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Measurements of crustal deformation in India

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ABSTRACT. Development of instruments for the purpose of measurements of crustal deformation at suitably selected locations in India was started in 1967 at the School of Research and Training in Earthquake Engineering, University of Roorkee. Now several permanent observatory vaults have been constructed and limited measurement done employing the instruments developed. The basic considerations influencing the plan of such measurements in the field have also been studied in detail. The paper briefly outlines the salient features and the present status of these studies.

1. 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 observations of the deformation of the earth's crust at suitably selected locations in India. 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 studies received a great impetus in 1970 when under the agreement No. I-35153, financial assistance was received for this work through U.S. PL-480 rupees funds. 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 (Himachal Pradesh) 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 given in this paper.

2. 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 capillary 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 Fig. 1 employes 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 1974); at Pophali and Koyna (Agrawal 1971) and Pandoh (Agrawal, Kumar and Kulshrestha 1975).

3. 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 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, Kumar and Kulshreshtha 1975).

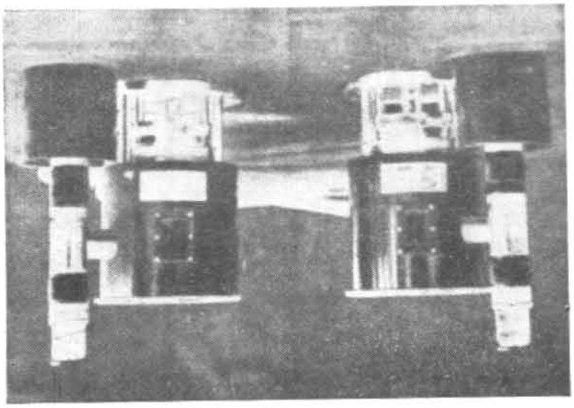

Fig. 1. Photograph of the Portable Water Tube Tiltmeter

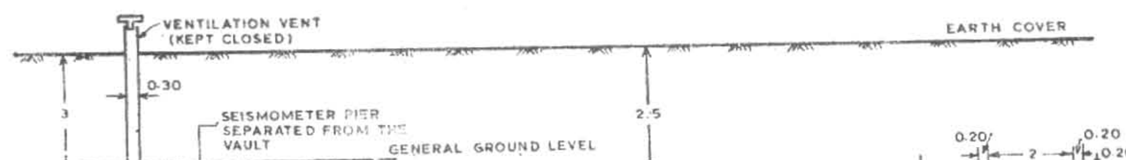

Fig. 2. Some of the details of the underground vault at Roorkee

4. 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 output 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 ten times. This effectively makes the chart width fourteen fold and allows greater resolution on the record. The first field installation of this system has been made at Pophali (Kumar, Agrawal and Arya 1974).

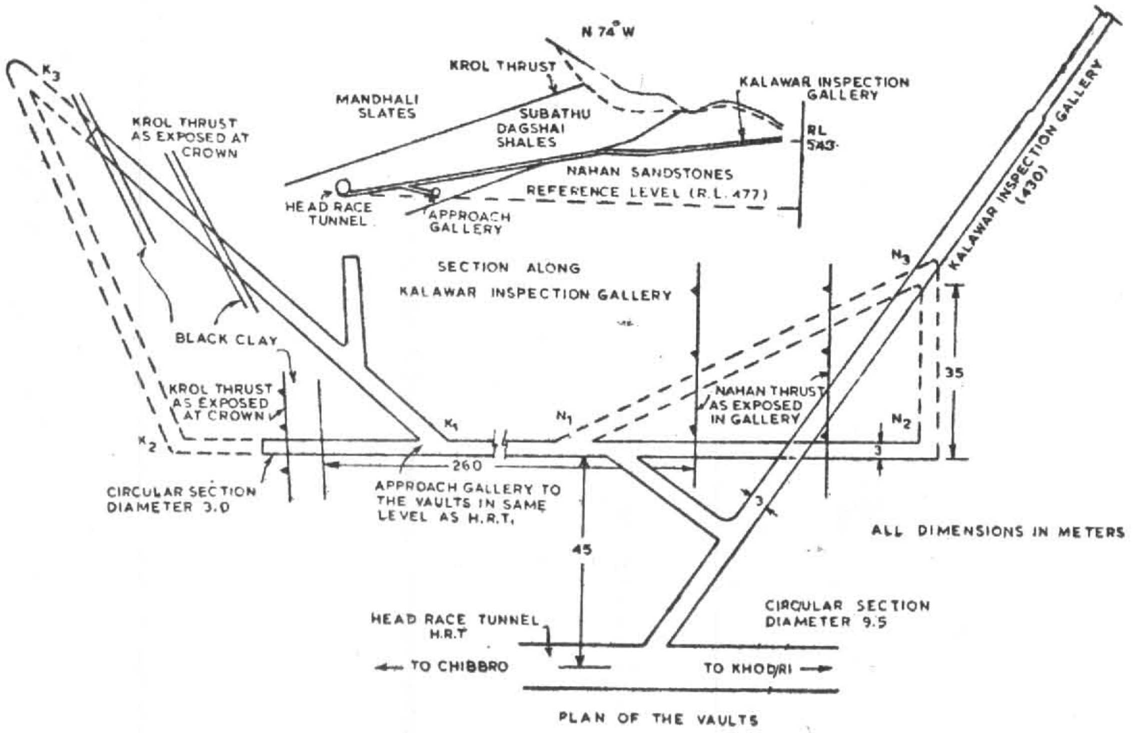

Fig. 3. Some of the details of the observatory vaults — constructed or under construction at Kalawar

5. 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, Singh and Arya 1974) and 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 known before hand, following simplified guideline 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 are 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 displacements have to be made, one of them can be oriented perpendicular to the strike direction. If out the 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.

6. The underground vault at Roorkee

An 18 m long and 2 m × 2 m section underground vault has been built at Roorkee. The details are as shown in Fig. 2. To avoid diurnal temperature changes and reduce the seasonal changes of temperature it was considered necessary to build it atleast 2 to 3 m below the ground level. In view of the shallow depth of watertable, the economy and convenience of construction the ceiling level of the vault was placed in the ground level and an

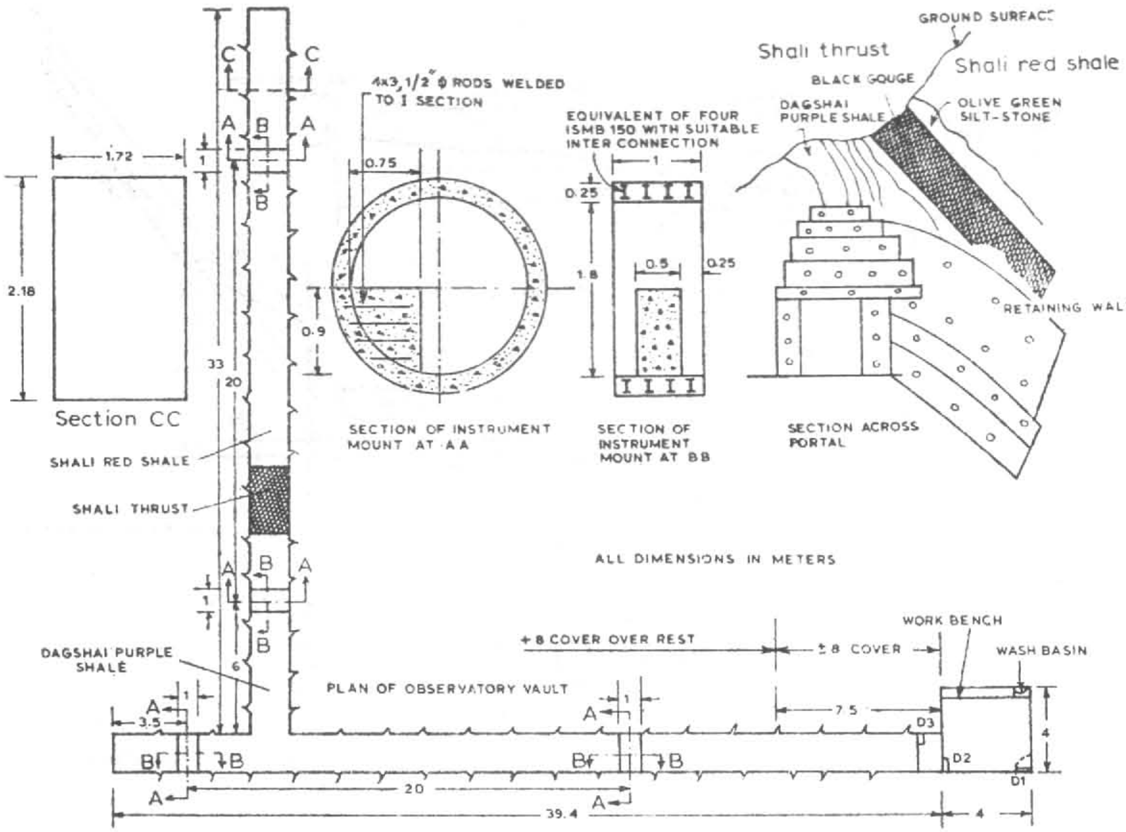

Fig. 4. Some of the details of the observatory vault at Harabagh

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 (6 m 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 instrument mounts M_1 and M_2 shown in Fig. 2, at distances of 10 m have been used for 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 to record the solid earth tide so far. This is perhaps due to the fact that the strain 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 upto 10^6 times.

7. 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 the Pophali Power House was suitable 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, Agrawal and Arya 1974).

8. 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 Fig. 3. The section along the Kalawar inspection gallery has also been given in this diagram. The construction of vault across Nahan thrust as at (N_1 N_2 N_3) was taken up afterwards and has since been completed. The instruments are kept ready for installation in the vault. 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 been published (Agrawal and Gaur 1971; Sinvhal *et al.* 1973).

9. The observatory vaults at Harabagh

An observatory vault under construction at Harabagh (Himachal Pradesh) across Krol thrust (local out crop named as shaly thrust) has been completed. The details of the vault are given in Fig. 4. The instruments which are already assembled are proposed to be installed in the next few months.

10. The observatory vaults near Shillong

An observatory vault in phylites has been constructed near the Adit colony of the Uniam Project, Government of Meghalaya. A pair of water tube tiltmeters are installed and observations being taken. One silica tube strainmeter has also been partially installed. The installations is to be completed in next two to three months.

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

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