Rock anchors to control heave of shale at CISTI building: a description of their performance from May 1982 to March 1983

Eden, W. J.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20338111
Internal Report (National Research Council of Canada. Division of Building Research), 1983-07-01

NATIONAL RESEARCH COUNCIL OF CANADA

DIVISION OF BUILDING RESEARCH

DBR INTERNAL REPORT NO. 476

ROCK ANCHORS TO CONTROL HEAVE OF SHALE AT CISTI BUILDING: A DESCRIPTION OF THEIR PERFORMANCE FROM MAY 1982 TO MARCH 1983

by W.J. Eden

Checked by: **Approved by:** L.W. Gold **Date:** July 1983

Prepared for: Records Purposes

PREFACE

This report has been prepared for record purposes for those immediately concerned with the test installation. It is planned to publish the information as soon as sufficient readings have been obtained to allow some conclusive evidence about the performance of the test installation, probably within two years time.

ROCK ANCHORS TO CONTROL HEAVE OF SHALE AT CISTI BUILDING: A DESCRIPTION OF THEIR PERFORMANCE FROM MAY 1982 TO MARCH 1983

W.J. Eden

INTRODUCTION

The 8-storey CISTI Building is founded partially on limestone and partially on black shale at the Montreal Road Laboratories of the National Research Council Canada (NRCC). Because the basement is founded on rock at 3 distinct levels, there was a possibility of shale heave. Several level points were therefore installed in the floor slab during the construction phase and have been monitored since 1973.

One area of the basement began to heave almost immediately; after 10 years, its maximum measured heave has exceeded 10 cm. An experimental floor was planned in 1981 and completed under contract in April 1982. A 6 × 8 ft (1.8 × 2.4 m) section of the floor was isolated and anchored by 4 rock anchors, and load cells were installed in it to measure the forces on the rock anchors. At present, load is continuing to build-up on the anchors. This report describes the site, presents the results of the level surveys, describes the anchored slab installation and gives the results of the first year of measurements.

SITE DESCRIPTION

The building consists of a rectangular 8-storey tower supported by 4 L-shaped shear walls which rest on drilled-in caissons. Surrounding the tower is a 2-storey structure founded on spread footings on bedrock. There are 4 levels of basement floors. About one quarter of the north side of the building rests on limestone, with the rest of the building on shale. Figure 1 is a sketch plan (not to exact scale) of the building which shows the location of the shear walls, the fault zone between the shale and the limestone, the various levels of the foundation, and the service tunnel. The lowest level is the service tunnel which runs through the building from north to south. The southeast corner of the building beyond the shear wall is at the service tunnel level. The next level, about 8 ft (2.4 m) above the service tunnel, is a machine room located in the northwest quadrant of the building. The remainder of the building, except for the extreme northern portion, is located about 4 ft (1.2 m) above the machine room. The extreme north portion of the building is located one floor above this, and is founded on the limestone.

The bedrock consists of limestone of the Ottawa formation north of the fault. The limestone has numerous fractures, but the bedding is generally massive. South of the fault is the Billings shale formation. The shale next to the fault is badly distorted and fractured, but is reasonably sound in the southeast corner. In the fractured zone there were numerous visible inclusions of pyrite crystals. Figures 2 and 3 show the fault zone and the distorted shale strata seen in the east face of the excavation for the service tunnel.

Since the bedrock contains many fractures, water moves freely through it. The water level is controlled by an underfloor drainage system leading to sump pump stations located in the service tunnel and in the southeast corner of the building.

LEVEL SURVEYS

During excavation, an asphalt membrane was sprayed on the bedrock surfaces to control weathering of the shale. Because of the fractures in the bedrock, it was probable that the asphalt membrane would have little effect and that shale heaving would occur. Accordingly, 12 reference points were placed in the floor slab on both sides of the excavation for the service tunnel in January 1973. These were points 93A to 93F in the machine room and points 17A to 17F in a corridor on the ground floor level. Floor surveys were conducted periodically beginning in January 1973 with a precise level using as reference bench marks set in the shear walls.

Within one year, it was evident that the floor in the machine room was heaving. No movement was evident in the corridor, probably because the reference points in it were all located next to a masonry wall which would restrain heave. Six new points 17A' to 17F' were installed in the middle of the corridor. Measurements at these points have been made every 3 months since March 1974.

In June 1975, 54 additional reference points, located as shown in Figure 4, were installed throughout the part of the building underlain by shale. Since June 1975, surveys have been conducted every 3 months.

According to the surveys, the heave has been confined to Room 93 (the machine room). Figure 5 is a record of heave with time for several points in Room 93. Points 93F and 83J have shown the highest rate of heave, about 1 cm per year. Point F has heaved more than 10 cm, but is now restrained by the rock anchor installation.

Very minor movements have been recorded outside Room 93. Some movement has been observed in Corridor 17, but is less than 0.5 cm.

ROCK ANCHORED SLAB

One possible method of controlling heave over a limited area is to anchor a footing to underlying unweathered rock. Such a method could be useful in controlling heave under machine foundations. To test the method, and to obtain an indication of the forces that the anchors would have to resist, the experimental slab was installed to cover a 6 × 8 ft (1.8 × 2.4 m) area including point 93F. The contractor, G.C. McRostie, describes this installation in considerable detail in his report No. SF-2322 to NRCC dated March 31, 1982.

Briefly, the installation consists of:

(1) a 6 × 8 ft (1.8 × 2.4 m) panel of floor slab cut free of restraint from the remaining floor slab with a concrete saw;

(2) four 2 1/8 in. (54 mm) BW rock anchors, 17 ft (5.2 m) long and grouted for the lower 8 1/2 ft (2.6 m), installed in the corners of the slab;

(3) a steel grillage applied to the surface to make it rigid; and

(4) four IRAD load cells installed between the grillage and the anchors to measure the load imposed on each anchor.

Figure 6 is a photograph of the completed installation taken in May 1982. Survey point 93F, located about the middle of the anchor slab, was not disturbed during the installation.

IRAD vibrating-wire load cells with a capacity of 75 tons each (747 kN) were chosen because of their compatibility with existing readout equipment. Each cell contains 3 vibrating wire strain gauges to account for any eccentricity in loading. After the installation was completed, a small preload of less than 1000 lb/anchor (4.448 N) was induced by tightening the jam nuts on the anchors.

From the following table, which gives the results of the readings for the first year, it is evident that load is accumulating on the anchors.

CONCLUSIONS

The CISTI building has been subjected to appreciable shale heave. To date, the most active heave is confined to an area east and south of the northwest shear wall. The rate of heave has been nearly constant over a 10-year period.

During the first year of operation, the anchored slab has performed as envisaged, with load accumulating on the anchors. It may take another 5 years to determine whether the design capacity of the anchors is sufficient.

Since other areas of the building could, in time, be affected by heave, periodic level surveys should be continued.

TABLE 1: MEASURED LOAD ON ANCHORS, lb (kN)

Date	May 3 1982	May 3 1982 (Prestress)	May 11 1982	June 8 1982	July 15 1982	Sept.28 1982	Dec.15 1982	Mar.3 1983
Cell No. 1	0	970 (435)	735 (329)	1109 (497)	1567 (702)	2399 (1075)	4243 (1902)	6475 (2902)
Cell No. 2	0	521 (233)	474 (212)	679 (304)	948 (425)	1153 (517)	1991 (892)	2639 (1183)
Cell No. 4	0	841 (377)	793 (355)	1110 (498)	1634 (732)	2856 (1280)	4918 (2204)	7139 (3200)
Cell No. 6	0	810 (363)	711 (319)	1038 (465)	1564 (701)	2659 (1192)	4067 (1823)	5912 (2650)
TOTAL, lb (kN)	0	3142 (1408)	2713 (1216)	3936 (1764)	5713 (2560)	9067 (4064)	15219 (6821)	22165 (9935)

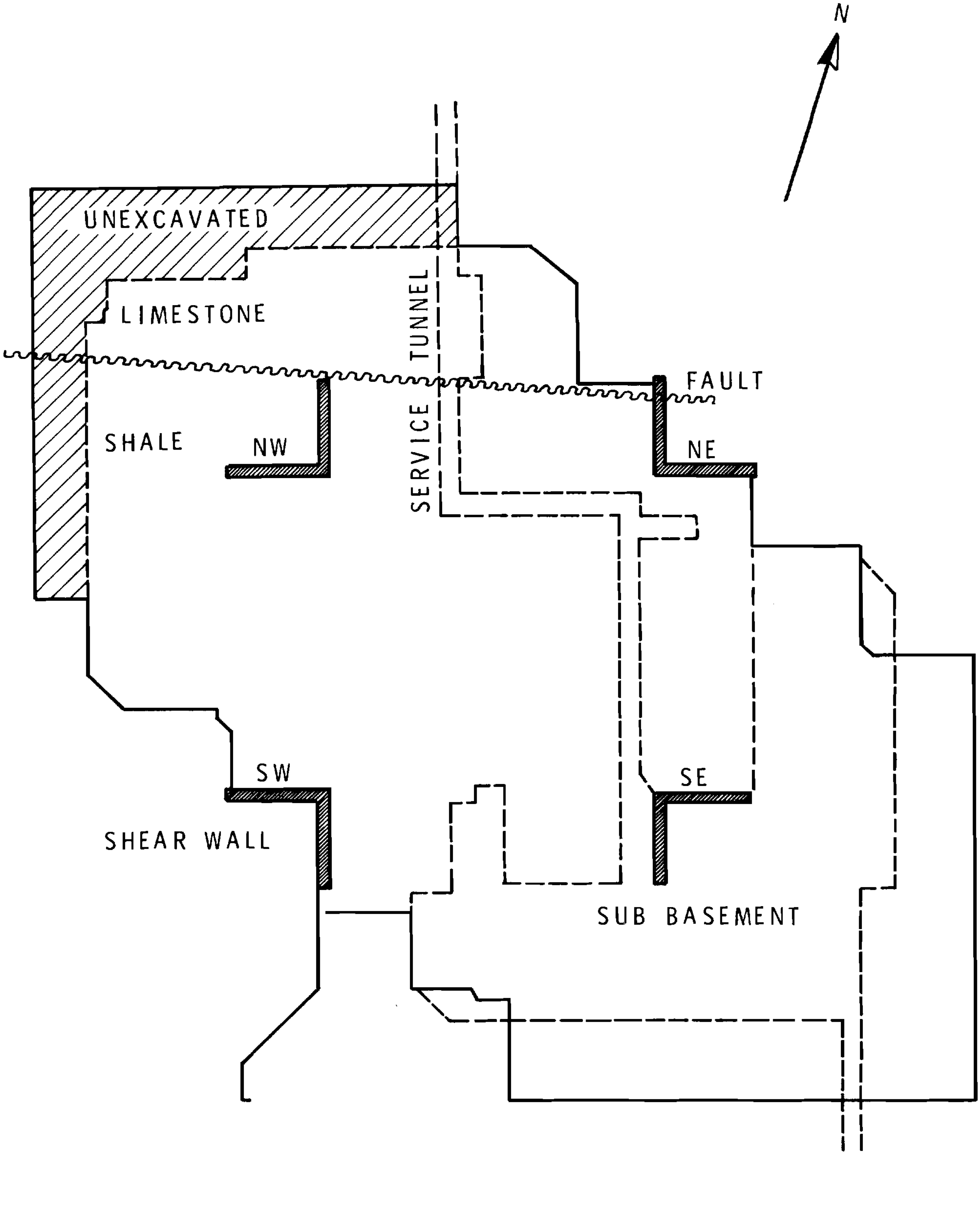


FIGURE 1

PLAN OF BUILDING SHOWING LOCATION OF FAULT ZONE

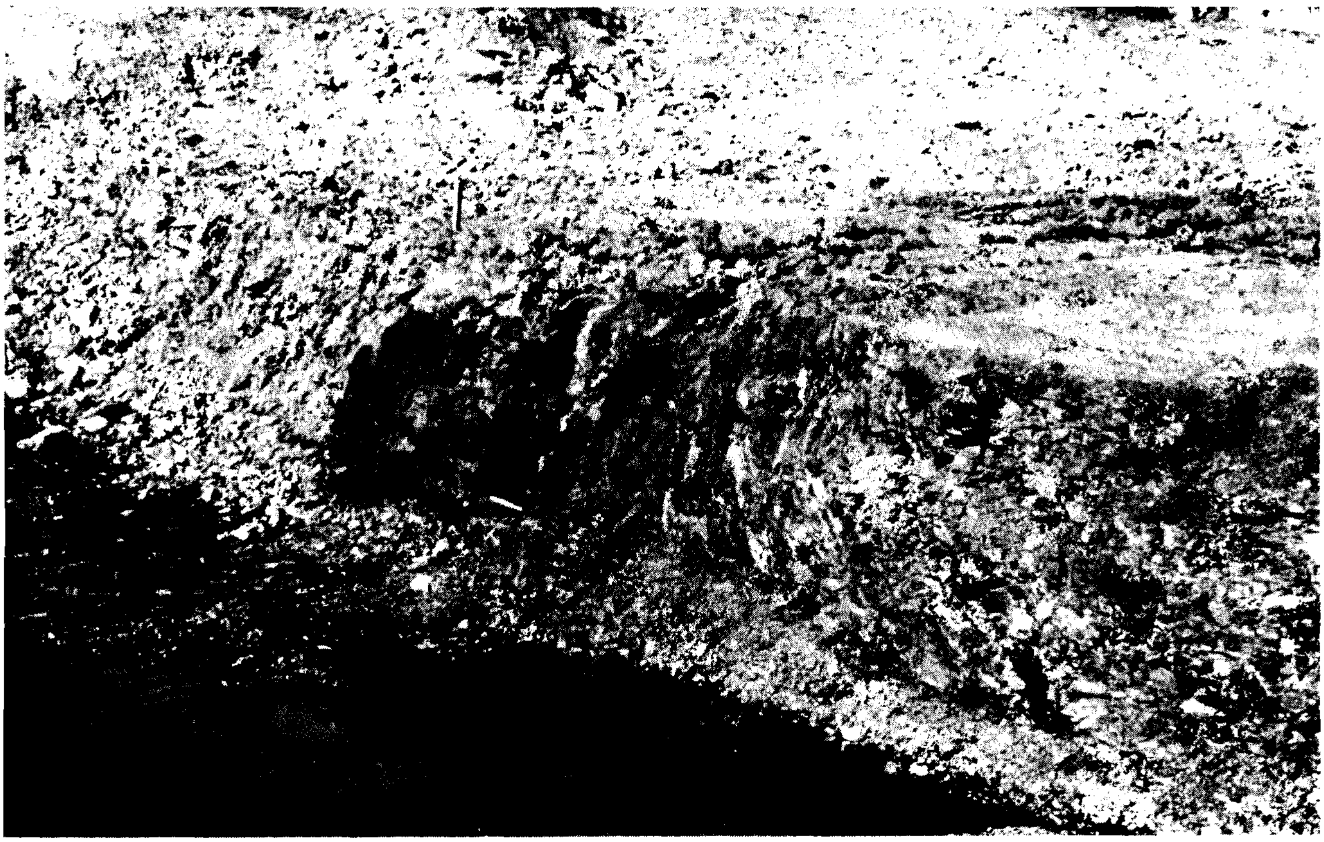


Figure 2   View of fault zone in bedrock

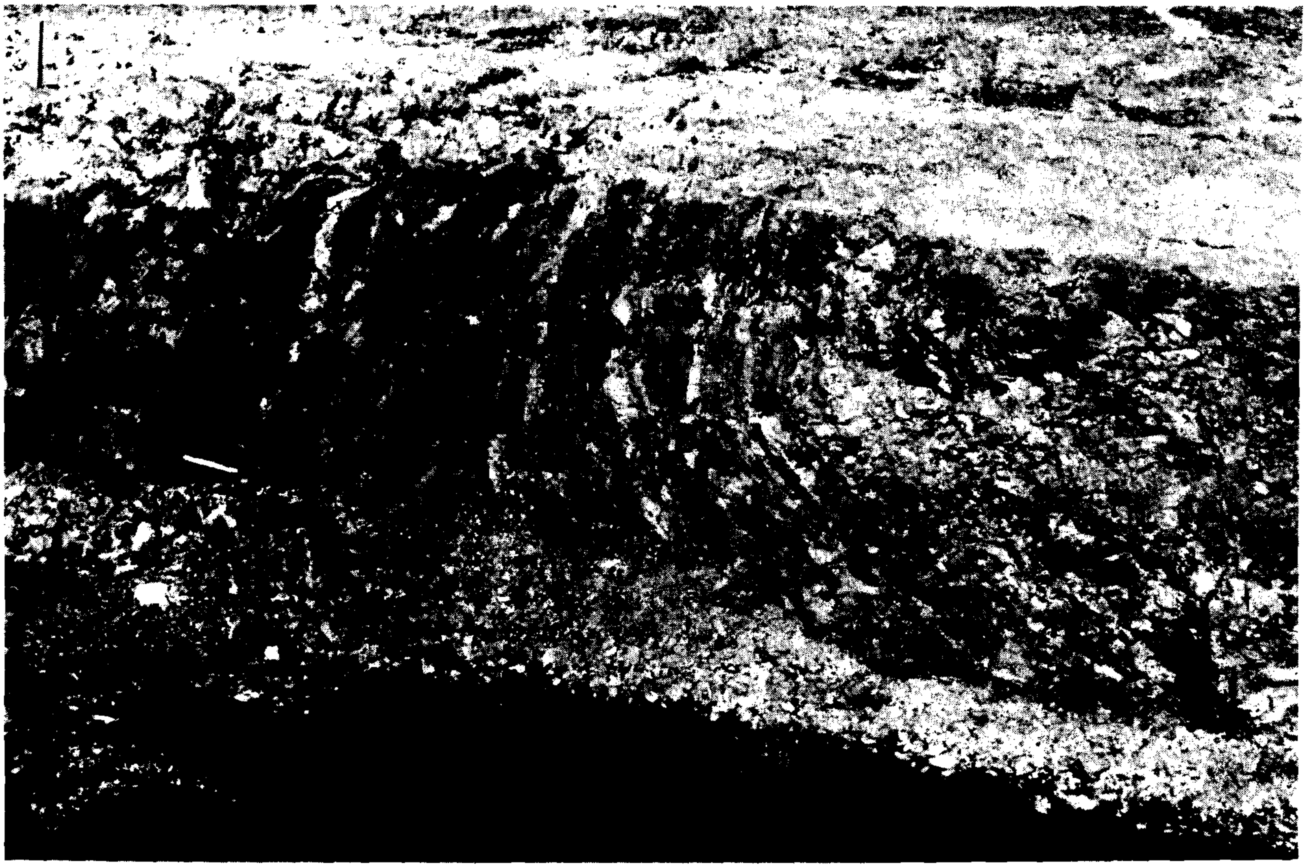
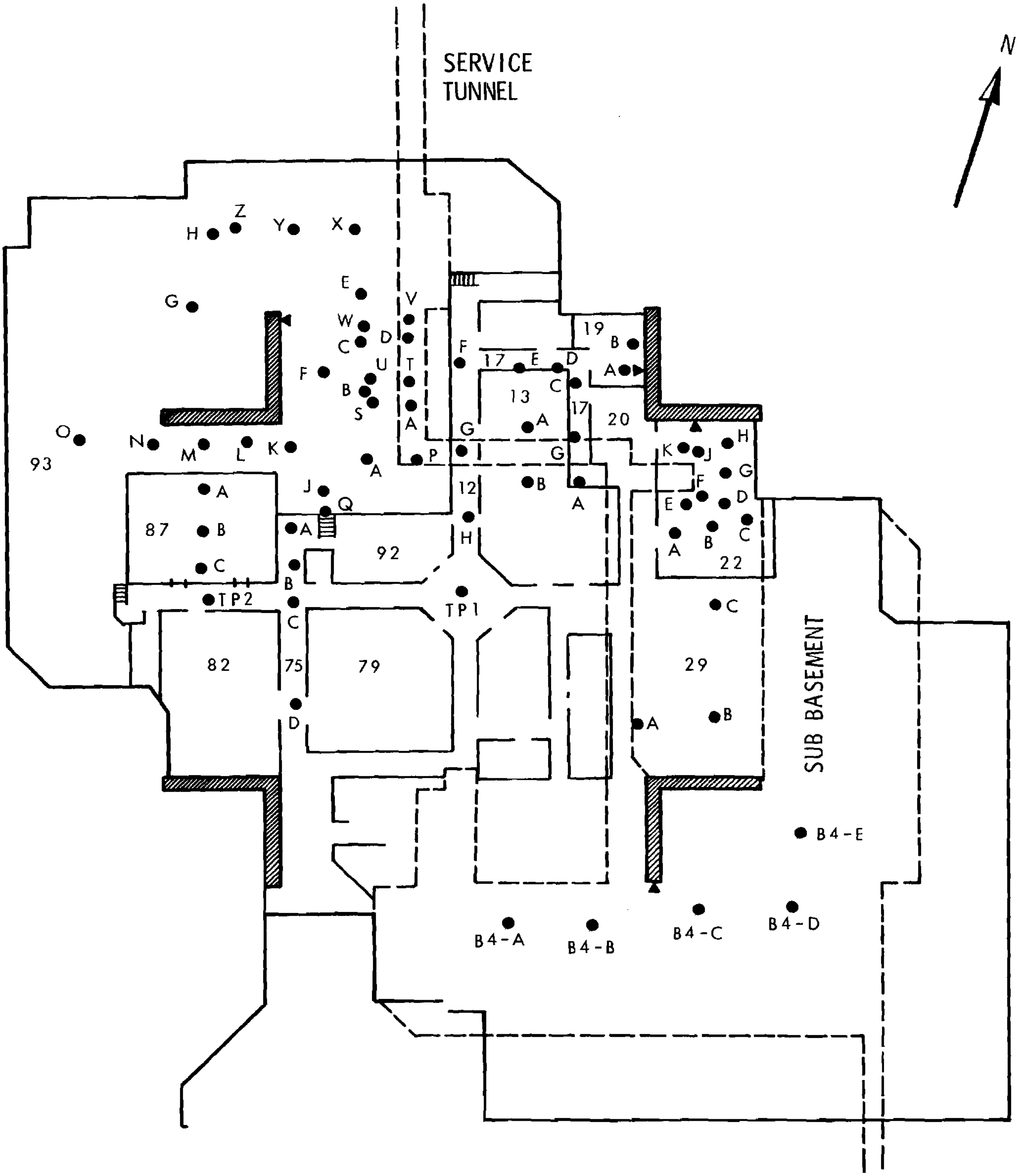


Figure 3 Disturbed shale strata next to fault
(Hammer at fault contact)



● A - SURVEY POINT

▲ REFERENCE PLUG IN SHEAR WALL

93 ROOM NO.

FIGURE 4

PLAN SHOWING LOCATION OF SURVEY POINTS

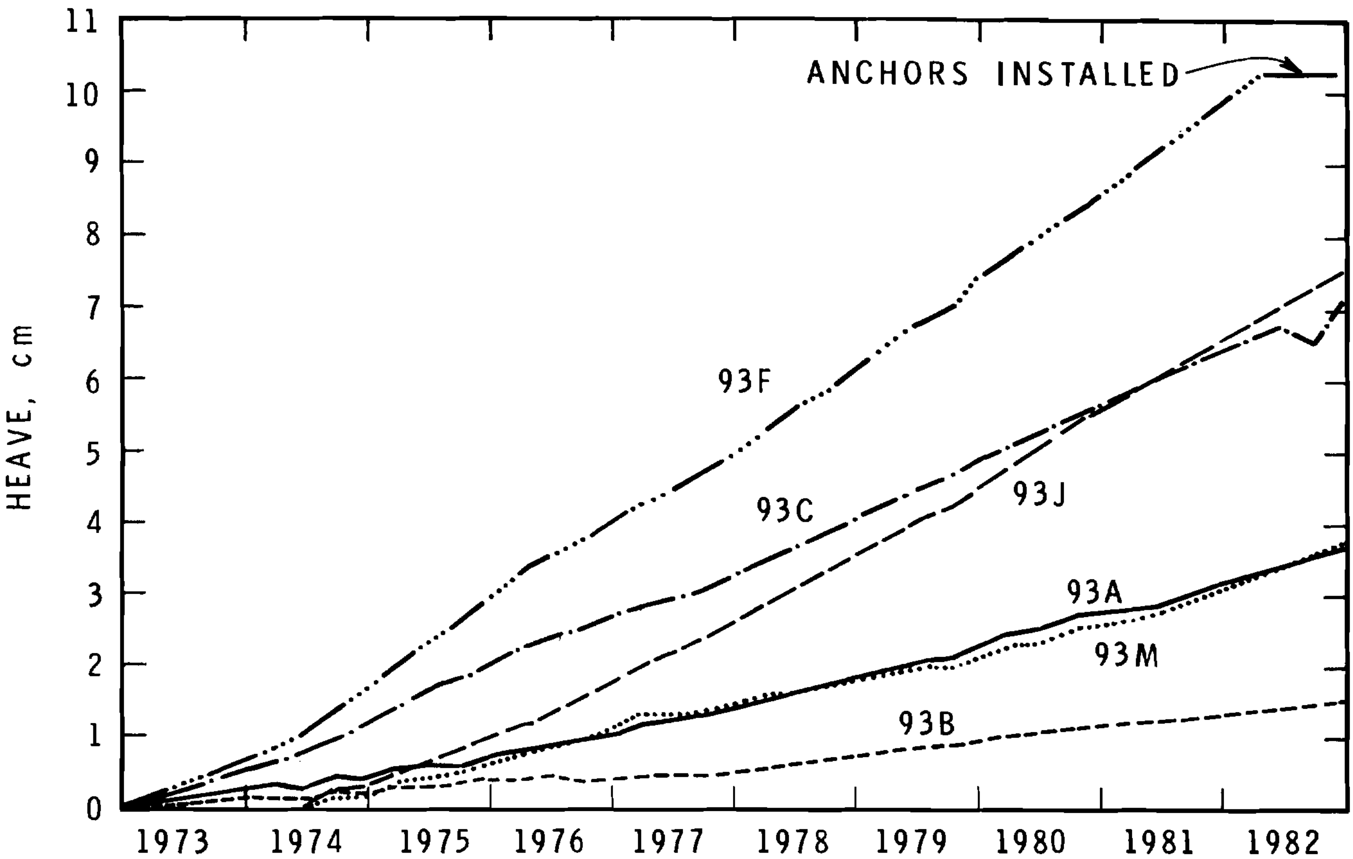


FIGURE 5

HEAVE RECORD AT SEVERAL POINTS

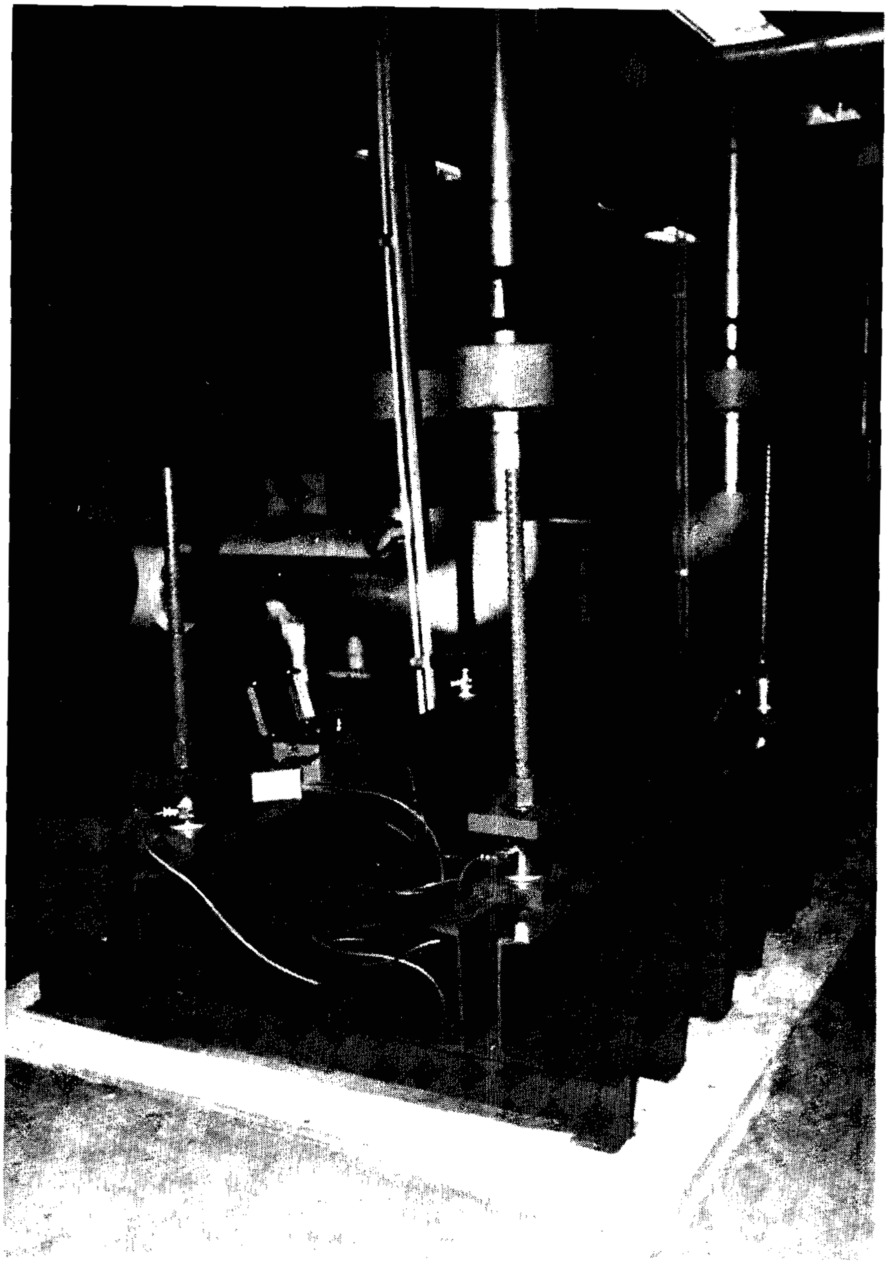


Figure 6 View of anchored slab installation