Paper No. 158, Bulletin, I. S. E. T. Vol. 12, No. 3, pp. 128-133 September 1975

A NOTE ON EARTH STRAIN AND FAULT CREEP MEASUREMENTS IN INDIA

P. N. AGRAWAL* AND A. S. ARYA*

INTRODUCTION

The design and development of "Portable Water Tube Tiltmeter" was taken up at the School of Research and Training in Earthquake Engineering, University of Roorkee, in early 1967. This marked the beginning of research directed to the measurements of earth strains and fault creep in terms of associated small scale movements. The possible application of these studies to the problem of earthquake prediction (Agrawal and Arya, 1974) has been the main long term objective in the plan of work. Field measurements were first started in 1968 using the initially developed Portable Water Tube Tiltmeter to determine the creep along a plane of sub recent movement in the close vicinity of Krol thrust and also Nahan thrust, both these locations being near Dehradun. The design of this instrument has been improved in various stages taking advantage of the field experience gained through the use of initially developed system. The work of development of invar wire strainmeter and silica tube strainmeters was taken up in 1970 and their first field applications were in 1972 and 1974 respectively. Since then these systems have been used at several important locations. Permanent observatory vaults are being set up at Pophali (Maharashtra), Kalawar (U.P.), Harabagh (H.P.) and Barapani (Meghalaya). A special vault has been built at Roorkee to permit extensive tests on the performance of these systems before their field use. The salient features and the present status of these developments are briefly reported in this note. Only those details are included which have not been published earlier.

PORTABLE WATER TUBE TILTMETER

The design of the 'Portable Water Tube Tiltmeter' initially developed at Roorkee (Agrawal and Gaur, 1968) was somewhat similar to the one described by Eton (1959). The micrometer spindle which was made of hardened mild steel was directly in contact with the water. Even during its use extending over short interval it was found that the water entered in the capilary space between the micrometer spindle and its guide. Naturally, after each field use the micrometer assembly had to be dismantled and cleaned. This led to rapid wearing of the micrometer spindle and its guide and introduced undesired errors in the repeat measurements on account of appreciable changes in the system errors. The finally developed system in Figure 1 employs a water leak proof cell to prevent the entry of water into the micrometer spindle even if the system is kept continuously filled with water for long term use. The change in the system errors with long term field use has been avoided to a considerable extent by the arrangement. In its latest design the system has become suitable even for permanent installation for periodic reading in the specially built underground vaults. The system when operated by a specially trained observer can permit easy resolution of relative vertical displacements up to $\pm 10\mu$. The instrument has been used at Kalawar across a plane of sub recent movements and Nahan thrust (Agrawal and Gaur, 1972); Pophali, Koyna (Agrawal, 1971) and Pandoh (Agrawal, et al., 1975).

INVAR WIRE STRAINMETER

The 'Invar wire Strainmeter' is the same as designed and developed at Cambridge (Bilham and King, 1970). The instrument has been found suitable for applications

*School of Research and Training in Earthquake Engineering, University of Roorkee, Roorkee, U.P. India.

where measurements have to be continued only over limited time and not for long term. This is because of permanent changes in the standard length of the wire used in the system for the purpose of the relative measurements. The system has been used successfully for field measurements at Kalawar (Sinvhal, et al., 1973) and Pandoh (Agrawal, et al., 1975).

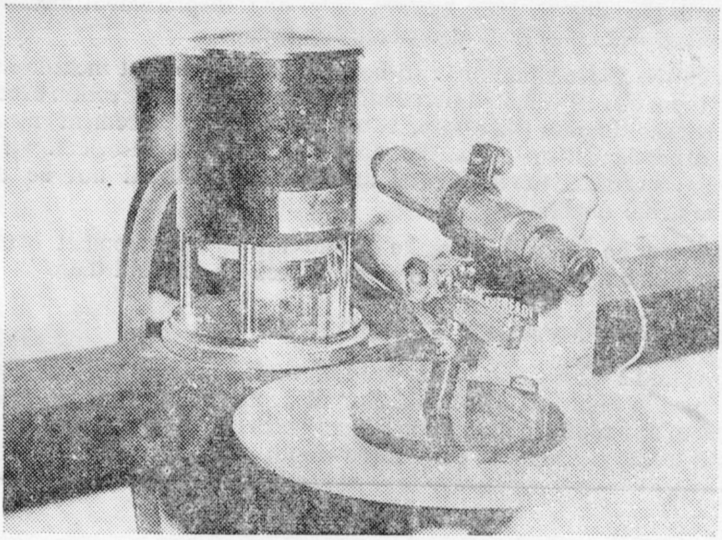

Fig. 1. Photograph of the Portable Water Tube Tilt-meter

ROORKEE SILICA TUBE STRAINMETER

The 'Roorkee Silica Tube Strainmeter is essentially the same as developed by Benioff (1935) except that the transducer used is an inductive type and not the variable reluctance type. The out put from the transducer (LVDT) is amplified and recorded on slow speed. A simple device consisting of a summing amplifier and voltage comparators (Allen, 1973) is used to permit automatic rezeroing of the signal on the chart recorder four times. This effectively makes the chart width four fold and allows greater resolution on the record. The first field installation of this system has been made at Pophali (Kumar, et al., 1974).

CONSIDERATIONS DETERMINING THE PLAN OF MEASUREMENTS

No general guide lines are available for the choice of the locations, plan and number of independent measurements that may be desirable for earth strain or fault creep studies in specific areas. The area of interest may either be comprising of homogenous rock condition or may possess well defined geological structural features. It may consist of hard or poor rock. A detailed study has been done (Agrawal, et al., 1974). On the basis of these studies it is now possible to plan measurements in field with some objectivity, although there are still several points of which the scientific significance is not clearly understood.

If the measurements are being planned near a fault or thrust, for which some of the parameters like strike direction, amount of dip and nature of faulting (true strike slip or dip slip) may be pre known, following simplified guidelines may be useful in deciding the minimum number of measurements;

(i) Only the strike of the fault plane being known two horizontal and one vertical displacement measurement are needed for the complete determination of the slip vector.

(ii) If the fault is purely strike slip and the strike direction is known—only one horizontal displacement measurement is sufficient.

(iii) If the strike and dip of the fault is known, two displacements (one horizontal and the other vertical) will be sufficient.

(iv) If the fault is purely dip slip (may be determined through observations of slicken sides) and the dip is also known, only one displacement measurement either horizontal or vertical will completely determine slip vector.

If in any of the above situations two horizontal displacement measurements have to be made, one of them can be oriented perpendicular to the strike direction except in case the fault plane is vertical. In case (iii) above, two horizontal displacement measurement of which one is perpendicular to the strike direction are also sufficient. If out of two measurements, one is vertical, the horizontal measurements should not be oriented perpendicular to the strike direction.

It may however be desirable to make one additional measurement over and above the minimum requirement so as to provide a cross check on the field data.

THE UNDER GROUND VAULT AT ROORKEE

An 18m long and 2×2m section underground vault has been built at Roorkee. The details are as shown in Figure 2. To avoid diurnal temperature changes and reduce the seasonal changes of temperature it was considered necessary to build it at least 2 to 3 m below the ground level. In view of the shallow depth of water table, the economy and

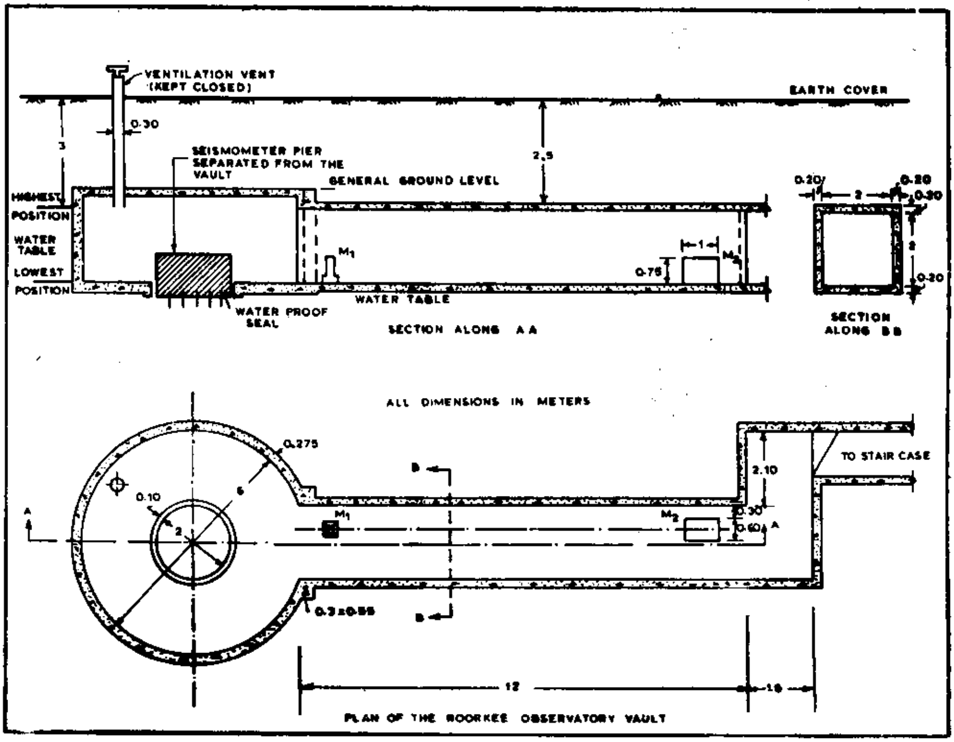

Fig. 2. Some of the details of Underground Vault at Roorkee

convenience of construction the ceiling level of the vault was placed in the ground level and an earth cover of 2.5 m placed over it. Thus, the diurnal temperature change is completely eliminated and the annual linearly distributed temperature change of about 6°C only has been registered. The annual change in the humidity which was large could not be controlled. The approach to the vault is through a 10 m long staircase with three doors. The dead end of the vault is circular in plan (6m in diameter) and has a pillar fixed to the ground and separated from the construction of the vault. This is for installation of seismometers.

The instrumet mounts M_1 and M_2 shown in Figure 2, at distances of 10m have been used for the installation of the Silica Tube Strainmeter. An invar wire strainmeter of equal length has also been installed at this location. These instruments could not be operated at suitable gain so far to record the solid earth tide. This is perhaps due to the fact that the stress in concrete may take long time to come to an equilibrium condition. However, these facilities have permitted extensive tests on the performance of the systems at gains of upto 10^6 times.

THE OBSERVATORY VAULT AT POPHALI

In view of the increased seismic activity of the Koyna region, it was decided to establish one permanent observatory for earth strain monitoring in the region. The inter-adit of Pophali Power House was suitabe for housing the instruments. The same was therefore improvised for the purpose and a Silica Tube Strainmeter was installed. This installation has been described in detail in an earlier paper (Kumar, et al., 1974).

THE OBSERVATORY VAULTS AT KALAWAR

Two observatory vaults one across Krol thrust and the other across Nahan thrust are under construction at Kalawar. These are being constructed by the Yamuna Valley Scheme, Department of Irrigation, Govt. of Uttar Pradesh. The Plan of these vaults is shown in Figure 3. The section along the Kalawar inspection gallery has also been given

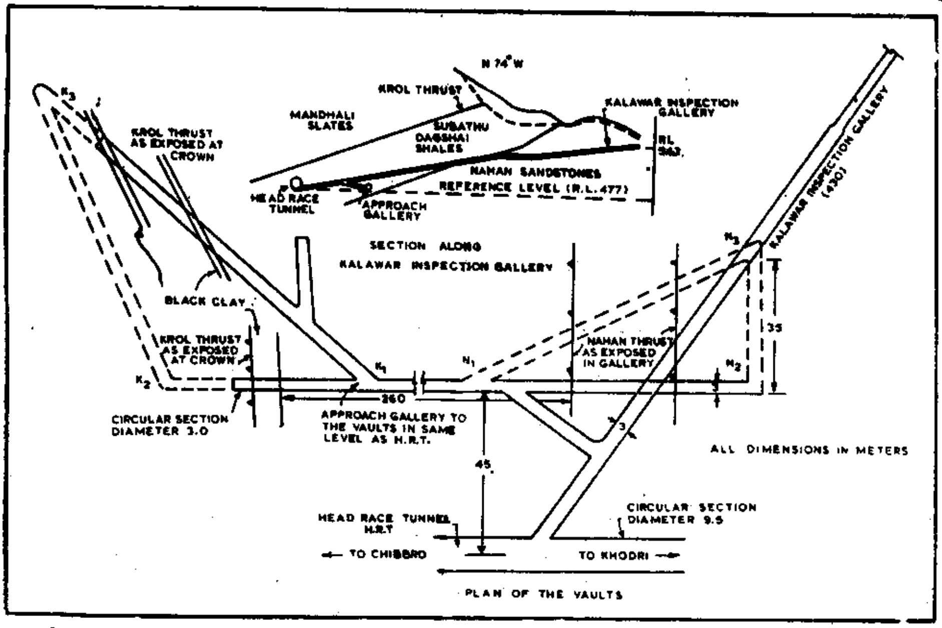

Fig. 3. Some of the Details of the Observatory Vaults Under Construction at Kalawar

in this diagram. The construction of vault across Nahan thrust as at (N_1 N_2 N_3) was taken up afterwards but is expected to be completed in about next six months. The construction of vault across Krol thrust has been delayed due to the departures of the Krol thrust from its anticipated positions two times. The final plan of the vault would be somewhat as indicated at (K_1 K_2 K_3).

Results from the instrumentation that was provided in this region have already been published (Agrawal and Gaur, 1971; Sinvhal, et al., 1973).

THE OBSERVATORY VAULT AT HARABAGH

An observatory vault under construction at Harabagh (Himachal Pradesh) across Krol thrust (local out crop named as Shali thrust) is nearing completion. The details of the vault are given in Figure 4. The instruments are proposed to be installed in the next few months.

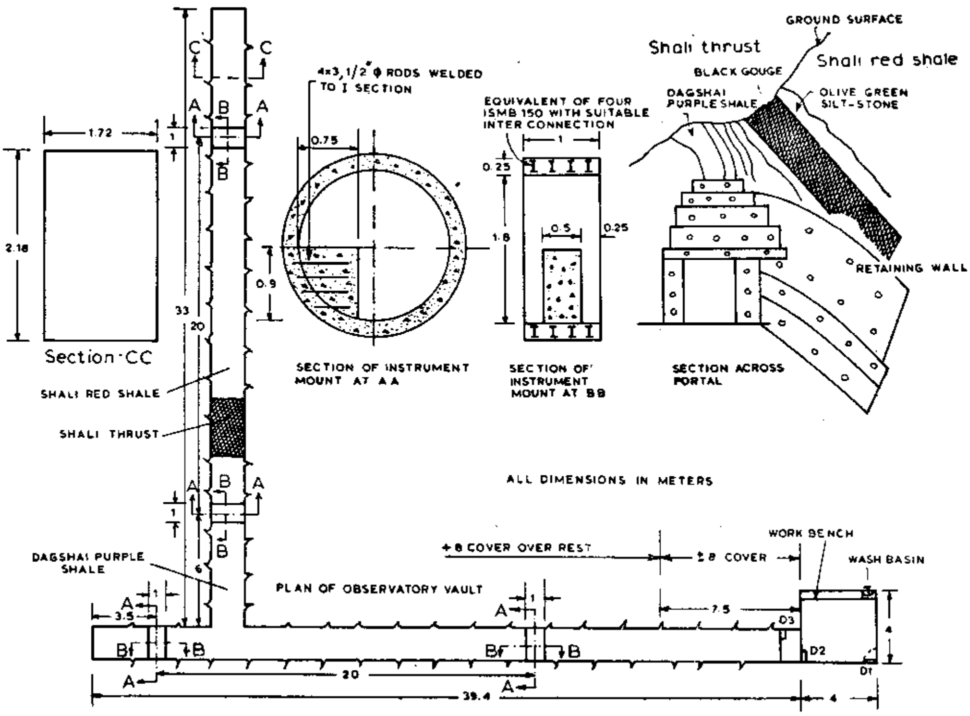

Fig. 4. Some of the Details of the Observatory Vault Under Construction at Harabagh

THE OBSERVATORY VAULT NEAR SHILLONG

The site for this observatory vault has been selected near the Adit Colony of the Umiam Project, Govt. of Meghalaya. The arrangements for construction through the Meghalaya State Electricity Board are under way.

CONCLUSIONS

A satisfactory beginning has been made for the measurements of earth strain and fault creep in the various tectonic provinces of the country. The initial efforts have been mainly directed to the design and development of instruments, and construction of few observatory vaults. The work taken up so far has to be consolidated by way of providing complete instrumentation at each of these vaults and collection of data.

ACKNOWLEDGEMENTS

The work has received continued guidance from Dr. Jai Krishna, Vice-Chancellor, University of Roorkee. The assistance from respective river valley projects only has made it possible to construct the observatory vaults.

The work is financially supported at School since Oct., 1969 through the grants received from U.S. PL-480 Rupee funds.

REFERENCES

Agrawal, P.N. and Gaur, V.K., (1968), "An Instrument for Observations of Secular Ground Tilt", Bull. Indian Soc. Earth Tech., Vol. 5, Nos. 3-4.

Agrawal, P.N (1971), Observations of Earth Surface Tilting in Koyna Pophali Region, Maharashtra, India", Bull. Seismo. Soc. Am., Vol. 61, No. 4, pp. 975-982.

Agrawal, P.N. and Gaur, V.K. (1971), "Study of Crustal Deformation in India", Tectonophysics, Vol. 15, pp. 287-296.

Agrawal, P.N. (1972), "December 11, 1967 Koyna Earthquake and Reservoir Filling", Bull. Seismo. Soc. Vol. 62, No. 2, pp. 661-662.

Agrawal, P.N. and Arya, A. S. (1974), "Research on Earthquake Prediction in India", Earthquake Engineering, Jai Krishna Sixtieth Birth Anniversary Commemoration Volume, Indian Soc. Earth. Tech.

Agrawal, P.N., Singh, V.N. and Arya, A.S. (1974), "Measurements of Small Scale movements in Active Tectonic Areas", Proc. Fifth Symp. Earthquake Engineering, Univ. of Roorkee.

Agrawal, P N, Kumar, V and Kulshreshtha, V. K. (1975), Measurement of Vertical and Horizontal Displacements in the Distress Reach of Pandoh-Baggi Tunnel" Unpublished School Report No. EQ 75-10.

Allen, R.V., (1973), "An Inexpensive Bias Stepper for Analog Recorders", Bull. Seismo. Soc. Am., Vol. 63, No. 1, pp. 323-327.

Benioff, H., (1935), "A Linear Strain Seismograph" Bull. Seismo. Soc. Am., Vol. 25, pp. 283-309.

Bilham, R. and King, G., (1970) "Strain-gauges for Geophysics", XII General Assembly. The European Commission of Seismology, Luxembourgh, Sept. 21-29.

Eton, J.P., (1959), "A Portable Water Tube Tiltmeter" Bull. Seismo. Soc. Am. Vol. 49, No. 4, pp. 301-316.

Kumar, V., Agrawal, P.N. and Arya, A.S., (1974), "Roorkee Silica Tube Strainmeter Installation at Pophali, Maharashtra, India", Proc. Fifth Symp. Earthquake Engg. Univ. of Roorkee.

Sinvhal, H., Agrawal, P.N., King, G. C. P. and Gaur, V.K., (1973), "Interpretation of Measured Movements at a Himalayan (Nahan) Thrust", Geoph. Jour. Royal Astro. Soc., Vol. 34, No. 2, pp. 203-210.