Final Report

Foundation Stabilization Research Studies
Foundation with Crawl Space on Loose Soils
Fairbanks, Alaska

Introduction

This property entered the Alaska Housing Finance Corporation's (AHFC) inventory in 1989 due to a number of problems noted in the house (i.e. sagging garage ceiling beam, severely cracked garage floor, and failing floor support beams and posts). In 1990 an engineering report prepared by Stutzmann Engineering Inc. concluded that the foundation of this house may be unstable due to underlying permafrost soil or unconsolidated soils left from receding permafrost. The house was subsequently deeded to the Permafrost Technology Foundation (PTF) by AHFC for the purpose of research to develop economic techniques for stabilizing the foundations of permafrost-sited houses. Permafrost underlying the foundation was suspected due to cracks found in the garage floor. Three test holes were drilled and revealed loose silty-sand and gravel to depths of 35 feet. Two of the test holes were outside the house, while one was drilled in the garage using a mobile drill. The test holes were inconclusive as to the presence of frozen soil (permafrost). The underlying soils exhibited very loose characteristics during drilling, indicating less than desirable compaction of the soils. Loose soils may settle during an earthquake or other dynamic event.

When PTF received the house, two additional permafrost exploration holes were drilled. These holes were located south of the southeast corner of the garage and midway along the west wall. These holes were drilled by Shannon and Wilson Inc. under contract to the Permafrost Technology Foundation. The holes were drilled to a depth of over 50 feet. No frozen soil was found to that depth, although the sampling spoon was noted to be "very cold to the touch." Once again the soils were found to be very loose throughout the entire depth of the drill hole.

Because the house showed no sign of permafrost and settlement damage was minimal, it was decided to monitor the structure for a period of time to see if any settlement or danger signs of settlement occurred. When no evidence of settlement was found after a year of monitoring the structure, the decision was made to continue the monitoring to determine the ultimate stability of the foundation and to gain data on what can be expected at a site with such very loose soils at depth.

Structure Description

The house is a single story, three bedroom, two bath structure with an attached two car garage. See Figure 1 which shows the floor plan. A crawl space approximately 3½ ft deep extends under the house except for the garage which has a concrete floor. The crawl space is accessible from a covered opening in the floor of one of the bedroom closets. The structure sits several feet above the street level and has a rather steep driveway. The elevation may have been required by the North Star Borough for flood protection in this location. Several neighboring houses are also built above the street in the same manner. A deck extends across the back of the house behind the kitchen and dining room.

Level Measurements

Level measurements were taken to determine the relative elevation of the floor. The level measurements were made using a small precise telescopic level (sometime referred to as a "contractor's level") mounted on a tripod and a surveyor's rod calibrated in millimeters. The millimeter rod was used instead of a standard surveyor's rod to give more precision to the measurements. Since the distance from the level to the rod was rarely over 5 meters (15 feet), the rod could easily be read to the nearest millimeter (0.04 in.).

It should be noted, however, that when level measurement are this precise, that perturbations can and do occur. These small changes are due to the placement of the rod from one measurement set to the next. Often the rod had to be placed behind furniture, and it was impossible to determine if it was sitting on the same spot as the previous measurement or if an electrical cord or a magazine etc. happened to be under the rod (even the thickness of several sheets of paper will show up at this precision). There was also the possibility for a gross error in reading the rod, since the level had the standard three cross hairs (center, upper and lower) used for measuring distances in surveying. If the operator was inexperienced (student labor was used for these measurements), a reading could be made using either the upper or lower cross hair instead of the center one. This error would yield an elevation that was in error by several tens of millimeters to as much as a few inches. These errors however are readily discernible when the data is plotted as a function of time.

Level data on the concrete slab floor in the basement was collected several times a year and accumulated for a period of six years. Each measurement location is designated on the floor plan by a letter. Different groups of letters were plotted together on the charts to show relevant comparisons such as the south wall or the diagonal across the structure. In each chart, all levels are referenced to a single reference point "A". This allows the elevation of each point to be compared as a relative elevation on the floor plan with respect to point A. From this data, differential elevations between different parts of the floor can be easily seen and tracked with time.

This system, however does not give information as to the absolute elevation of the house with respect to the ground outside, and therefore any elevation variation of point A is also reflected in all other points. Determining absolute elevations requires a stable surveyor's benchmark or other stable reference outside of the structure. At this location a nail was driven into a large tree to attempt to provide a stable reference, however this did not prove to be reliably stable. Nevertheless, the relative elevations allow differential settlement to be tracked, and that is the most important information for these studies.

For perspective, a differential floor elevation of one to two inches (25 mm to 50 mm) is not noticeable to the unaided eye, and up to four inches (100 mm) over the distance across a normal room, although noticeable, is not an overly unpleasant condition with which to live.

Temperature Measurement

When the permafrost test borings were drilled, a thermistor string with 12 thermistors was placed in each hole. In addition, three thermistor strings were placed in pipes that were driven into the soil at three locations in the crawl space beneath the structure. The thermistor strings were positioned to measure temperatures at various depths from the surface to 54 ft. These temperatures were monitored periodically at the same time the level measurements were taken (and sometimes more often) resulting in a data base of six years of soil temperatures for the site. The temperature data was plotted with respect to time to give a graphic indication of the trends over the duration of the study.

Thermistors are capable of measuring temperature to the nearest one thousandth of a °C. However, the nearest one tenth of a degree is probably satisfactory for our purposes for everything except the location of the actual freezing front. Thermistors are more accurate than thermocouples; however, they have the disadvantage of being more fragile, and they can drift a few thousands of a degree over time. To obtain the maximum accuracy, the strings must be calibrated in a reference bath both before and after their use. These thermistor strings were calibrated before placing them in the hole, but since once installed they are buried, it is impractical to remove them without destroying them, therefore the secondary calibration cannot be made. The temperatures, therefore, cannot be relied upon to more than about a tenth of a degree.

Thermistors located at various depths allow us to track the temperatures at those depths to determine if the permafrost is getting deeper, remaining stable, or actually rising. The data also alerts us to any anomalies in temperature that may occur due to outside influences such as new construction nearby, landscaping modifications, or damage or deterioration of protective insulation. Since no permafrost was found at this location, the temperature data here is not as important as in sites underlain by permafrost. However, the temperature trends over the years of measurement are valuable data to be used for control and reference to other sites that do have permafrost.

Geotechnical Exploration

In order to determine the condition of the soils below the structure, two boreholes were drilled to a depth of over 50 feet. Twenty soil samples were taken at regular intervals of depth during the drilling of each hole. In the appendix the boring hole logs show the boring log of the hole near the southwest corner of the house. Samples were collected by driving a split-spoon sample core barrel through the hollow stem using a 300 pound hammer and a 30 inch drop. The number of hammer blows required to drive the core barrel gives information on the competency of the soil at each sample depth. These samples are considered "disturbed samples." However, since they are retrieved essentially intact in their natural state, they provide useful information about the soil. This method of sampling was continued until frozen ground was encountered. Below this, the soils were sampled with a dry core barrel. This brings to the surface a five-foot-long, three-inch-diameter, intact soil sample. Representative soil samples were then sent to the laboratory for analysis of grain size and water content. With this data, a model of the soil conditions and types was constructed for the hole. This model does not necessarily apply to the soils under the structure since soil conditions can, and often do, change radically over short distances, but if boreholes on both sides of the structure are similar in nature, then the soils beneath the house can be inferred.

Results and Conclusions

Temperature data from the site indicates that even at the 50 foot depth the temperature of the soils is undergoing a gradual increase. Temperature on the southeast corner rose from 1.4 to 2.3°C from October 1992 to January 1997, and on the west side of the house temperature rose from 1.9°C in August 1992 to 2.5°C in January 1997. A similar upward trend in the temperature was obvious at shallower depths. Even at the 20 ft depth, temperature rose 0.4°C and 0.2°C in the west and southeast holes respectively. If permafrost did underlie this location (and obviously it did at some time in the past even if it was not present at the time of construction), it has receded to below the 50 ft depth. At this depth, further melting takes place very slowly and will not be a significant factor with respect to settlement of the house. The loose soils left behind by the melting permafrost, however, is another matter that must be assessed.

Loose soils can allow settlement due to a number of conditions: the increased load placed on the soil at the time of construction, increases in the soil moisture due to watering of the lawn or snow melt from the roof, additional loads from later construction, etc. Any of these can cause the soil to compact allowing the surface and anything sitting on it to subside. The subsidence normally occurs very slowly over several months or a few years causing a slow wracking of the structure. Subsidence in this house appears to be very slow, the maximum being 5/8 in. over nearly six years in the northeast corner. The garage appears to be moving somewhat more, with 1½ in. of elevation change occurring. However, the garage floor slab has risen with respect to the rest of the house by that much and appears to be somewhat cyclic suggesting a frost heave effect. The question then becomes one of will the house continue to subside or has it reached stability. Only continued long-term monitoring can answer this question. In any case, nothing in the data suggests that the settlement, if it does continue, will be anything but very slow making it easy to compensate for the elevation changes before any structural damage could occur.

Loose soils also raise the concern of settlement during a dynamic event such as an earthquake. During the period over which the level measurements were made on this house there were 15 earthquakes over Richter 4.0. and, of those, one was 5.0 on Nov 1, 1992 and one was 6.2 on October 6, 1995. This last one was the most significant event, since it was not only the largest but also it was the shallowest at only 9 km below the surface. It was felt very strongly by residents of Fairbanks. However, reviewing the data on level measurements shows that no significant measurable settlement can be identified in our data during any of these events. This suggests that either settlement into the loose soils beneath the structure was not triggered by a dynamic event of this magnitude or that settlement into the loose soils was already complete before the Permafrost Technology Foundation started monitoring the structure. These circumstances and observations do not preclude the possibility of settlement during a more severe earthquake or other type of dynamic event.

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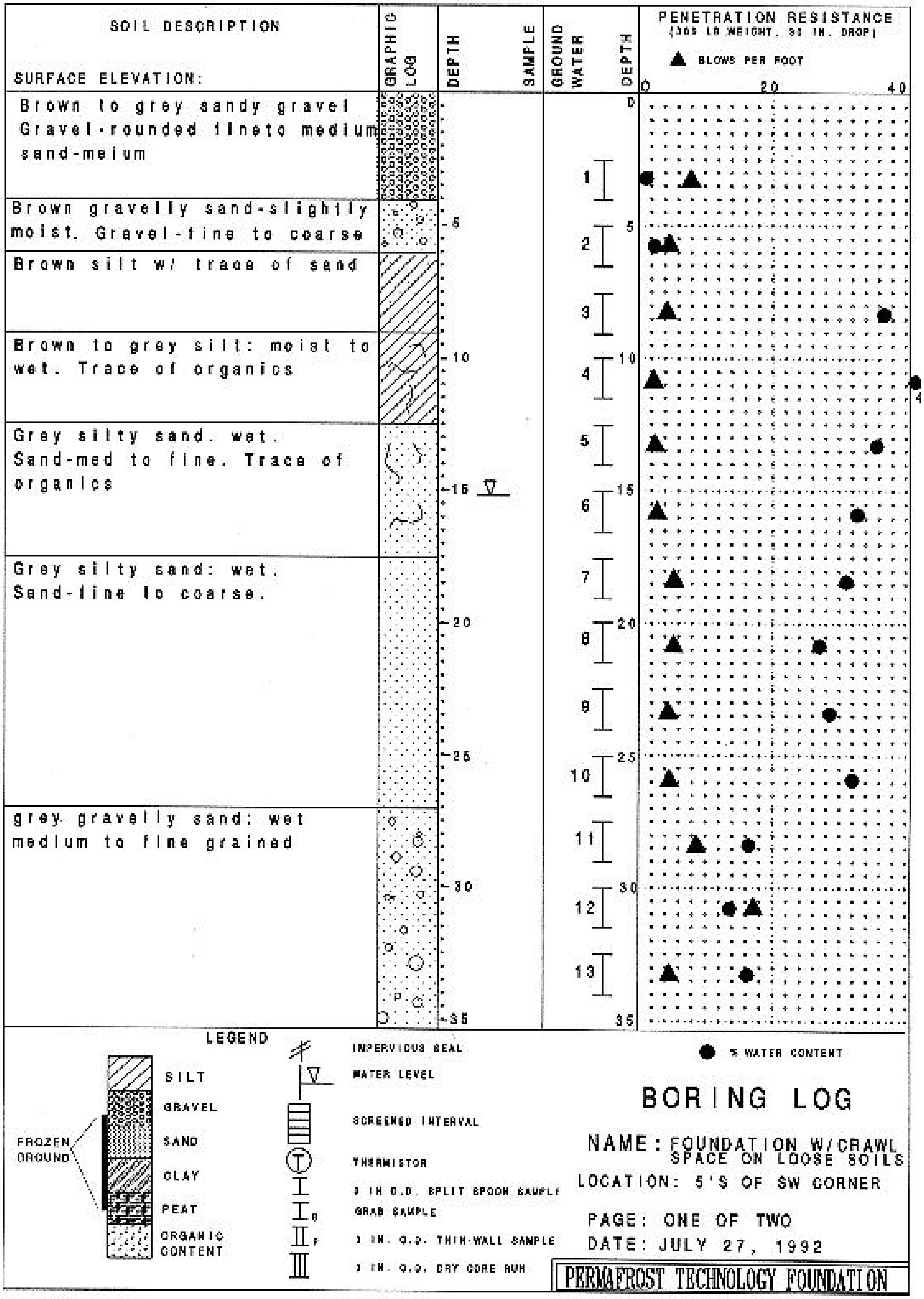
Appendix
Bore Hole Logs



SOIL DESCRIPTION

SURFACE ELEVATION:

Brown to grey sandy gravel
Gravel-rounded fineto medium
sand-meium

Brown gravelly sand-slightly
moist. Gravel-fine to coarse

Brown silt w/ trace of sand

Brown to grey silt: moist to
wet. Trace of organics

Grey silty sand. wet.
Sand-med to fine. Trace of
organics

Grey silty sand: wet.
Sand-fine to coarse.

grey gravelly sand: wet
medium to fine grained

PENETRATION RESISTANCE
(300 LB WEIGHT, 30 IN. DROP)

▲ BLOWS PER FOOT

● % WATER CONTENT

LEGEND

SILT
GRAVEL
SAND
CLAY
PEAT
ORGANIC CONTENT
FROZEN GROUND

IMPERVIOUS SEAL
WATER LEVEL
SCREENED INTERVAL
THERMISTOR
2 IN O.D. SPLIT SPOON SAMPLE
GRAB SAMPLE
3 IN. O.D. THIN-WALL SAMPLE
3 IN. O.D. DRY CORE RUN

BORING LOG

NAME: FOUNDATION W/CRAWL SPACE ON LOOSE SOILS
LOCATION: 5'S OF SW CORNER

PAGE: ONE OF TWO
DATE: JULY 27, 1992

PERMAFROST TECHNOLOGY FOUNDATION

SOIL DESCRIPTION

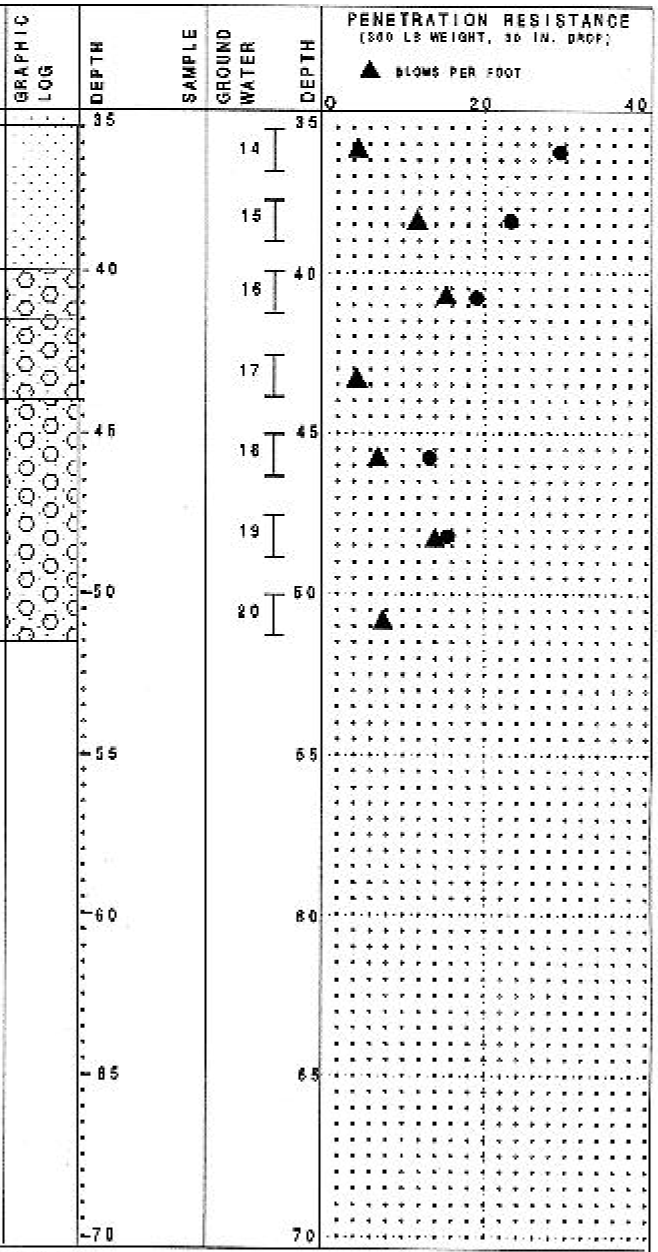
SURFACE ELEVATION:

Grey sand; wet. Medium to fine grained.

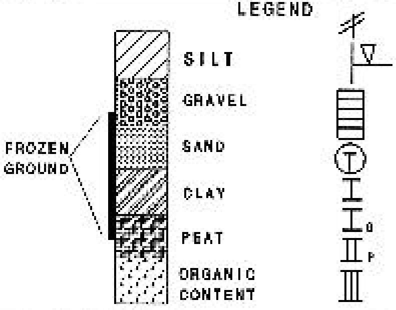
Grey sandy gravel; wet. Sand-med coarse. Gravel-fine to coarse.

Medium Sand coated gravel. Spoon cool to touch.

Grey sandy gravel;wet. Sand-fine to coarse; gravel-medium. Spoon very cold to touch.



LEGEND



IMPERVIOUS SEAL

WATER LEVEL

SCREENED INTERVAL

THERMISTOR

3 IN O.D. SPLIT SPOON SAMPLE

GRAB SAMPLE

3 IN. O.D. THIN-WALL SAMPLE

3 IN. O.D. DRY CORE RUN

● % WATER CONTENT

BORING LOG

NAME: FOUNDATION W CRAWL SPACE ON LOOSE SOILS

LOCATION: 5'S of SW CORNER

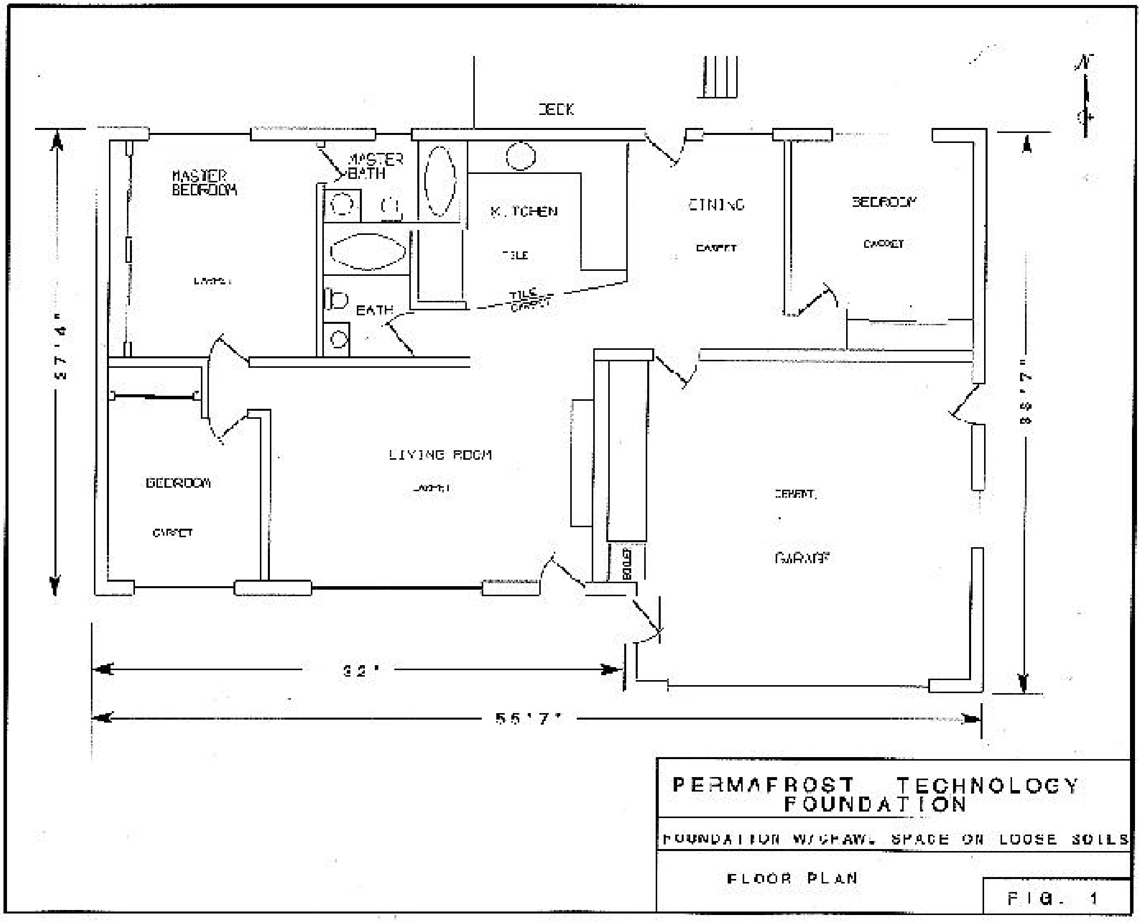
PAGE: TWO OF TWO

DATE: JULY 27, 1992

ST

PERMAFROST TECHNOLOGY FOUNDATION

Floorplan


DECK
MASTER BEDROOM
CARPET
MASTER BATH
KITCHEN
TILE
TILE
CARPET
DINING
CARPET
BEDROOM
CARPET
BATH
LIVING ROOM
CARPET
BEDROOM
CARPET
CEMENT
GARAGE
BOILER
57'4"
35'7"
32'
55'7"
N
PERMAFROST TECHNOLOGY FOUNDATION
FOUNDATION W/CRAWL SPACE ON LOOSE SOILS
FLOOR PLAN
FIG. 1
