BUILDING DIGEST
CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

THE INVESTIGATION OF BOULDER DEPOSITS

Introduction

The study of boulder deposits and deposits with a large percentage of gravel is of importance in river valley projects where heavy structures are needed to be founded on such deposits. The investigation of such deposits is of paramount importance in India in the context of large river valley projects.

In general, boulder deposits are of fluvial or glacial origin. The boulders may be in contact with each other or may exist in a matrix of filler material like sand, silt or even clay. The behaviour of such deposits is governed by the proportion of the boulders or gravel and the filler material. If the filler material exists only in the interstices of the boulders, the boulders being in contact, the behaviour is entirely governed by the boulder. On the other hand, if the boulders exist in a matrix of filler material the properties of the matrix governs the behaviour, the presence of the gravel or boulders reducing, to some extent, the compressibility of the matrix material.

Methods of Investigation

The usual methods of investigation adopted for fined grain soils is of not much use in such deposits. The large size of the aggregates in the soil render the ordinary laboratory methods with small samples ineffective. The only course open to an investigator is to adopt in-situ large scale field tests.

Field Tests

(i) **Trial Pits :-** These are of sufficiently large size (5×5 m), with proper side slopes or with shored sides may be used to ascertain the depth of such deposits. During the course of the excavation sample collection for grain size analysis, and water content can be made. The pits can also be used at different stages for density determination. The density determination with the water displacement method, similar to the sand displacement used for ordinary soils, is well adopted for this purpose.

(ii) **Dynamic Cone Tests :-** Dynamic cone tests can be performed for the investigation if the boulder size does not exceed 12 to 15 cm. The test set up is similar to that of the standard penetration test with Standard SPT sampler being replaced by a push fit cast iron cone of 60° apex angle and base diameter 6.25 cm. The cone is driven in from the surface or from the level of the proposed footing by a 65 Kg. hammer dropping from a height of 75 cms. The number of blows for every 15 cm penetration is counted and a plot of the cumulative number of blows with D/Bc ratio (D depth, Bc cone diameter) is prepared. A typical plot is shown in Fig. 1.

(iii) **In-Situ Shear Tests :-** Two types of shear tests can be performed at the site. The first is to cut out a block of the boulder soil and shear it under a normal load. This test is called Boulder-Boulder Test (BBT). The other type, called the Concrete-Boulder Test (CBT), consists in casting a concrete block and pushing it laterally under a given normal load. It has been found that the residual shear values obtained from both the tests are the same. This test has the advantage that it eliminates the needs for a shear box. Often times the concrete blocks used for load tests can be used for this purpose and thus serve the purposes of the shear and load tests.

The test set up, with a sample of the results for both types of tests is shown in Figs. 2, 3 and 4. The normal load used in the tests is either the existing overburden pressure or such pressure that will not cause a bearing capacity failure under the block.

(iv) **Load Tests :-** Considering the large size of aggregates involved, large size footings need to be used in the test. Steel plates are not of much use because of seating difficulties. Best results are obtained with cast-in situ concrete blocks or with precast blocks set with fresh mortar so that there is perfect bond between the soil and the block.

These may be loaded using loaded kentledges and hydraulic jacks. The deflection can be measured with dial gauges or with the levelling instruments if the deflections are large.

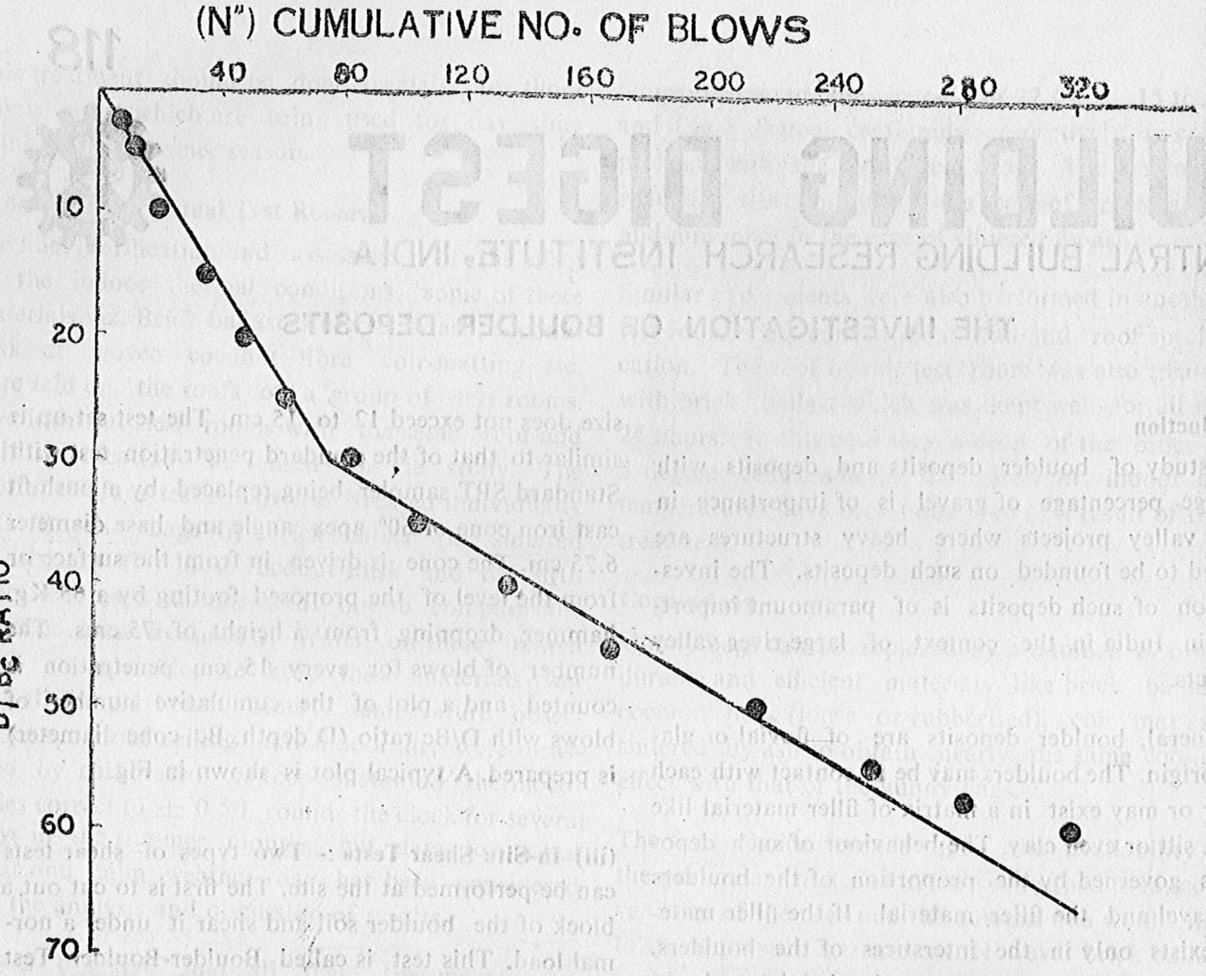

FIG. 1 TYPICAL PLOT OF DEPTH / WIDTH (D/Bc) AND CUMMULATIVE No. OF BLOWS (N")

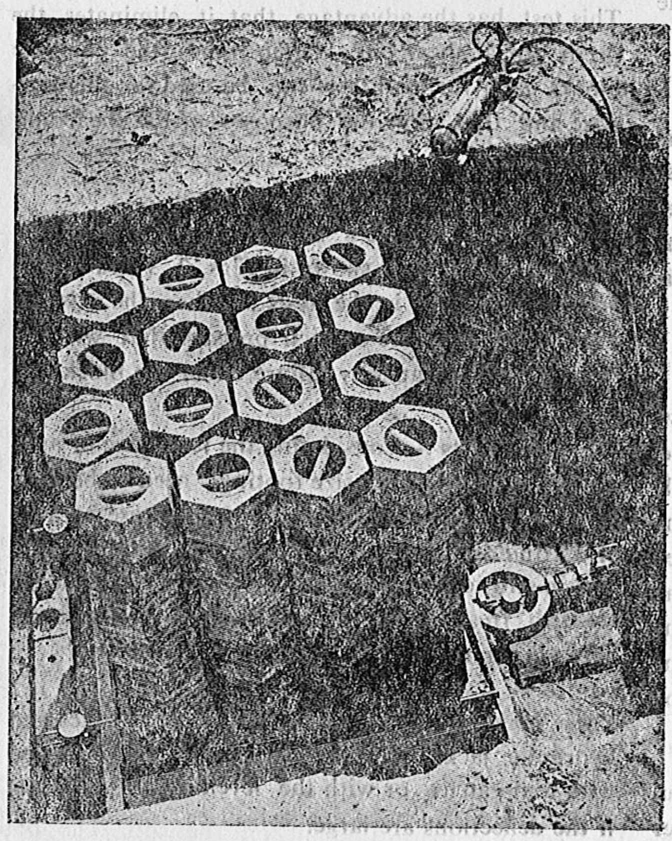

Fig. 2. IN-SITU SHEAR TEST (BBT) SET-UP

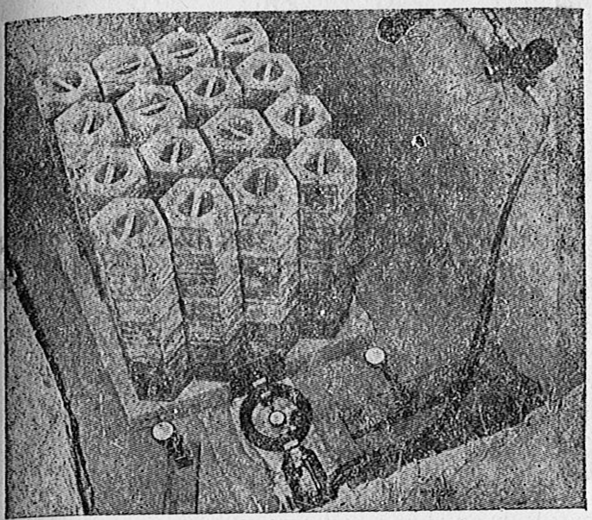

Fig. 3. IN-SITU SHEAR TEST (CBT) SET-UP

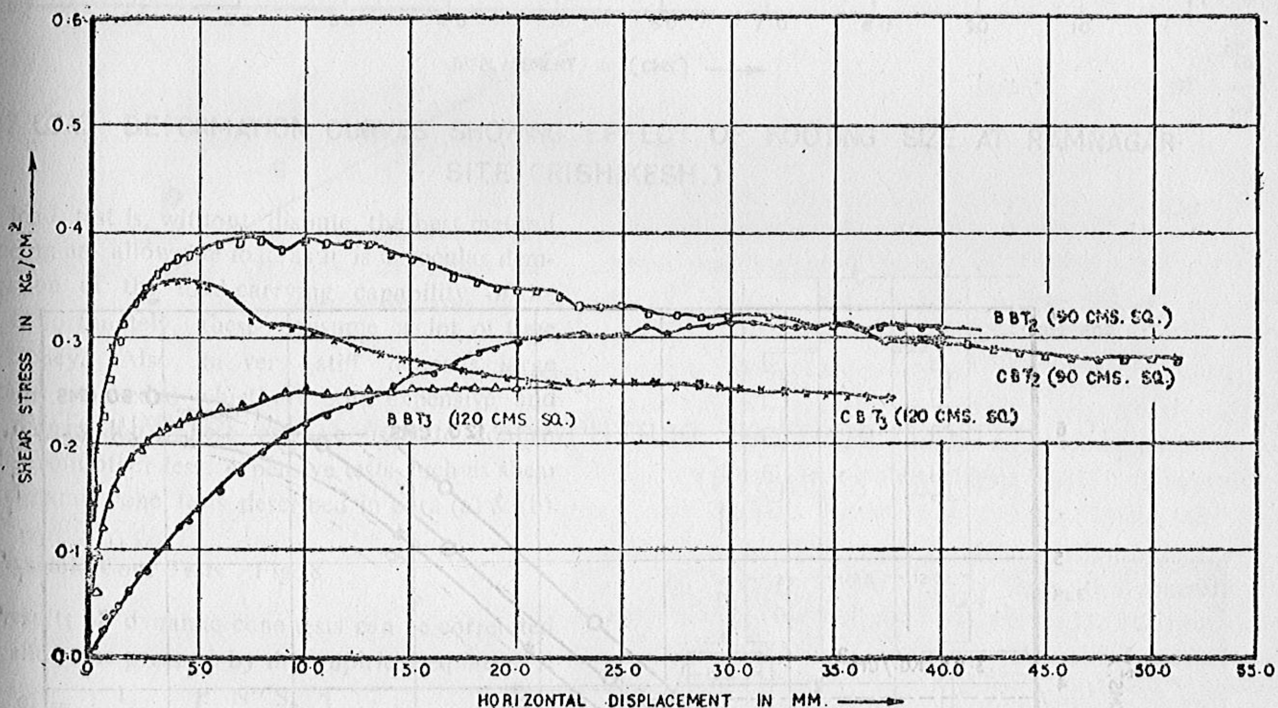

FIG. 4 COMPARISION OF BBT AND CBT SHEAR TEST RESULTS AT MUNI KA RETI SITE (RISHIKESH)

Typical set-up and results are shown in Figs. 5 and 6.

The size of the block used in the tests should be large enough to reflect the group behaviour of the boulder and the filler material. Generally, the block size should be of the order of 8 to 10 times the average boulder size. In practice, a 100×100×15cm reinforced block is sufficient for the purpose.

Behaviour Under Load

The boulder soil unlike the ordinary soil shows certain peculiar characteristics when the boulder proportion is large, the deposit shows an initial rapid compression followed by a stage where the compression decreases considerably as the boulders take over the load carrying function. In such cases it is of advantage to have the allowable load well in excess of the load at which initial compression occurs, thus reducing settlements at working loads.

In other cases, i.e. where the boulder quantity is small normal methods of interpretation can be used (I S: 1888-1971).

Typical cases are shown in Fig. 7.

Allowable Soil Pressure

The purpose of all soil investigation is to find a suitable load to be put on the soil. The boulder deposit is no exception.

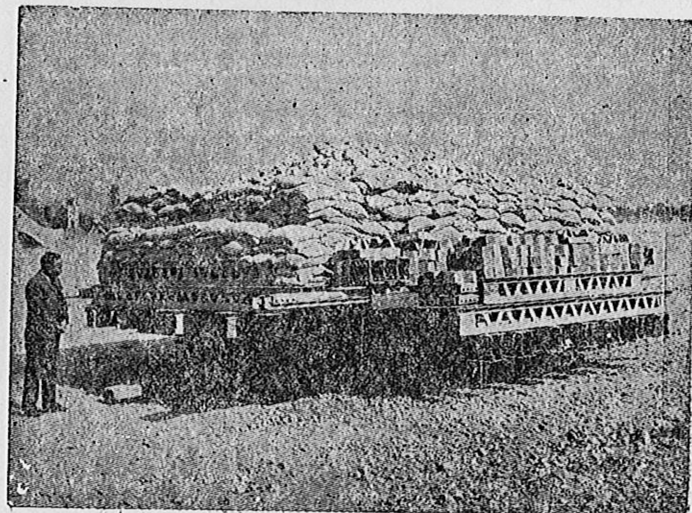

Fig. 5. LARGE SCALE LOAD TEST ON BOULDER DEPOSITS AT RISHIKESH

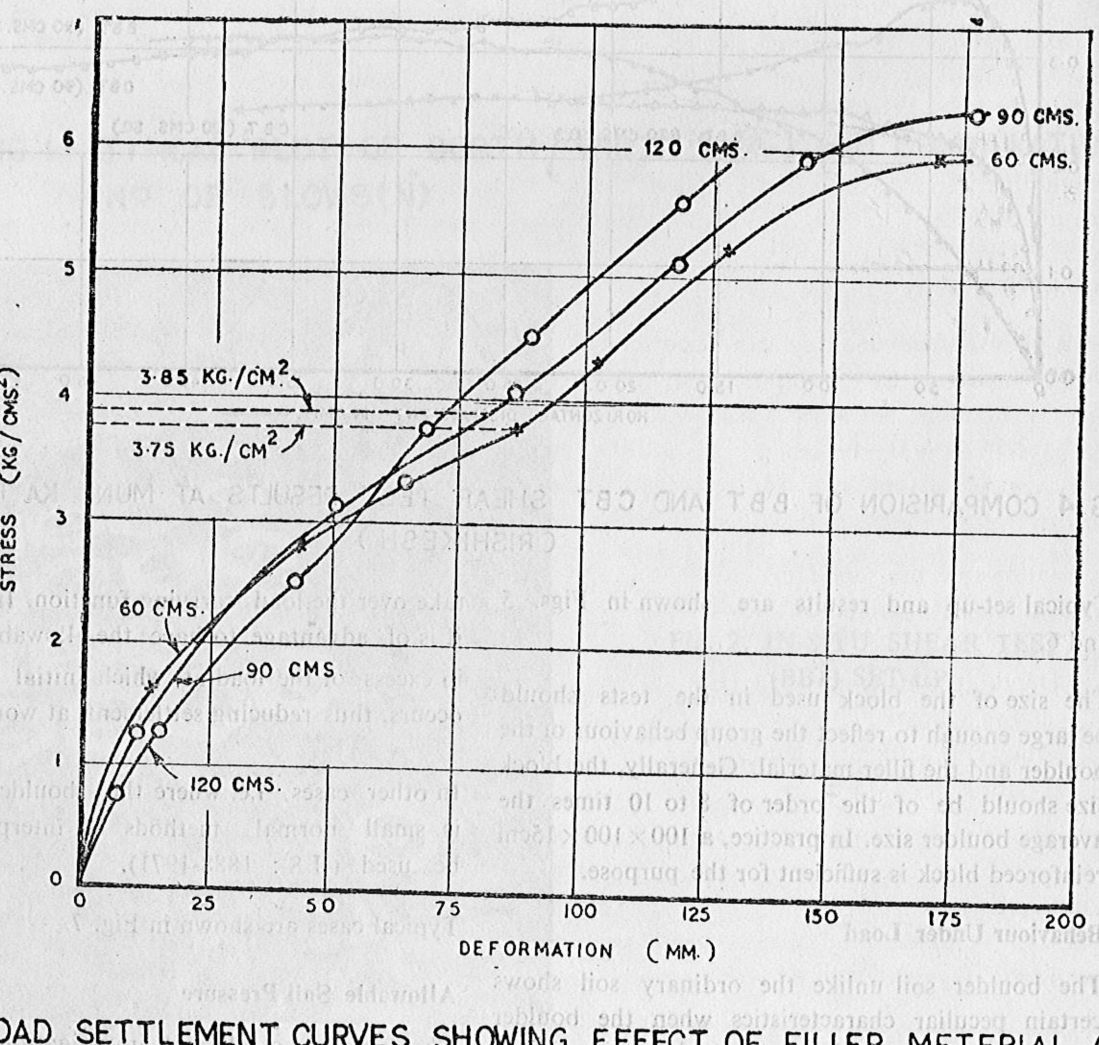

FIG. 6 LOAD SETTLEMENT CURVES SHOWING EFFECT OF FILLER METERIAL AT FACTORY SITE (RISHIKESH)

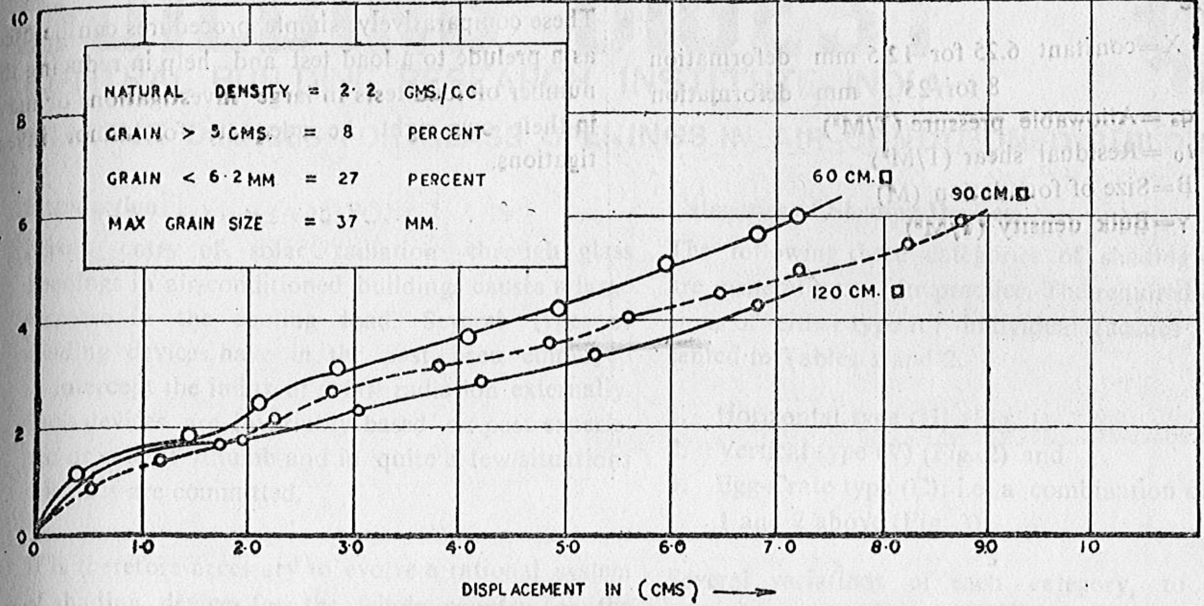

FIG.7 LOAD DEFORMATION CURVES SHOWING EFFECT OF FOOTING SIZE AT RAMNAGAR SITE (RISHIKESH.)

The load test is, without dispute, the best method of finding an allowable load as it is an ocular demonstration of the load carrying capability of the soil. Unfortunately, these consume a lot of time and money. Also, in very stiff deposits large reactions are needed which are both expensive and time consuming. These can be used to confirm results from other less expensive tests such as shear and dynamic cone tests described in para (a) & (b).

(a) Dynamic Cone Tests Fig. 8.

The results of dynamic cone tests can be correlated with allowable pressure by the empirical equation :

$$q_a = \frac{1}{2.54} \left[\frac{N'' S_a}{D_c \; B_f} \right]$$

where

- q_a = allowable pressure T/m²
- N″ = Cumulative number of blows upto depth D_c .
- D_c = Depth at which blows vs D/B_c curve shows a break
- S_a = Allowable settlement (cm)
- B_f = Footing size (M)

Comparison with load test results for footings up to 120 cm. show a high degree of correlation (Coeff. of correlation 0.9).

(b) Shear Tests Figs. 2, 3 and 4.

The value of residual shear τ_0 can be related to the allowable pressure at 12 mm. deformation by the empirical equation :

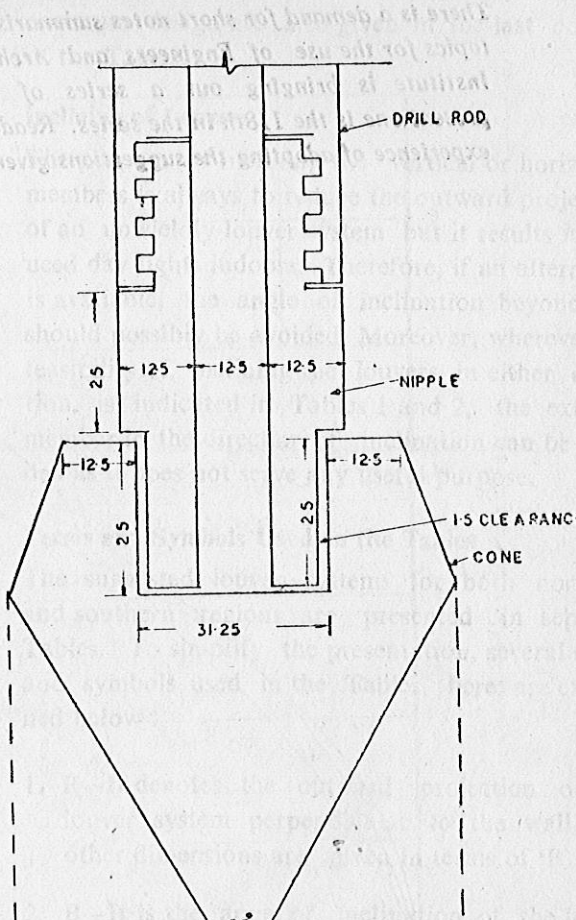

FIG 8· DIAGRAMMATIC SKETCH OF 62·5MM DIA.CONE

ALL DIMENSIONS IN MM

$$q_a = (X)\, t_0 \left[\frac{B+0.3}{B}\right]^2 \gamma$$

where

X = constant 6.25 for 12.5 mm deformation
8 for 25 mm deformation

q_a = Allowable pressure (T/M^2)

t_0 = Residual shear (T/M^2)

B = Size of foundation (M)

γ = Bulk density (T/M^3)

Comparison with load tests shows a high degree of correlation (coeff. of correlation 0.8)

These comparatively simple procedures can be used as a prelude to a load test and help in reducing the number of load tests in large investigations or may, in their own right, be adequate for minor investigations.

There is a demand for short notes summarising available information on selected building topics for the use of Engineers and Architects in India. To meet the need this Institute is bringing out a series of Building Digests from time to time and the present one is the 118th in the series. Readers are requested to send to the Institute their experience of adopting the suggestions given in this Digest.

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