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Development of a Computer Interfaced Fatigue Test Set-Up for Soil Stabilised Pavement Materials

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Introduction

Good quality road aggregates are getting scarce and costly and at the same time they are not available in many locations because of high cost of haulage when the quarry site is too far. Under the circumstances, road construction using mixture of soil, sand, weak aggregates, flyash, lime, portland cement etc. emerge as viable solutions at lower cost depending upon the site and quality of locally available materials.

California Bearing Ratio is not the appropriate test property for pavement design for any soil stabilised with portland cement, lime or lime-flyash mixture since those materials have considerable low strength. It is the elastic modulus of the such materials together with their fatigue properties at the prevailing vehicle speed, that should be used for pavement design (Bhattacharya and Pandey, 1986; Bhattacharya and Pandey, 1987a; Pandey and Mandal, 1988; and Reddy and Pandey, 1995).

One of the major handicaps facing the highway engineers is the non-availability of a suitable equipment in Indian market for evaluation of elastic modulus and fatigue behaviour of lime/flyash/cement treated soils. The instruments like INSTRON and MTS closed loop testing machines may cost as high as fifteen lakhs of rupees and soil mechanics or highway engineering laboratories possessing modest fund can not acquire them. This paper

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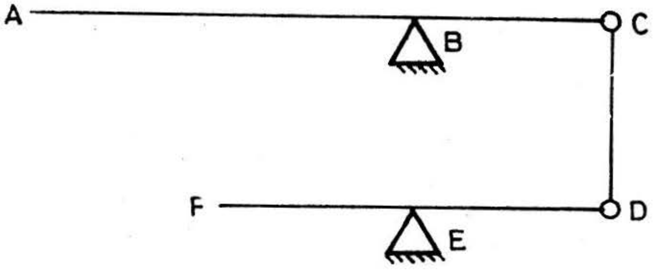

FIGURE 1 : Principle of the Test Set-Up

describes fabrication of a fatigue test equipment, working in constant strain mode for evaluation of elastic modulus and fatigue behaviour of soil stabilised materials.

The equipment developed earlier by the senior author (Bhattacharya and Pandey, 1987a) was suitable for low frequency tests on soil specimen under triaxial stress condition.

Basic Characteristics of the Test Set-Up

Nature of Traffic loading

A pavement made up of cement treated soil, sand or aggregates behaves like an elastic plate under fast moving traffic; and the repeated flexural tensile stresses induced by the wheel loads, cause fracture of the material. The number of repetitions of fracture depends upon the magnitude of flexural stress; and higher the stress, lower is the number of repetitions required for the fatigue failure.

It is, therefore, necessary to apply cyclic flexural load of various magnitudes to the beam specimen at a frequency simulating the prevailing speed of commercial vehicles which is about 50 to 60 kmph. The frequency of 10 Hertz (Hz) corresponds to a speed of about 60 kmph for bituminous roads (SIPCL, 1978), hence for a cement treated soil also, same frequency is used for the laboratory testing though cement treated materials are less sensitive to the speed of testing.

Principle

Principle of lever is used in fabricating the test set up. Figure 1 shows lever arms AC and FD with fulcrums at B and E. A vertical link CD joins AC and FD. They are connected with the help of four bearings provided at B, C, D, and E. The locations of B and E are so chosen that ratios of lever

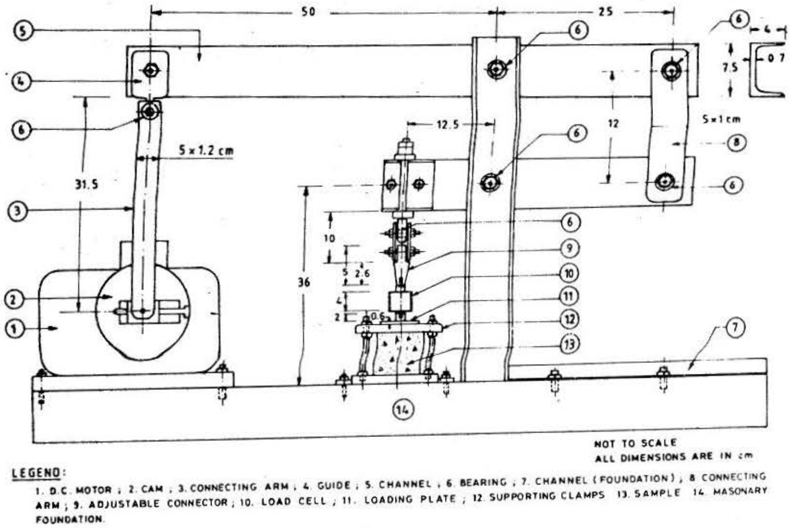

FIGURE 2 : Experimental Set-Up (Side View)

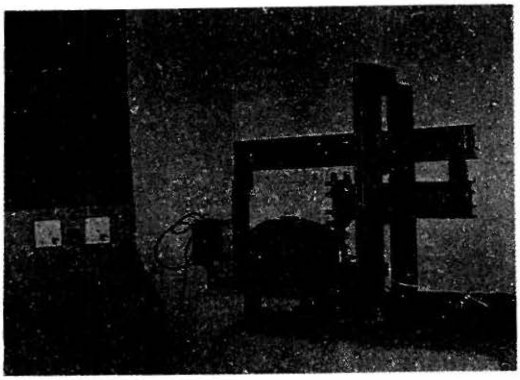

FIGURE 3 : Experimental Set-Up

arms AB and BC as well as DE and EF are each equal to 2 to 1, so that load applied at A is magnified by four times at F. Some of the mechanical vibrations produced at A are filtered out in the system and a smooth vertical displacement is obtained at F due to the rotation caused by a cam fitted to a motor at A.

Components of Test Set-Up

The schematic diagram of the experimental set-up developed by the authors is shown in Fig. 2 and a close-up view is given in Fig. 3. Part 13 of Fig. 2 shows the cross section of the beam specimen under third point loading.

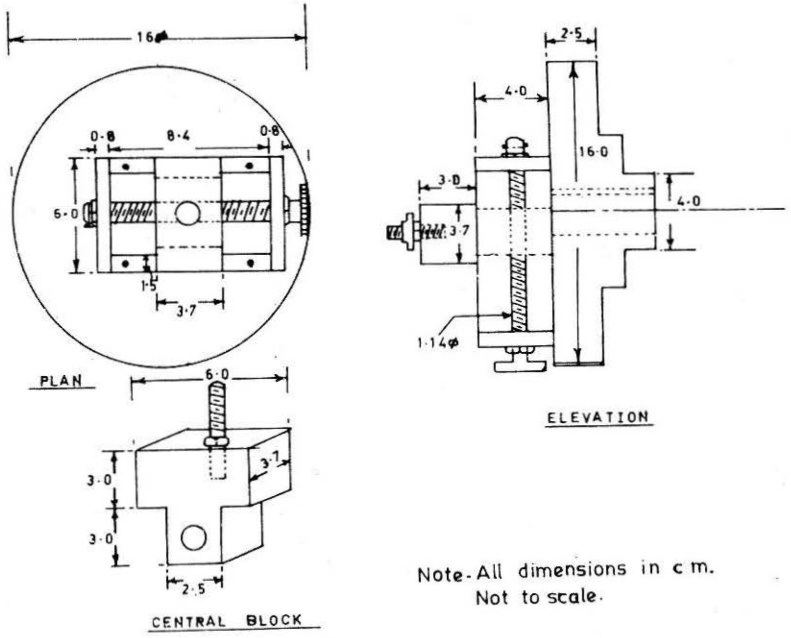

FIGURE 4 : Details of Cam

The important components of the set-up are described below :

DC Motor

A variable speed D.C. motor of 2 H.P. was installed over a concrete foundation in the transverse direction of the main-frame channels so as to impose a constant deflection through a cam arrangement.

Cam

The cam connected to the D.C. motor is capable of providing the desired eccentricity. The details are shown in Fig. 4. Different values of deflections are applied by changing the eccentricity of the cam. A mechanical counter is connected to the cam for recording the number of cyclic loading.

Speed Controller

An electrically operated speed controlling unit has been connected with the D.C. motor having in-built voltage stabilizer. The variac provided in the unit regulates the current which in turn controls the speed.

Measurement of Load and Deflection

A tension–compression load cell was mounted over the specimen for monitoring of the applied load during cyclic loading. The deflection caused by the applied load was recorded by using an LVDT below the specimen at the central point.

The load and the deflection values were used to determine the elastic modulus, the bending stress and the bending strain in the beam.

Universal Amplifier

Output voltages from the load cell and LVDT were raised between 100 mV and 10 V by means of an amplifier available in the laboratory so that the signals can be digitized and stored in a PC using a data acquisition card.

Computer Interfacing

Data acquisition cards with built-in Analog–Digital (A/D) converter, compatible with PCs of various makes are commercially available in the market. In the present set-up, the data card PCL-208 was fitted to a PC of the Highway Engineering laboratory. The software supplied along with the card was used for data acquisition.

Screw Terminal Board (1994b)

The signals from the load cell and the LVDT after the required amplification were taken to the screw terminal board which in turn connected to the PCL-208 by means of a 24 pin connector cord. The board provides a connector pin configuration through which user can design his own sequence of connections from the origin of electrical pulse to the PCL card. The R–C network present in this card acts as protection device to voltage sensitive components and suppresses spikes.

PCL-208 (1994c)

The key features of this card are :

1. Switch selectable 16 single-ended or 8 differential analog input channels.
2. 12 bit successive approximation converter to convert analog inputs. The maximum ranges being ±10 V for bipolar and +10 V for unipolar cases.

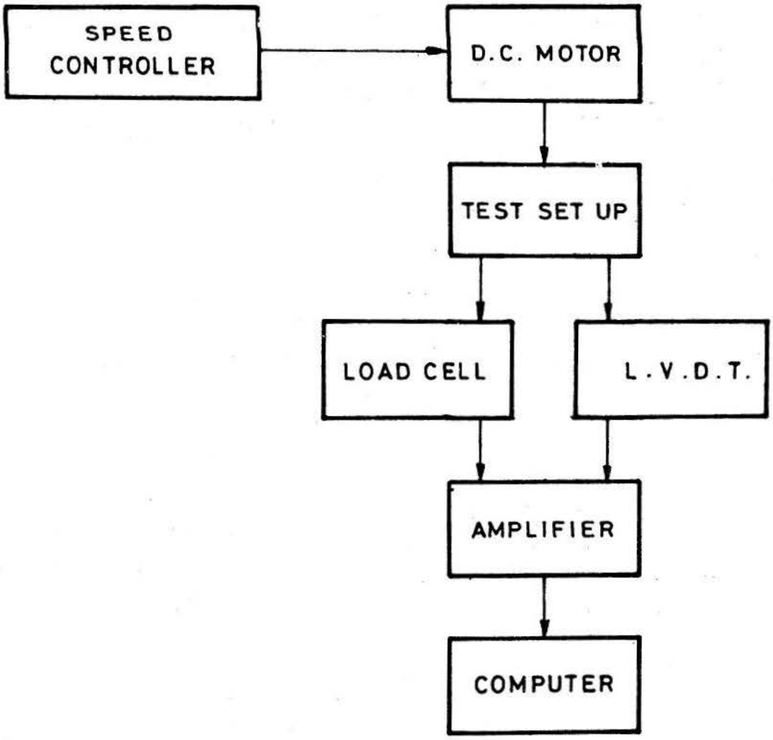

FIGURE 5 : Block Diagram of the Test System

3. Three A/D trigger modes : software trigger, programmable pacer and external pulse trigger.
4. The maximum A/D sampling rate is 60 kHz in Direct Memory Access mode. The programmable timer provides pacer output at the rate of 2.5 MHz to 71 minutes/pulse to the A/D. The timer time base is switch selectable 10 MHz or 1 MHz.

For this research, the sampling rate was selected as 1000 Hz and data was stored for 0.5 sec for each experiment. Figure 5 illustrates flow diagram of the test system.

Calibration

Load Cell

For calibration of the load cell, a load of known magnitude was applied with the help of proving ring and the change in voltage displayed in the screen of the PC is noted. A number of readings were taken at different applied loads and the mean value was taken for standardisation at

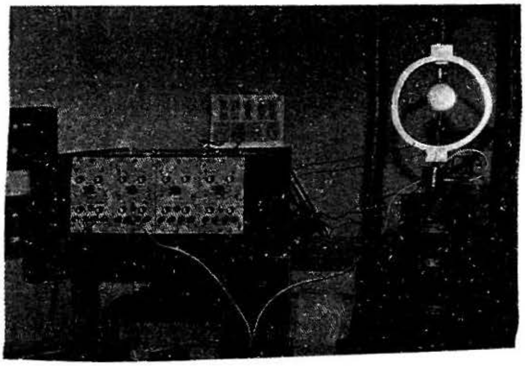

FIGURE 6 : Calibration Process

different sensitivity knob settings of the amplifier. Figure 6 shows the calibration process by means of a proving ring.

LVDT

Similarly, for a known displacement applied to the core of the LVDT, the resulting voltage change in the PC is recorded.

Figures 7 (a) and (b) represent the calibration charts for the load cell and LVDT, respectively, for different sensitivity settings of the amplifier.

Use of the Equipment for Test of Stabilised Soil

Preparation of the Test Specimens

To determine the working of the equipment, cement treated and lime treated laterite soils were used for laboratory tests. Lime soil mixture had a lime content of 5%, while the cement treated had 12% of the cement by weight of dry soil. The weighed amount of soil mixed with lime and/or cement at the optimum moisture contents (OMC) was transferred in three layers into a mould of size 76 mm × 80 mm × 380 mm, each layer being rodded 25 times with a 12 mm diameter bullet ended steel rod. Necessary static load was applied to obtain the required density. The materials and their density values are given in Table 1 (1992). The sample was covered in airtight polyethylene packets and was kept in an oven at 50 °C for 3 days for curing. This was equivalent to 40 to 50 days of curing at room temperature (1992).

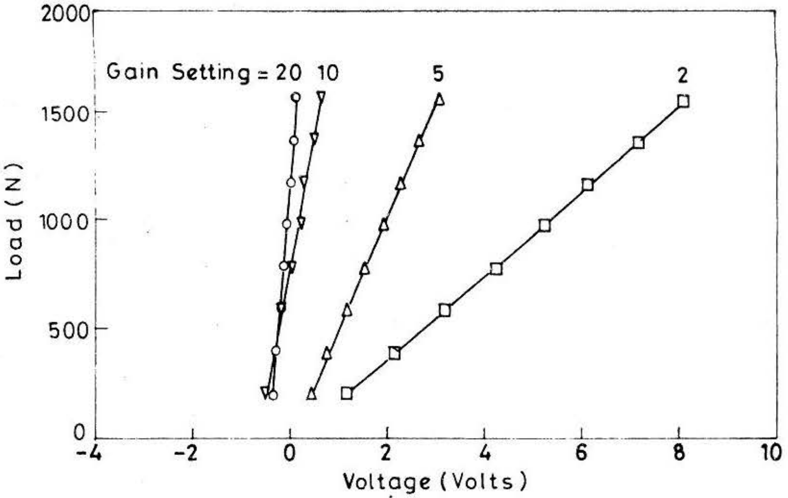

FIGURE 7a : Calibration of Load Cell

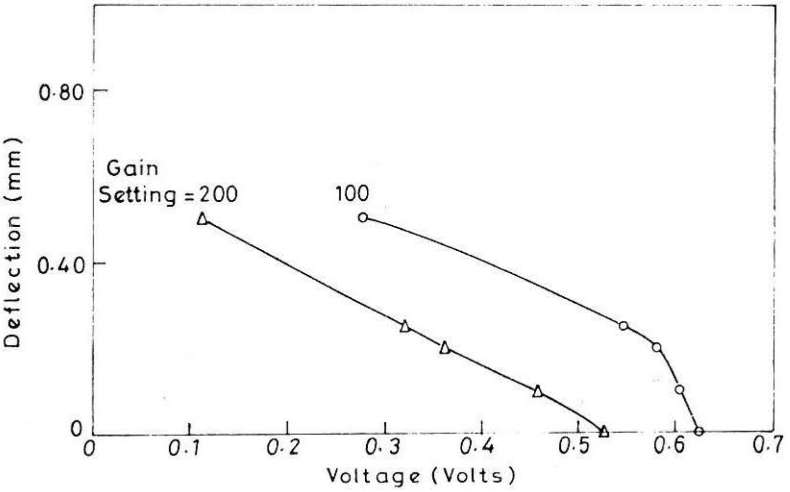

FIGURE 7b : Calibration of LVDT

Test of the Beam Specimens

The beam of the soil mix was placed properly in the horizontal position as shown in Fig. 8. All the connections were checked to ensure proper functioning of the machine before starting the motor. The required deflection was adjusted by changing the eccentricity of the cam. The LDVT was placed under the centre of the specimen to record the deformation.

The motor was run for approximately two minutes for conditioning of

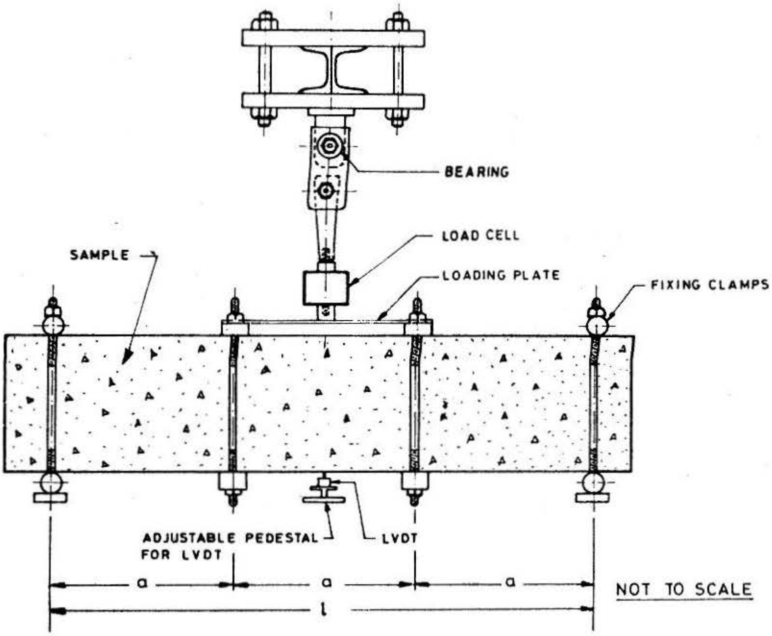

FIGURE 8 : Longitudinal View of the Specimen under Cyclic Load

the specimen, and after that the amplifier and the PC were switched on to record load and deflection.

The data acquisition was done for 0.5 seconds to record 500 cycles of load and deformation at an acquisition speed of 1000 Hz. The acquired data for load and deflection were plotted by a standard software and are shown in Figs. 9(a) and 9(b).

Results and Analysis

From the collected data the dynamic modulus (E) of the stabilised soil can be calculated using the following equation :

$$E = \frac{P\,a}{48\,I\,y} \times \left(3a^2 - 4l^2\right) \tag{1}$$

where
E = dynamic modulus (MPa),
P = total applied load (N),
I = $bd^3/12$ = moment of inertia of section (mm^4),
b = width of beam (mm),
d = average depth of beam (mm),

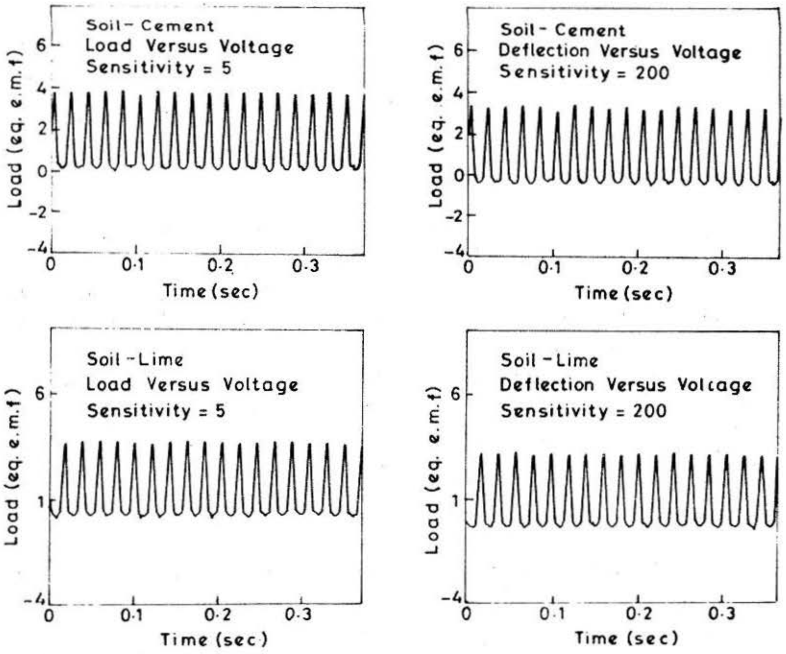

FIGURE 9 : Graphical Representation of Acquired Data

y = central deflection (mm),
I = effective length of beam (= 345 mm), and
a = distance between centre of support to load point (= 115 mm)

$$E = \frac{P \times 115}{48\, I\, y} \times \left[3(345)^2 - 4(115)^2\right] \tag{2}$$

$$E = \frac{728753 \times P}{I\, y}\ \text{MPa} \tag{3}$$

Tensile stress in the central part of the beam is determined from the equation :

$$\varepsilon_t = \frac{\sigma}{E} = \frac{M\, d}{2\, I\, E} \tag{4}$$

where ε_t = tensile strain,
M = bending moment = $Pa/2$, and
s = tensile stress = $Md/2I$

The above parameters were calculated for the two samples and are represented in Table 2

Cost of the Apparatus

Total cost of the apparatus including PC, data acquisition card, amplifier, load cell, LVDT and electric motor comes to *about Rs. 1.85 lakhs*. But most of them are generally available in the highway or soil mechanics laboratories and assembling them in a working condition is not a costly proposition. The interfacing technique can be used for recording of load cell and LVDT readings for any type of tests in the laboratory.

Acknowledgement

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Notations

E = dynamic modulus

P = total applied load

I = $bd^3/12$ = moment of inertia of section

b = width of beam

d = average depth of beam

y = central deflection

l = effective length of beam

a = distance between centre of support to load point

ε_t = tensile strain

M = bending moment = $Pa/2$

σ = tensile strain = $Md/2I$