Indigenous Development of an Improved Magnetic Settlement Gauge

by

R.K. Bhandari*

P. Srivastava**

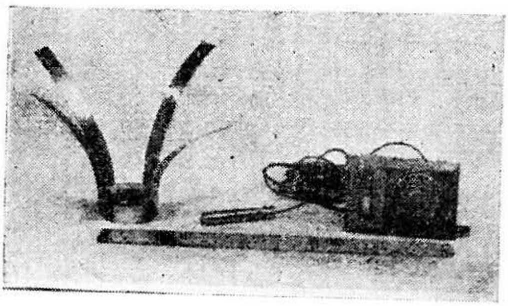
Introduction

Burland, Moore and Smith (1972) were the first to describe a precise borehole extensometer consisting of a number of ring magnets serving as markers. The markers were initially embedded at different depths in a borehole and later located at intervals of time by conducting a reed-switch sensor in a central access tube. Based exactly on the above principle Railway Research Design and Standards Organisations, Lucknow developed the first magnetic extensometer in India for measuring ground heave (Palit, 1977). Infrequent availability of indigenous ring magnets led Nagarkar et. al (1978) to develop a settlement gauge utilising four bar magnets instead of a single ring magnet. Disadvantages of such a gauge have been discussed by Bhandari and Srivastava (1978).

The paper describes an indigenously fabricated improved, more compact more rugged and a precise magnetic settlement gauge. Table I compares the gauge with those already known.

The Settlement Gauge and the Sensing Unit

The settlement gauge reported herein (Figure 1 and Figure 2) employs a ring magnet of 44 mm outer diameter, 30 mm inner diameter and 6 mm thickness. It is encapsulated in a nylon, PVC or any other nonmagnetic corrosion proof material. The overall size of the settlement markers thus becomes 60 mm diameter × 15 mm thickness. Every settlement marker possesses four steel springs 100 mm long, 20 mm wide and 1 mm thick at



FIGRE 1 Magnet Settlement Marker

* Head soil Engincerng Division Central Building Researeh Institute, Roorkee, India.

** Senior Research Fellow Central Building Research Institute, Roorkee, India.

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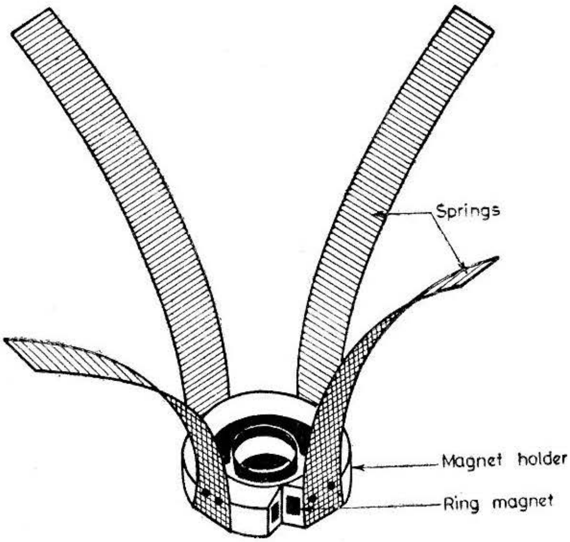

FIGURE 2 Magnet Settlement Marker

its outer periphery. The springs become an integral part of the casting that contains the ring magnet.

The sensing torpedo consists of a reed-switch housed in a non-corrosive material such as brass or stainless steel, Figure 3. A solid state detector unit i.e. an Audio-flasher unit (Figure 4) is connected to the torpedo by means of a graduated cable.

Transistors T_1 and T_2 from complimentary oscillator, the frequency of which is controlled by feed back components, R_1 and C_1. Working on a 6V battery it has enough power to drive a low impedence speaker directly. An indicator bulb is connected in parallel with the circuit, so that when the battery supply is on due to actuation of the reed switch, the bulb glows. The reed-switches used are Mark-6 single porle-single throw, Form-A type, requiring 17.5 to 52.5$\pm$ 7.5 stock ampere turns for getting actuated. Hence the magnetic field required to actuate the reed switch works out to be of the order of 50 Gauss only. That such order of magnetic field could be provided by a single ring magnet suggests that four bar magnets used by Nagarkar et.al. (1978) are not necessary.

Working Principle

The reed-switch, housed in a torpedo, when comes under the influence of the magnetic field of the ring magnet, the fine gap between the two ferrite electrodes of the reed-switch gets closed. As soon as that happens, the sensing unit gives light and audio indication. Working principle of the reed-switch is shoven in Figure 5

Installation

Various steps involved in installing the settlement gauge in the ground are given below:

TABLE 1

Magnetic Reed Switch Type Settlement Gauges Developed by Differeat Agencies

Reference/Type	Size and special features	Material of Magnet used	Method of Installation	Accuracy of Measurement
1	2	3	4	5
Burland et. al (1972) Burland and Moore (1974) (BRE, UK)	Permanent Ring Magnet of 3.2 cm internal dia. was coated with epoxy resin and mounted on to a 7.6 cm dia. PVC tube of short length	Axially oriented ferrite ring magnet	In a borehole 10 cm in dia., the magnet holders fitted with ring magnets were installed by means of an insertion tool lowered to the required depth. Magnet holder gets anchored by the bite of strong springs into the virgin ground as the insertion tool is withdrawn. Borehole is grouted to prevent buckling of the central PVC pipe	± 0.2 mm, as high as ± 0.02 mm; with precise guidance of reed switch
Nagarkar et. al. (1978) (MERI, India)	Settlement Plate made of mild steel 18 cm OD 8.5 cm ID and 1 cm thickness magnetised by four rectangular bar magnets of the size 5 cmx 1.5 cmx 1 cm	Not mentioned	In a 30 cm diameter borehole (under-reamed to 66 cm dia. at depth where magnet mounted plates were to be installed) a central PVC pipe (6 cm O.D., 4.8 cm I.D.) is inserted. Settlement plates are the left in place one by one and the borehole back filled with the augered material compacted to field density. Support from the virgin ground is not achieved	± 1 mm
Kapur (1978)	Wooden or plastic magnet holder	Axially oriented ferrite ring magnet	A 10 cm diameter borehole is made. Magnet holder support is achieved by the bite of the springs on the magnet holder with the virgin soil	± 2 mm
(CBRI, India)	A ring magnet 4.0 cm OD, 3.0 cm ID and 0.4 cm thickness is encapsulated in Nylon or PVC magnet holder mounted with strong stainless steel springs. Overall dimensions, 5 cm dia. and 1.5 cm thickness.	Axially oriented ferrite ring magnet	A 7.5 cm diameter borehole is made into which the central PVC tube is first lowered. The magnet holders are then slid to the required depths one by one. They are held to the virgin ground by means of four strong springs of strainless steel	± 1 mm with and graduated scale (least count = 1 mm)

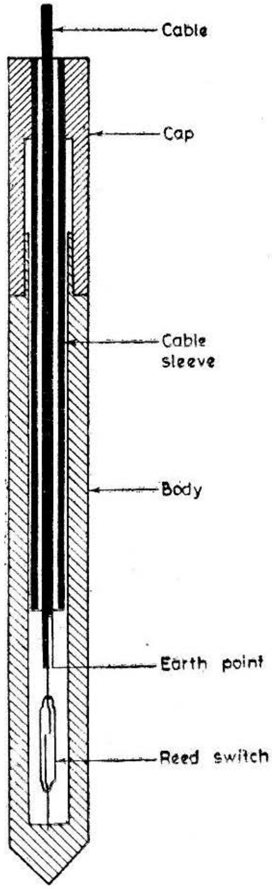

FIGURE 3 Torped to house Reed-Switch

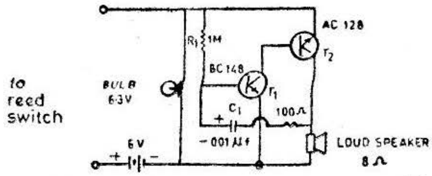

FIGURE 4 Audio, Flasher detector Unit

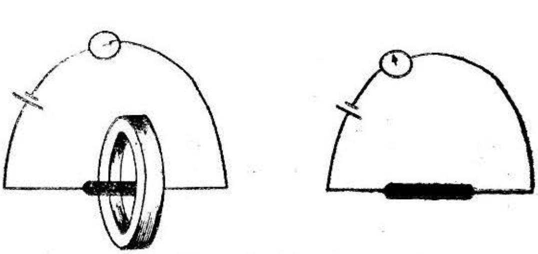

FIGURE 5 Working principle of the reed switch

(*a*) Make a bore hole of 75 mm diameter a little beyond the depth upto which the settlements are to be recorded. Ensure no loose material remains at the bottom of the hole. Resort to tamping of earch, if necessary.

(*b*) Lower a *PVC* semi rigid pipe (0*D*=19mm and *ID*=14mm with bottom plugged) down the borehole.

(*c*) Press the settlement point to position by means of an ejector pipe keeping the springs in upward direction. The ejector pipe should have a length equal to the depth of installation plus about two meters.

(*d*) Withdraw the ejector pipe leaving the settlement point at the required depth.

(*e*) Backfill the borehole with augered or bailed out material. Compact the filler soil to the in situ density as closely as possible and plug the borehole at the top. A detachable top cap provided on the central pipe will prevent any foreign matter getting into the pipe.

(*f*) If a number of settlement points are to be lowered in the same borehole, each settlement point should be kept in a separate lowering pipe (0*D* = 85mm and *ID* = 75mm) and pushed out at the appropriate depths using an ejector. The length of the lowering pipe should be equal to the depth of installation plus on metre. In this manner any number of settlement points may be installed bottom upwards at various depths, one after the other.

(*g*) A concrete platform may be constructed at the ground level and a 50mm *GI* pipe, 1 metre long, may be cast in the concrete platform in order to protect the *PVC* pipe. The *GI* pipe should be protected by a detachable cap.

Performance Studies

The settlement gauges of the design reported in the paper were installed in very large numbers (*a*) for monitoring ground movements in a black cotton soll area in Indore (*b*) for monitoring settlements of a soft marine clay formation in Visakhapatnam under a preload. Observations taken over a period of last six months have confirmed the repeatability and reliability of measurements

Concluding Remarks

Comparision of the various types of magnetic settlement gauges given in Table 1 reveals that the magnetic settlement gauge reported in the paper is superior in quality and performance to those developed by others and reported earlier. It employs ferrite magnets instead of ordinary steel magnets for longevity. The installation is also simple and easy. In routine field measurements with tape or graduated torpedocable, an accuracy of ± 1mm can be achieved. If the measurements of depth are made using a metal rod fitted with a screw gauge instead of the graduated table and if temperature correction is applied an accuracy as high as ± 0.02mm can be achieved in the measurement. Since the settlement markers are smaller in size than those provided in earlier models, the sub-soil is disturbcd, during installation, to a far lesser extent.

References

BHANDARI, R.K, SRIVASTAVA, P. (1978) Discussion presented on 'A New Settlement Gauge - Reed Switch Type'. *Proc. of GEOCON India*, Conference on Geotechnical Engineering, Vol. 1

BURLAND J.B. MOORE, JFA AND SMITH, PDK (1972) 'A Simple and precise Borehole Extensometer' *Geotechnique*, Vol 22, pp 174-77.

BURLAND J.B. AND MOORE, JFA (1974) 'The Measurement of Ground Displacement Around Deep Excavation' *Symp. on Field Instrumentation in Geotechnical Engineering*, London, Butterworths.

KAPUR, O.P. (1978) 'Instruments for Measuring Stresses and Movements for Underground Structures' *Proc. of GEOCON-India*, Conference Geotechnical Engineering, Vol. 1.

NAGARKAR, P.K., DESHMUKH, S.G., SHURPAL, T.W. AND KULKARNI, A. 1978) 'A New Settlement Gauge—Reed Switch Type'. *Proc. of GEOCON—India*, Conference on Geotechnical Engineering, Vol. 1.

PALIT, B.K. (1977) 'Foundation Instrumention in Cut and Cover Section of MTP, Calcutta'. *Seminar on Foundation Instrumention*, CBRI, Roorkee, May.