loading cycle while the recovery of the strain on removal of the load is comparatively very small indicating a permanent set in the rock mass by closing of cracks and joints. The deformations in the 2nd, 3rd, 4th and 5th cycles of loading are used for calculating the deformation moduli at different stress levels. Similarly, the recovery in the 2nd, 3rd, 4th and 5th cycles of unloading are used for calculating the delastic moduli at the corresponding stress levels. For reporting the average deformation modulus and the elastic modulus, the values corresponding to the last cycle may be considered.

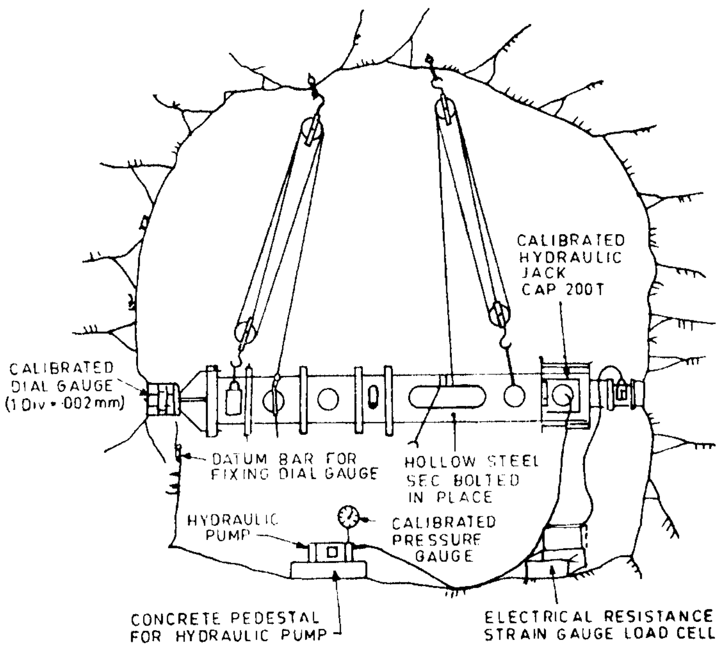


FIG. 3 SET UP FOR UNIAXIAL JACKING EQUIPMENT FOR WIDER TUNNEL LOCATIONS

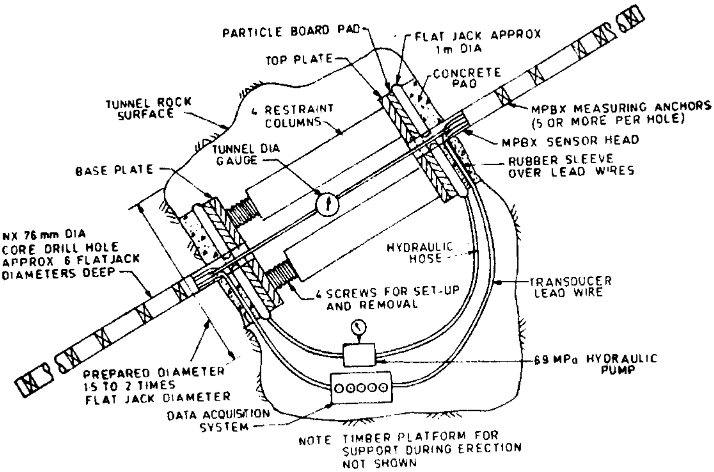


FIG. 4 SET UP FOR UNIAXIAL JACKING EQUIPMENT IN DRIFTS WHERE DEFORMATIONS ARE MEASURED INSIDE THE ROCK MASS

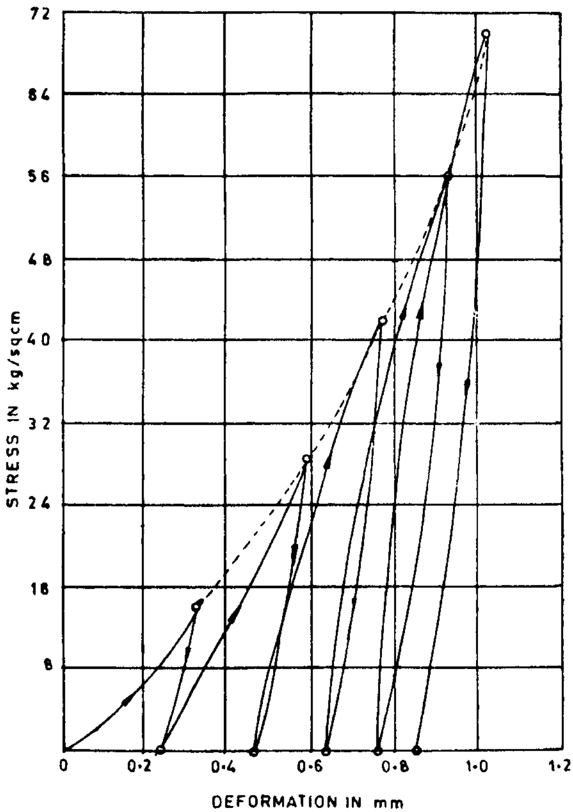


FIG. 5 DEFORMATION *Versus* STRESS APPLIED

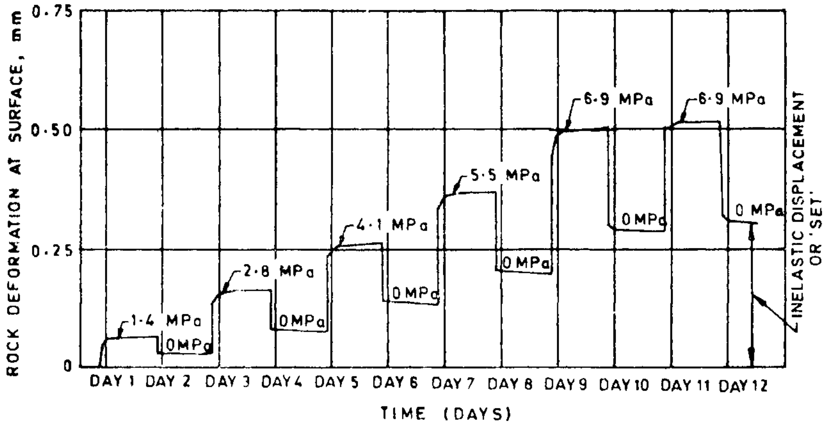


FIG. 6 ROCK DEFORMATION AT SURFACE *Versus* TIME-UNIAXIAL JACKING TEST

6.2 The deformation of a rock is partly elastic (reversible) and partly plastic (irreversible) and includes mainly deformation of rock, displacement on account of closure of joints existing in the rock mass and displacement by sliding along the fissures. The sum total of these is called the deformation of the rock mass, which is thus complicated and includes elastic, plastic and time dependent behaviour.

6.3 The purpose of the uniaxial jacking test is to determine the extent to which the rock mass shall deform under externally applied loads. Care is thus needed in the interpretation of the results of the tests so that the settlement of the structure is correctly estimated. Computations for the determination of modulus of deformation should include all deformations due to applied loads whether elastic or plastic and the creep effect and exclude any deformation on account of blast damage, surface preparation or any other loosening effect which is assumed equal to deformation in the first cycle resulting in consolidation of disturbed zone of rock mass.

6.4 The effect of creep shall be taken care of while computing the deformation mudulus.

6.5 The evaluation of deformation modulus is based on Boussinesq solution for a point load on infinite homogeneous, isotropic and linearly elastic material.

The modulus of deformation corresponding to test set up described in **4.3** and **4.4**, for each cycle shall be calculated from the following formula:

$$Ed = m\,\frac{(1 - \nu^2)}{\delta} \times \frac{P}{\sqrt{A}}$$

where

Ed = modulus of deformation in kg/cm²;

m = 0·96 for circular plate, and 0·95 for square plate;

ν = Poisson's ratio of the rock from the laboratory tests on representative rock cores. If its value has not been determined in the lab, it may taken to fall between 0·20 and 0·30. Its value for different rock types shall be assumed as 0·20 for excellent rocks such as granite, etc, 0·25 for gneiss, quartzites, etc, and 0·30 for mica schist, slates, etc;

δ = deformation of the test slate in one loading cycle in cm;

P = total load on the test plate in kg; and

A = area of test plate in cm².

Similarly, elastic modulus (Ee) shall be calculated for each cycle from the above equation by taking δ equal to recoverable deformation of that cycle.

6.6 For the test set up described in **4.5**, the displacement at and point beneath the centre of a circular loaded area is expressed as follows:

$$\delta = \frac{2P(1-\nu^2)}{E}\left[\sqrt{R^2 + Z^2} - Z\right] - \frac{PZ(1+\nu)}{E}\left[\frac{Z}{\sqrt{R^2+Z^2}} - 1\right]$$

where

δ = displacement in the direction of loading,

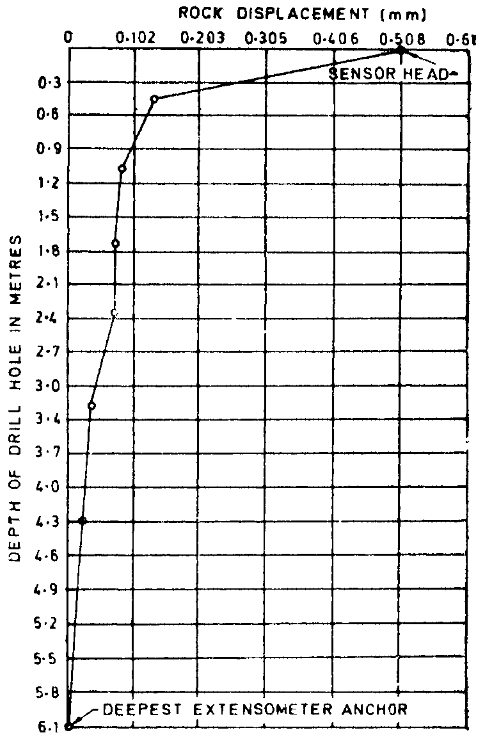
Z = Distance from loaded surface to the point where displacement is measured,

P = stress at loaded surface,

R = radius of loaded area,

ν = Poisson's ratio of the rock, and

E = modulus of elasticity.



ANCHOR DEPTHS

Sensor Head	0 0 m
Anchor One	0.5 m
Anchor Two	1.1 m
Anchor Three	1.8 m
Anchor Four	2.4 m
Anchor Five	3.2 m
Anchor Six	4.3 m
Anchor Seven	6.0 m

0-Depth where rock deformation was measured when load were applied at surface (0-Depth)

FIG. 7 ROCK DEFORMATION *Versus* DEPTH-UNIAXIAL JACKING TEST WITH BOREHOLE EXTENSOMETERS

At the loaded surface, where value of 'Z' is zero, the above equation may be rewritten as:

$$Ed = 2.P.R\,(1 - \nu^2)/\delta$$

But in the test set up in question, the load shall be applied through a circular flat jack with a hole in the centre and therefore considering R_1 as inner radius and R_2 as outer radius of the flat jack the displacement expression becomes as:

$$\delta = \frac{2P(1-\nu^2)}{Ed}\left[\sqrt{R_2^2 + Z^2} - \sqrt{R_1^2 + Z^2}\right] + \frac{P\,Z^2(1+\nu)}{Ed}\left[\frac{1}{\sqrt{R_1^2 + Z^2}} - \frac{1}{\sqrt{R_2^2 + Z_1^2}}\right]$$

By putting the values of R_1, R_2, and Z, the displacement at a particular point '1' or '2' may be expressed as:

$$\delta_1 = P.(K_1)/Ed \text{ or } \delta_2 = P.(K_2)/Ed$$

Therefore, the modulus of deformation of the rock mass in the zone between depth Z_1 and Z_2 may be determined from the following equation:

$$Ed = P.(K_1 - K_2)/(\delta_1 - \delta_2)$$

6.7 Besides, creep factor shall also be calculated for each cycle by the following expression (*see* Fig. 6):

$$\text{Creep Factor}(\%) = \frac{\text{creep of the cycle}}{\text{deformation during load increase}} \times 100$$

7 REPORTING OF THE RESULTS

7.1 In addition to the information in **2.5**, the report of the test should also include the following:

a) Whether the test was conducted in a drift or on a rock surface in open;

b) Location of the test site indicating three dimensional coordinates, drift number, chainage, etc;

c) Extent of rock/loose burden above the test site;

d) Whether the test was conducted on floor, or on roof or on side walls;

e) Period elapsed between excavation of the site and testing;

f) Direction of testing, that is, whether vertical, horizontal or inclined;

g) Orientation of the rock mass stratification and the direction of loading during testing;

h) A complete geological description of the rock mass with RMR and Q.

j) *In-situ* stresses in the rock mass;

k) Name of the testing agency;

m) A description of the uniaxial apparatus including the photos of the installed equipment, specifications, accuracy, sensitivity of all the pressure and deformation instruments;

n) Tabulation of the observed data;

p) Plots of stress *Versus* deformation, time *Versus* deformation and depth *Versus* deformation;

q) Deformation and elastic moduli at different stresses levels;

r) Creep factors at different stress levels;

s) Any other relevant information; and

t) A plot between *Ed*/*Er* and RMR will help in selecting design deformation modulus.

8 APPLICATION OF MODULUS OF DEFORMATION

8.1 The designer should be careful in application of *in-situ* moduli of rock mass on the following points:

a) Modulus of deformation (*Ed*) for static analysis of foundation of dams, etc, corresponding to various stress levels in the rock foundation;

b) Dynamic modulus for dynamic analysis of dams, etc, which may be taken equal to elastic modulus (*Ee*) corresponding to the maximum stress level of the test. This is recommended because dynamic deformation will be simulated more realistically by *Ee* than by *Ed*;

c) Elastic modulus (*Ee*) for design of concrete lining in pressure tunnels and penstocks, etc, because internal water pressure leads to reduction of deviatoric stresses within the rock mass;

d) In practice, the *in-situ* rock mass lies under confining pressure due to depth, but the deformation modulus is measured with almost no confining pressure. Besides, in drifts the tests are performed in elasto-plastic zone near the surface of the rock mass. Thus, in poor rock masses the increase in modulus of deformation with confining pressure and depth below ground surface becomes important and pronounced. However, it leads to a conservative design of borehole extensometers are not used; and

e) In river valley projects, rock mass gets saturated in some areas after charging water conductor system/after filling of reservoir. The modulus of deformation and elastic modulus are reduced drastically specially in poor rocks with water sensitive minerals. Thus these moduli should be multiplied by suitable correction factors for saturation where tests are not done on saturated rock masses.

NOTES

1 The settlement of foundations of high dams specially in narrow valleys should be analysed by the 3 D Finite Element Method (Two dimensional analysis is found to give very conservative and unrealistic results).

2 If the behaviour of the rock mass is plastic, non-linear analysis should be performed.

Standard Mark

The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act, 1986* and the Rules and Regulations made thereunder. The Standard Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well defined system of inspection, testing and quality control which is devised and supervised by BIS and operated by the producer. Standard marked products are also continuously checked by BIS for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Handbook' and 'Standards Monthly Additions'. Comments on this Indian Standard may be sent to BIS giving the following reference:

Doc : No. CED 48 (4967)

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones : 331 01 31, 331 13 75

Telegrams : Manaksanstha
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Regional Offices:	Telephone
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Eastern : 1/14 C. I. T. Scheme VII M, V. I. P. Road, Maniktola CALCUTTA 700054	37 84 99, 37 85 61 37 86 26, 37 86 62
Northern : SCO 445-446, Sector 35-C, CHANDIGARH 160036	53 38 43, 53 16 40 53 23 84
Southern : C. I. T. Campus, IV Cross Road, MADRAS 600113	235 02 16, 235 04 42 235 15 19, 235 23 15
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Printed at Printograph, New Delhi, India