Thirteenth Bjerrum Memorial Lecture: A case history of mysterious settlements in a building

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This lecture describes the investigation of large and damaging settlements in the One Lombard Building in San Francisco Calif. The cause of the settlements was a mystery. Although it was known that settlement began during construction of a major new sewer near the building, it was not clear how the settlements could be related to the sewer construction activities. The paper explains the cause of the settlements and describes the technique used to remedy the problem. The legal and insurance aspects of the case, in some ways more mysterious than the technical aspects, are also described.

Key words: settlement, foundations, clay, dewatering, pile driving, underpinning.

Ce discours décrit l'enquête menée sur les tassements importants qui ont endommagé l'immeuble One Lombard, à San Francisco en Californie. La raison des tassements était mystérieuse. Il était connu que les tassements ont commencé durant la construction d'une nouvelle voierie des eaux importante à proximité du bâtiment. Par contre, la manière dont les tassements pouvaient être corrélés avec la construction de la voierie n'était pas claire. Cet article explique la cause des tassements et décrit les techniques utilisées pour remédier au problème. Les aspects légaux et relatifs aux assurances de ce cas, parfois plus mystérieux que le point de vue technique, sont aussi traités.

Mots clés : tassement, fondations, argile, rabattement, fonçage de pieux.

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Introduction

The One Lombard Building is located, as shown in Fig. 1, at the northeast corner of Lombard and Battery streets, east of Telegraph Hill, in San Francisco. Built in 1901, it was owned by the Union Can Company and was originally called the Merchants Ice and Cold Storage building (Olmsted *et al.* 1977). As can be seen in Fig. 2, the building is three stories high and is constructed of brick.

The soil conditions beneath the building are shown in Fig. 3. In approximately 1881, 3–5 m of rock, rubble, and loose sand were filled on top of the Bay Mud at the site to raise the area above the level of San Francisco Bay (Dow 1973). The Bay Mud beneath the building is about 10 m thick; it is underlain by 3–5 m of loose silty sands and, at greater depths, by dense sands and stiff clays overlying the Franciscan bedrock (Harding–Lawson Associates 1976). The exterior walls and the upper two floors of the building are supported on wooden piles that are believed to extend down into the loose silty sand. The ground floor is a concrete slab, supported directly on the ground.

In 1958 the ground floor of the building was converted from cold storage to frozen food storage. A sand fill 1.2 m thick, with a network of pipes circulating heated oil, was used to prevent the foundation from freezing. In 1976 the entire building was converted to office space. The upper two floors were occupied by the offices of an architectural firm, the California Redwood Association, and attorneys. The ground floor was occupied by a firm involved in computer accounting for banks.

During the renovation the insulating sand fill in the ground floor was removed, and a concrete slab was cast on grade. In the area to be occupied by the accounting firm's computers and tape drives, a "computer floor" was installed. As shown in Fig. 4, this computer floor consists of 600 mm square panels supported on a steel frame. The steel frame is in turn supported by adjustable supports 300 mm high, resting on the concrete slab on grade.

Early in 1978, soon after the building was renovated and occupied, the ground floor tenant began to experience problems with the operation of the computers and tape drives in the first floor of the building. It was discovered that these problems were due to movements of the computer floor, which were caused by settlements of the slab that supported the computer floor system. Settlement measurements were begun in March 1978. The settlements measured in room 29 are shown in Fig. 5. It can be seen that, by the end of August 1978, the measured settlements varied from a minimum of a few millimetres to a maximum of about 125 mm.

At other locations the floor slab was not settling. However, when holes were cored through the slab, it was found that the soil was settling away from the bottom of the slab in some places, leaving voids as large as 200 mm between the bottom of the slab and the top of the ground. This resulted in the fearsome possibility that the slab at these locations might collapse suddenly, with consequences even worse than those caused by the gradual settlement. Where voids were found they were grouted to minimize the potential for floor collapse.

The building owners found it necessary to have crews available virtually around the clock to relevel the floors to remedy problems with the computers that were caused by settlement. This maintenance operation was very expensive. In the period from January through August 1978 the owners spent approximately $500 000 maintaining the levelness of the floors, grouting beneath the slabs, and making various types of measurements in and around the building.

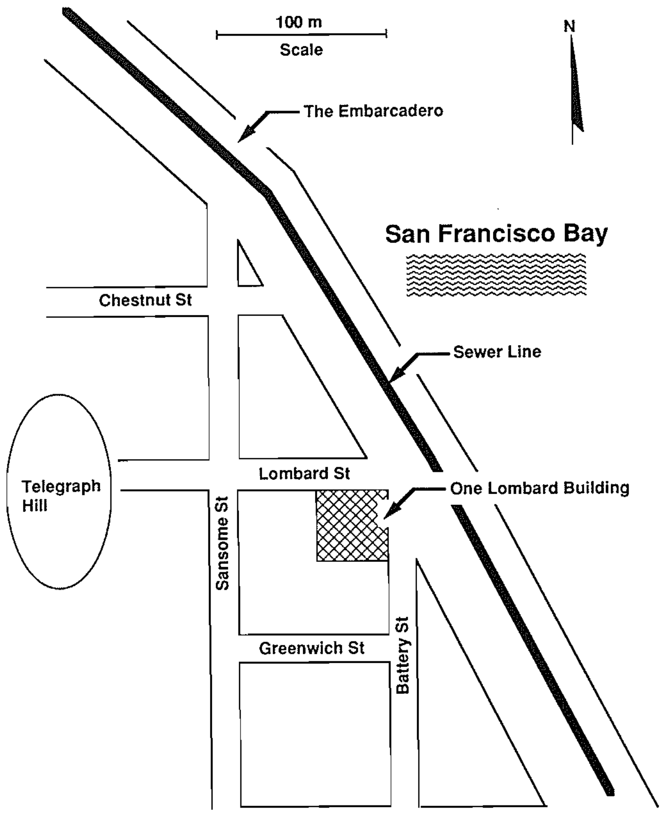


FIG. 1. The One Lombard Building, northeast of downtown San Francisco.

The situation in August 1978

At the time the settlements in the building were noted, a major interceptor sewer line was being constructed along the Embarcadero, north and east of the One Lombard Building, as shown in Fig. 1. The owners of the building had a strong suspicion that the settlement within their building was caused in some way by the sewer construction and had begun to collect information that they could use in a lawsuit to recover damages from the City of San Francisco (the owner of the sewer) and Granite–Yaminishi (the contractor).

The building owners had installed three observation wells around the building in June 1978. As shown in Fig. 6, the measured water levels were lower than normal, which in this area was about −2 m San Francisco City datum. At well 2 the water level was about 3 m lower than normal in August 1978. It was suspected that these abnormally low water levels were caused by dewatering for a sewerage pumping plant being constructed along the sewer line about 300 m north of the building. At the pumping plant the water level had been lowered about 20 m by the dewatering. In the opinions of the building owners, this dewatering was the most likely cause of the large and damaging settlements in their building.

The writer was hired by the owners of the building in August 1978 to collect information concerning the cause of the settlement. It was clear that the owners' reason for hiring the writer was to collect information for use in the intended lawsuit against the city and the contractor and to have an informed expert prepared to support their case. The writer made it clear that he could not limit his investigation to the narrow purpose of proving that the sewer construction was the cause of the problem because it had not yet been determined beyond reasonable doubt that this was so. He could, however, conduct an investigation to determine the cause of the settlements, provided that the building owners were willing to investigate any and all possible causes. The owners agreed readily, still convinced in their own minds that the sewer construction must be the reason for the settlements in their building.

Investigations from September to December 1978

After reviewing the conditions in the building and the information that had already been collected by the owners, the writer concluded that there were at least four possible causes of the settlement: (1) groundwater lowering, (2) vibrations from driving sheet piles for excavation bracing along the sewer, (3) movements of the bracing during excavation of the sewer trench, and (4) thawing of frozen ground. The last of these possible causes was related to the possibility that the insulating system beneath the building might have been somehow ineffective, and the ground beneath the building might have become frozen during the period when the building was used for storage of frozen food. It was reported, however, that no frozen ground had been encountered during renovation of the building, and it thus appeared that the insulating system had been effective.

To investigate these possible causes of settlement, a program of investigation was undertaken in September 1978. The investigation included these activities: (1) obtain records of dewatering for the sewer to determine when, where, and how far the water table had been lowered; (2) obtain sheet-pile driving records to determine how far from the building sheet piles were being driven when the settlements began; (3) measure vibrations during sheet-pile driving to determine the likely vibration levels in the building when the settlements began; (4) core more floor slabs to look for voids, to determine with greater precision the extent of the area within the building affected by the settlements; (5) core the sidewalks around the building to look for voids, to determine if the ground was settling outside the building as well as inside; (6) measure the temperature of the ground beneath the slab to determine if the ground might have been frozen; and (7) measure the elevations of pile-supported parts of the building periodically to determine if they were settling or stable.

Vibrations due to sheet-pile driving

The first measurements of vibrations induced by sheet-pile driving were made close to a pile being driven. The predominant frequency of the induced ground vibrations was 10–25 cps. At a distance of 1 m from the pile, the particle velocity was about 60 mm/s. At a distance of 3 m from the pile, the particle velocity dropped off to about 25 mm/s. Because the settlements had begun when sheet piles were being driven 300 m from the building, the writer inferred that the resulting particle velocities due to sheet-pile driving must have been very small at the time the settlements began.

Accelerations were also measured within the building, at a time when sheet piles were being driven about 75 m away. The acceleration induced by the pile driving was $0.030g$, only slightly greater than the acceleration ($0.024g$) due to a train passing on the nearby track. The background acceleration level in the building was $0.009g$. It seemed unlikely that the accelerations due to sheet-pile driving would have exceeded

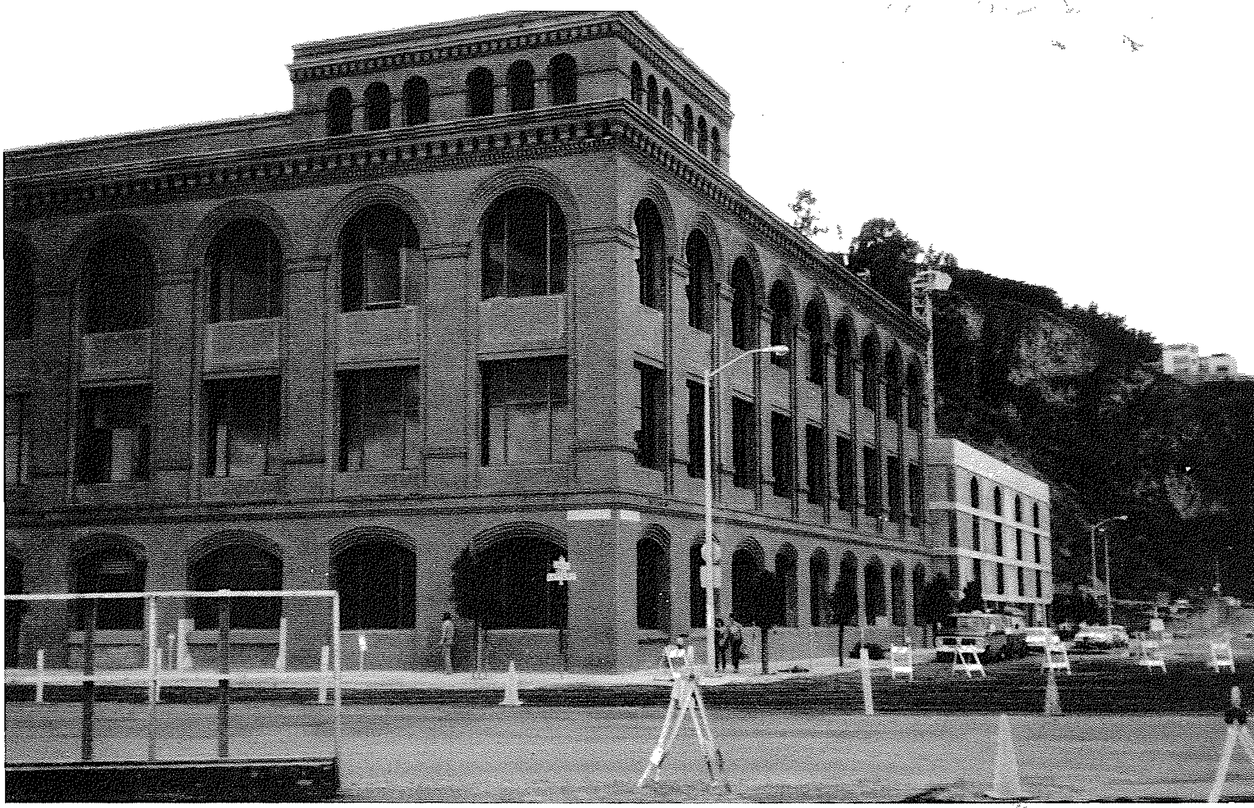


FIG. 2. Photograph of the One Lombard Building, with sewer excavation at bottom and Telegraph Hill visible in background.

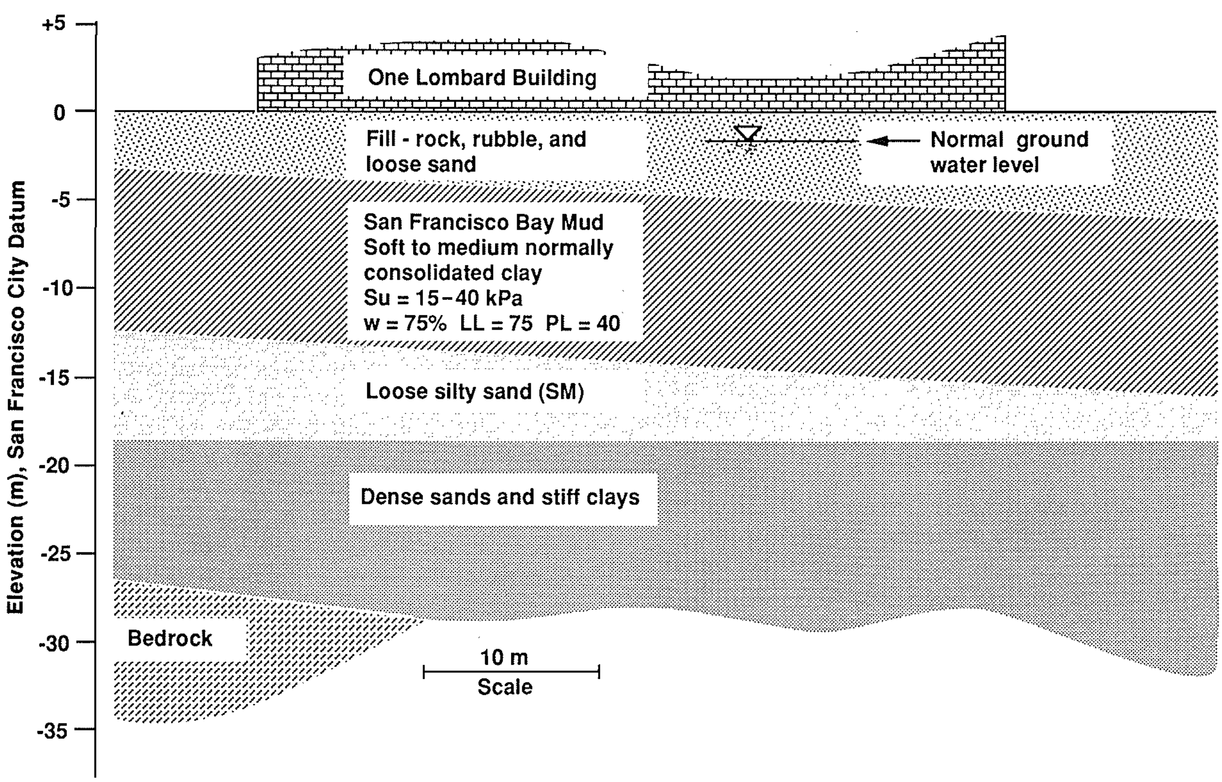


FIG. 3. Soil conditions at One Lombard. Section along Battery Street, looking west (after Harding–Lawson Associates 1976).

those due to passage of a train, or perhaps even the background accelerations, at the time the settlements began, when sheet piles were being driven 300 m away from the building.

Also relevant was the fact that bearing piles had been driven for adjacent buildings to the south and the west of the One Lombard Building in 1950 and 1977, with no apparent effect on the One Lombard Building. The bearing piles

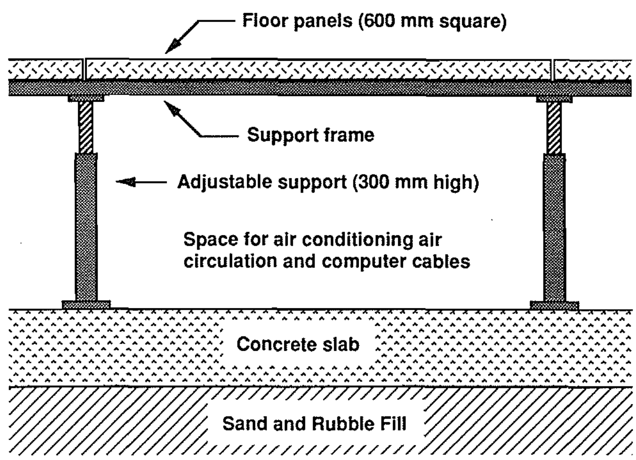


FIG. 4. Floor system used in computer rooms.

were driven much closer to the One Lombard Building than were the sheet piles for the sewer, and their driving presumably would have induced even larger vibrations in the ground because they were displacement piles, but no settlements had been noted at the time the piles were driven. As a result of these investigations, vibrations due to sheet-pile driving were eliminated as a possible cause of the settlements.

Movements of excavation bracing

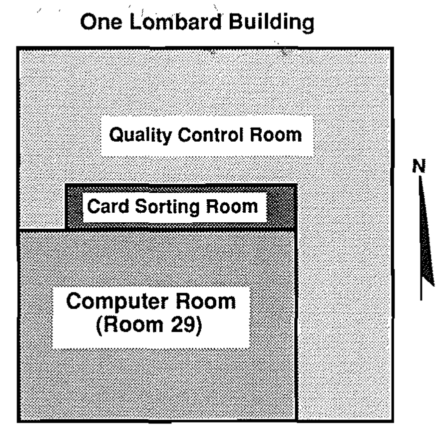
The conditions of the bracing for the sewer excavation near the One Lombard Building were examined closely to determine if movements of the ground supported by the bracing might have caused the settlements in the building. There were readily discernable signs of movement. About 3 m behind the sheeting, in the direction of the One Lombard Building, an open crack about 25 mm wide was visible at the ground surface. However, this crack was about 20 m from the One Lombard Building, and no cracks could be found closer to the building.

A careful examination was also made of the conditions of the sidewalk and the curb adjacent to the One Lombard Building. These had been poured when the building was renovated in 1977. It was noted that the curb had separated from the sidewalk by as much as 4 mm. The sidewalk had separated from the building by 4–6 mm and had settled about 20–25 mm with respect to the wall of the building. Only one crack could be found in the sidewalk.

This investigation indicated that the movements outside the building were smaller than those inside. Particularly, it was clear that the ground movements close to the sewer excavation were not larger than those in the building. Accordingly, movements of the excavation bracing were eliminated as the cause of the settlements in the building.

Groundwater levels

Observations of the groundwater levels around the building continued in September through December 1978, as shown in Fig. 6. The water level in observation well 2 continued to drop until early October and then rose rapidly to a level about 1.0 m below normal. During this period, however, the settlements continued at an undiminished rate. By December 1, 1978, the maximum measured settlement in room 29 had increased to 200 mm. The rate of settlement was as large as ever, despite the fact that the groundwater levels near the building had returned to near-normal levels.



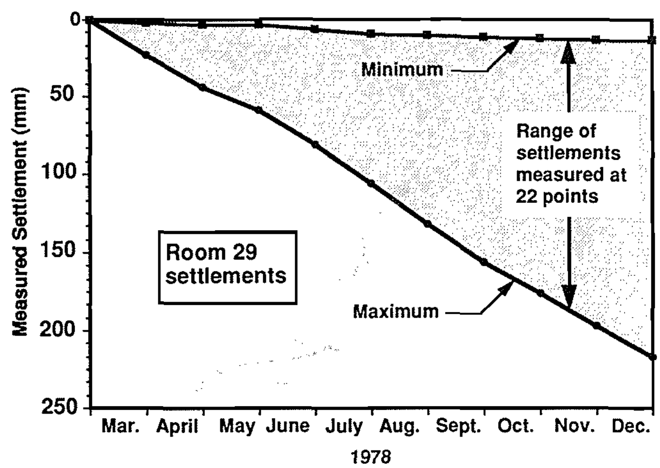


FIG. 5. Measured settlements in the One Lombard Building.

These observations seemed to argue against the settlements being caused by the increase in effective stress accompanying a drop in groundwater level. A drop in groundwater level of 1.0 m, which was the condition when the settlements started and again in December 1978, would increase the effective stress in the soils beneath the building by roughly 8 kPa. This was less than the surcharge due to the weight of the 1.2 m thick insulating fill that had been in the building from 1958 to 1976. The surcharge due to this fill would have been about 20 kPa. Furthermore, it was unlikely that the live loads due to the weight of the computer equipment were as large as the loads of the frozen food stored in the building from 1958 to 1976. It therefore appeared to be virtually impossible that the loading on the soils beneath the building were larger in 1978 than they had been in the period from 1958 to 1976.

Although settlement due to increase in effective stress could be ruled out as a possible cause of settlements, another mechanism related to the drop in groundwater level could not be dismissed so readily. This possible mechanism for settlement stemmed from the nature of the fill beneath the building, which consisted of rock, rubble, and loose sand. In places the sand lay over the top of the rock and rubble, which likely contained large open voids. A change in the groundwater level beneath the building might trigger migration of the sand down into the voids in the rock, as sand flows from the top to the bottom of an hour glass. Once begun, this action could be kept in motion by the small levels

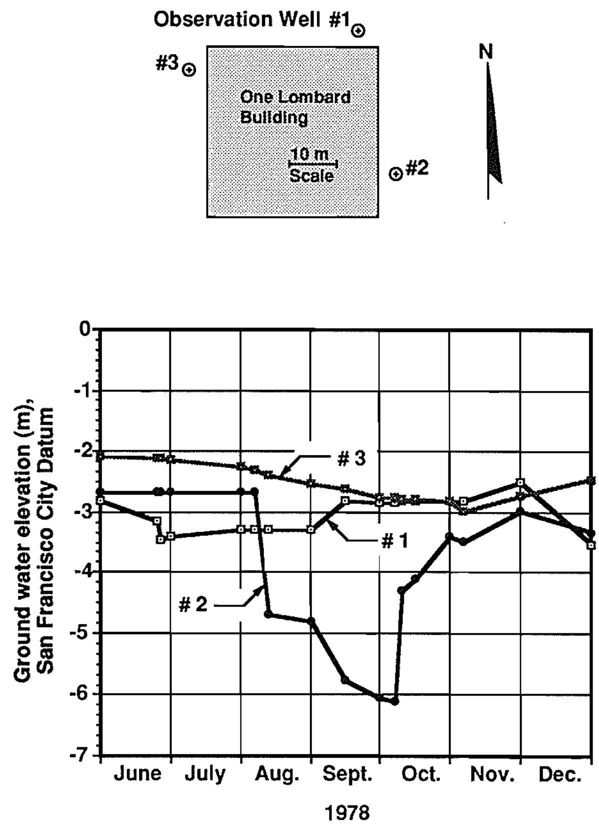


FIG. 6. Water levels in observation wells.

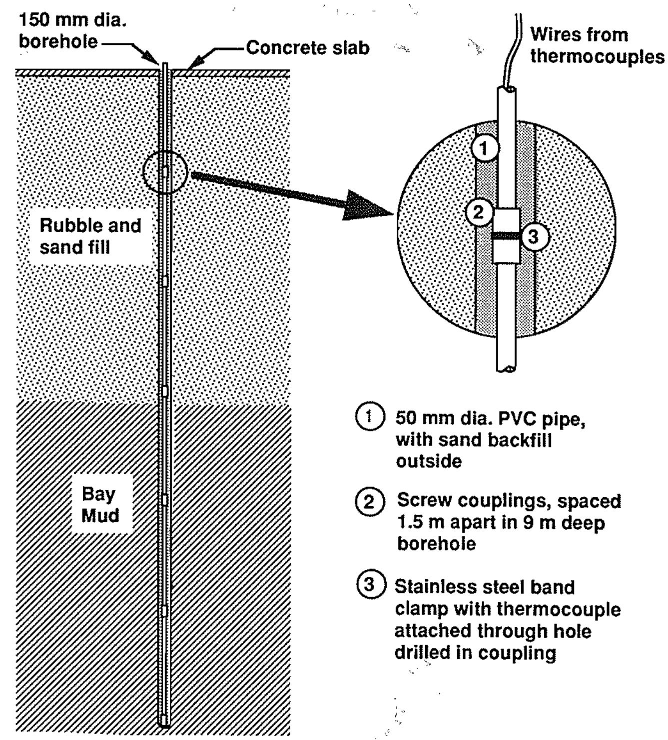


FIG. 7. Thermocouples in PVC casing used for measuring ground temperatures (designed and built by C. Chan, University of California, Berkeley).

of vibration in the building and could conceivably result in settlements as large as those observed.

Ground temperatures

The next phase of the investigation was to measure the temperatures of the ground beneath the building to determine if the ground might have been frozen in the past. The owners of the building were not enthusiastic about this part of the study. Measuring the ground temperatures would require drilling one or more boreboles inside the building, which would be dirty and disruptive. Also, if the settlements in the building were caused by thawing of frozen ground, it would not be possible to collect damages from the city and the sewer contractor. Despite their reservations, however, the owners agreed that the investigation should proceed.

In the San Francisco area the ground temperature at a depth of 6 m is 13°C and is constant year-round. During the 18 years when the One Lombard Building was used as a frozen food storage warehouse, the temperature in the storage areas was −18°C. Hypothesizing for the purpose of argument that some portions of the insulating system did not work, the temperature of the ground beneath the building would have been lowered considerably during the 18 year period of frozen food storage. Then the ground would have begun to warm up again in July 1977 when renovation was begun. Professor Jim Mitchell, the writer's colleague, estimated that if this hypothesized situation had in fact existed, the temperature of the ground 4.5 m beneath the floor of the building would be 7°C or lower in December 1978. The residual effect of ground freezing would thus be at least 6°C, a magnitude that could be easily measured.

To make these measurements, the device shown in Fig. 7 was developed by Clarence Chan, another of the writer's colleagues. It consists of PVC pipe, in 1.5 m lengths, with screw couplings. A stainless steel band clamp was attached around each coupling, with a thermocouple attached through a hole drilled through the plastic coupling. The thermocouple wires extended to the surface inside the watertight PVC casing. The instrument was light and easily portable. The entire device could be folded into a 1.5 m length and carried in one hand. It was assembled one section at a time as it was lowered into a 9 m deep borehole and was backfilled with uniformly graded sand after the full length had been installed. Two trial runs were made, installing these devices at locations outside the building, to be sure all the problems had been solved before attempting to install one inside the building. Both of the trial devices worked well, reaching stable temperatures within an hour after installation.

Installing one of the thermocouple strings inside the building was a difficult undertaking. A location just outside the wall of room 29 was chosen, where a small track-mounted drill rig could be positioned inside the building. The drill rig is shown in Fig. 8. The drilling completely disrupted the normal operations of the office area with dirt, noise, and exhaust fumes. Needless to say, the office workers who were displaced to the remote areas of the room were extremely unhappy with this rude intrusion on their normally clean and quiet work environment.

After coring through the concrete floor, drilling was begun with an auger, as shown in Fig. 8. After advancing a short distance, the auger encountered an obstruction, probably a piece of rubble or a large rock. More than an hour of drilling produced only 1–2 mm advance. However, it was decided to continue because it seemed certain that once the

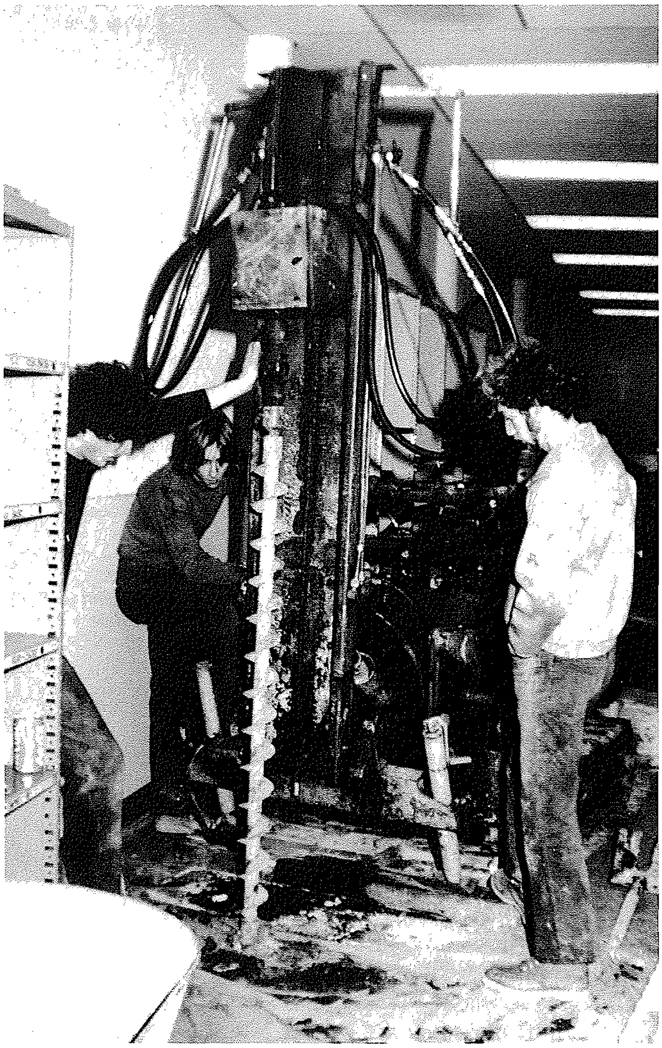


FIG. 8. Drilling beneath the floor slab at borehole A inside the One Lombard Building, adjacent to room 29.

FIG. 9. Firing the 30.06 rifle down the borehole to break up an obstruction.

messy drill rig was removed, it would never be permitted in the building again. At this point the drill foreman (an 18 year old driller with 20 years of experience) suggested a way to solve the problem. He said that in previous cases where he had run into problems with obstructions, he had fired a few rounds from his 30.06 rifle down the hole to break up the obstruction. The writer agreed that this sounded like a good idea, especially since there did not seem to be any alternatives. Within an hour and a half the driller retrieved his rifle and brought it into the building, wrapped in a blanket to keep it out of sight of the office workers, who already viewed our operation with revulsion. Then, as shown in Fig. 9, the driller fired five rounds down the hole. His previous experience with the technique seemed to be confirmed by the fact that he brought not only the rifle, but a steel plate with a hole in the center to catch any bullets that might ricochet off the obstruction.

After this treatment, the drill rig was moved back onto the hole and broke through the obstruction. When the Bay Mud was encountered beneath the fill, and handfulls were removed from the auger flight, it was very easy to discern that the mud was extremely cold. Holding the mud in one's hand was like holding a handful of ice cream. Even before the thermocouple string was installed and ground temperatures were measured, it was clear that the Bay Mud must have been frozen, because even 18 months after shutdown of the freezer system, its temperature was still close to freezing.

The thermocouple string was installed at this location (hole A) on December 22, 1978. The ground temperatures 1 week later are shown in the upper right corner of Fig. 10. It can be seen that the minimum temperature, at a depth of about 4.5 m, is 0°C. The salinity of the water in the Bay Mud was about 17 000 ppm, and the freezing temperature was estimated to be about -2.2°C. Although the mud was not frozen at 0°C, it had been warming for 18 months, and it was clear that it had been frozen during the frozen food storage operation.

The cause of the settlements

The next question that arose was what effect freezing and thawing would have on San Francisco Bay Mud. To find out, a test was performed in which a consolidation test specimen was frozen and thawed while under load. The apparatus and the results of the test are shown in Fig. 11.

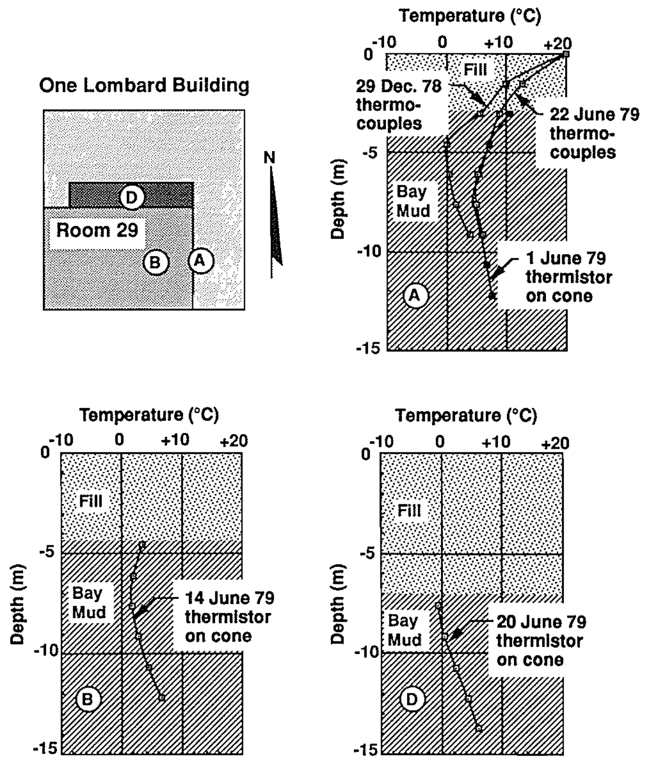


FIG. 10. Measured temperatures beneath the One Lombard Building.

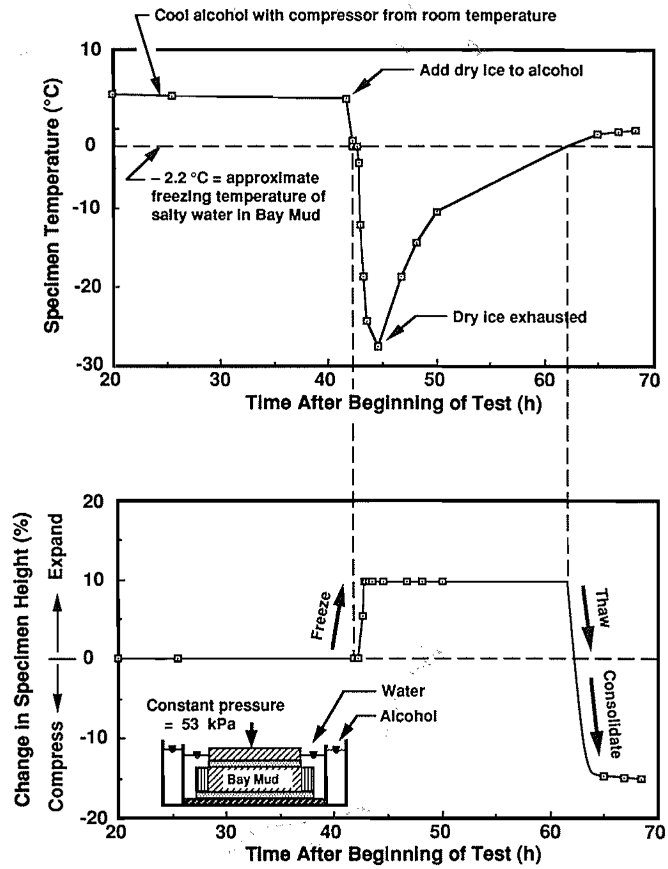


FIG. 11. Freeze–thaw test on undisturbed San Francisco Bay Mud.

An undisturbed specimen of Bay Mud from Hamilton Air Force Base in Marin County, 102 mm in diameter and 25.4 mm high, was subjected to the same vertical pressure that it had carried in the ground, 53 kPa. Cooling coils in the surrounding alcohol bath were used to reduce the temperature of the apparatus and the specimen. The temperature of the test specimen was measured by a thermistor at its base.

After about 40 h the temperature had been reduced to 4°C, as shown in the upper part of Fig. 11. At this stage dry ice was added to the alcohol bath, and the specimen froze very quickly. In a period of about 3 h the temperature dropped to −28°C. At this point the dry ice was exhausted, and the temperature of the specimen began to increase. After about 20 h in a frozen condition, the specimen thawed.

As shown in the lower part of Fig. 11, the height of the specimen remained constant until the specimen froze. Then the height of the specimen increased by about 10%. During the period while the specimen was frozen, its height remained constant. When it thawed, its height decreased, first due to thawing, and then due to consolidation. Eventually, when it again came to equilibrium under the 53 kPa load it had carried all the time, its height had decreased by 15%.

These results show that freezing and thawing Bay Mud could result in settlements, in this case 15% of the frozen thickness. As the water in the voids of the Bay Mud freezes and expands, adjacent particles are moved apart, and whatever bonds exist between them are broken. The result is that when the mud thaws, it is essentially a completely remolded material, no longer in equilibrium with the load it carried previously. Consequently, it consolidates until it reaches a new equilibrium condition under the load, and as it consolidates it compresses.

There was no way to determine the thickness of mud beneath the building which had been frozen. Considering that the settlement resulting from freezing and thawing would be about 15% of the frozen thickness, freezing a 2 m thickness of Bay Mud could produce 300 mm of settlement, which was eventually estimated to be about the maximum settlement of the ground beneath the building.

Although the owners of the One Lombard Building were at first unhappy when the writer explained that the damage to their building was due to freezing and thawing of the Bay Mud beneath it, they soon learned that this cause of damage was covered by their insurance policy. After having the writer's work and findings reviewed by a geotechnical engineer experienced in frost problems, the insurance company agreed that freezing and thawing was the cause of the settlement and paid the owners of the building about $800 000 for the costs of damages and repair.

Investigation from January to June 1979

Once the cause of the settlements was determined, the next question was what to do. The options were as follows.

(1) Watch and wait. This would be a continuation of the status quo. This course was undesirable because the tenant in the ground floor was very unhappy with the frequent problems that were being experienced with computers and tape drives and with the frequent interference caused by maintenance activities. It was also undesirable to continue this course because the costs of maintenance were high.

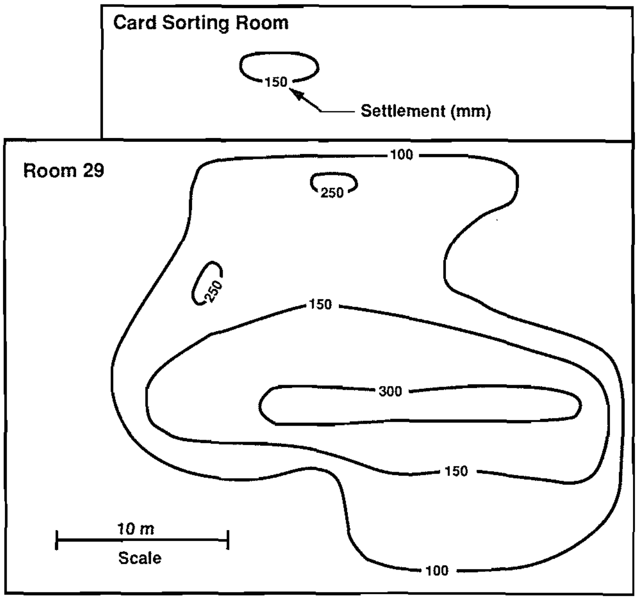


FIG. 12. Settlement contours based on measurements of distance from computer floor down to top of concrete slab, April 1979.

(2) Construct a structural slab for the ground floor, supported by the existing piles. This would be an expensive proposition, primarily because it would involve moving the ground floor tenant out while the work was done and back when it was finished. Because the tenant company worked around the clock, 7 days a week, this move would be very expensive. The cost of the move was estimated at $500 000. An important question concerned with this option was whether the existing piles could carry the load of the ground floor without settling.

(3) Construct a structural slab for the ground floor and install new micropiles to support it so that no new loads would be added to the existing piles. This would be safer but more expensive than option 2.

To be able to evaluate these options, the owners asked the writer to conduct an investigation to determine how much of the ground floor would need to be replaced with a pile-supported structural slab and to determine if the existing piles could carry the additional loads without settling.

The magnitude and extent of the settlements in room 29 and a card-sorting room were surveyed by measuring the distance from the bottom of the frame supporting the computer floor to the top of the concrete slab. Assuming that the maintenance operation had kept the computer floor at the same elevation while the slab settled (a reasonable presumption), the settlement at any point could be estimated as the difference between the measured spacing and the initial spacing (300 mm). This method was an improvement over the settlement measurements that had been made previously because all parts of the rooms could be included, and because some settlement had occurred before the settlement measurements were begun. Contours of settlement determined in this way are shown in Fig. 12. The largest settlements, near the center of room 29, were slightly more than 300 mm.

Additional borings were made in the locations in room 29 and the card-sorting room where the greatest amount of settlement had occurred. It was not possible to take the drill rig into the computer areas to make these borings. They had to be advanced by hand, by driving 100 mm diameter heavy gauge steel pipe through the sand and rubble fill with a sledge hammer, a tedious and exhausting job. When the top of the Bay Mud was reached, vane shear tests and cone penetration tests were performed in the mud, working through the 100 mm diameter casing.

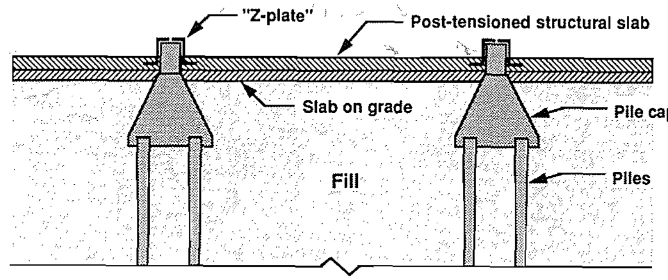


FIG. 13. Post-tensioned structural slab and "Z-plate" connection to pile cap.

The soil conditions at the locations of the borings, and the measured ground temperatures, are shown in Fig. 10. The ground temperatures at the new boring locations (B and D) were measured using a thermistor on the tip of a cone penetrometer. This technique was used also at a new hole adjacent to hole A, where the thermocouple string had been installed. As shown in the upper right part of Fig. 10, ground temperatures measured on June 22, 1979, using the thermocouple string were essentially the same as those measured on June 1, 1979, using the thermistor on the cone. This similarity indicates that the measurements made with the thermistor are accurate. The coldest ground temperature measured anywhere beneath the building was $-1\,°C$, measured in hole D on June 20, 1979.

By analyzing the loads on the existing piles and estimating their capacities, it was concluded that a new structural floor could be supported by the existing piles without causing them to settle significantly. On this basis option 2 above was chosen, and a structural slab was built in room 29 and the card-storing room. One of the owners of the building was an innovative contractor who managed to construct the new slab without moving the ground floor tenant out of the building. This was done by building the slab bit by bit, in 5 m square sections. The post-tensioned slabs were supported from the existing pile caps as shown in Fig. 13. A photograph of one of the "Z-plate" connectors between the slabs and the pile caps is shown in Fig. 14.

Although construction of the structural slab in sections was time-consuming, it avoided having to move the tenant out and back and resulted in considerable savings. After it was completed there was no settlement of the piles, and thus no further settlement of the computer floor. The settlement of the ground beneath the slab was monitored by means of steel dowels driven into the ground through holes in the concrete slab. These settlements were very small, and measurements were discontinued within a few months. It was concluded that the remedy adopted had been fully successful.

Epilogue: the lawsuit

As a consequence of having paid a claim for the damages to the One Lombard Building, the building owners' insurance company held the right to pursue damages from any other

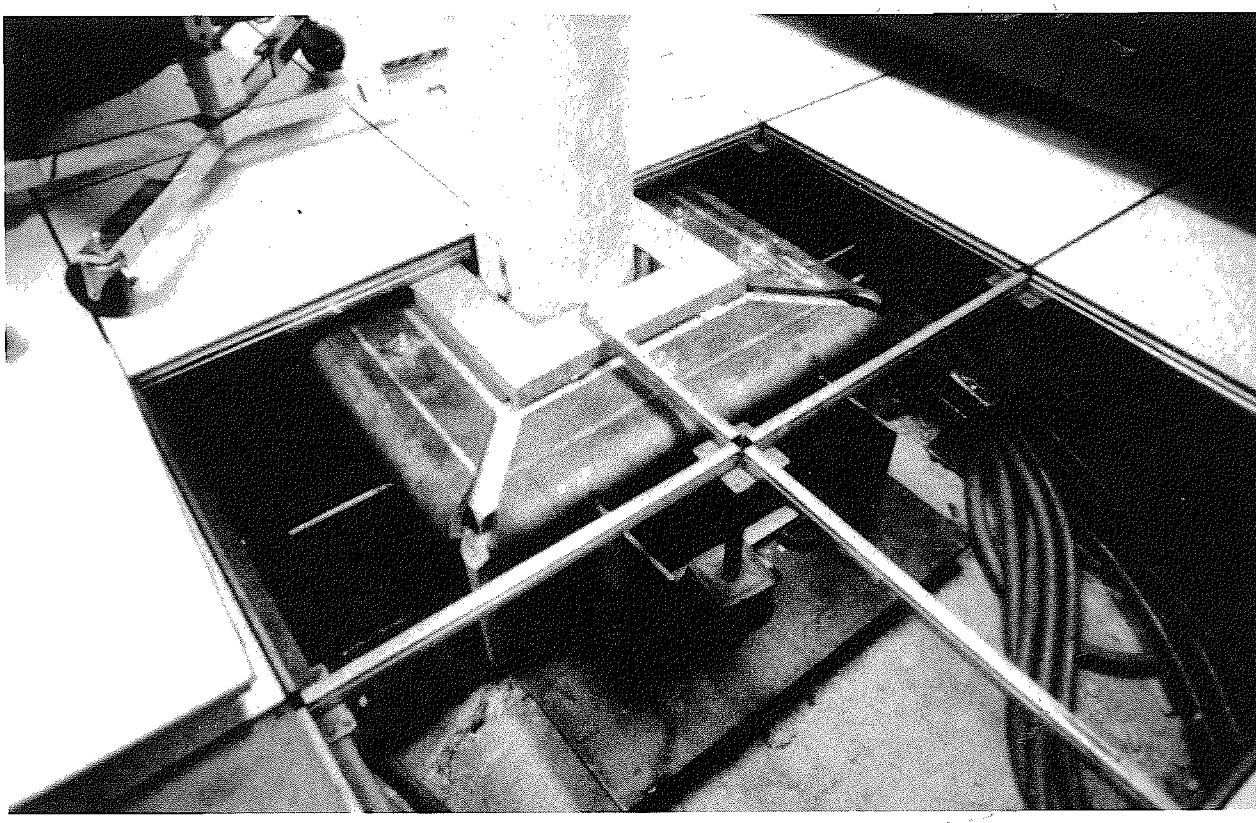


FIG. 14. "Z-plate" used to transfer load of new post-tensioned slab (not yet poured when photograph was taken) to top of existing pile cap.

party. In 1983, the insurance company sued the City of San Francisco and the sewer contractor for the cost of the damages the insurance company had paid to the building owners. Although the insurance company had previously agreed that the settlement in the building was caused by thawing of frozen ground, its suit claimed that the damage was caused by construction of the sewer.

The case was tried before a jury. The writer was subpoenaed by the city and the contractor to testify as a "percipient witness." In this capacity his testimony was confined to narrowly restricted statements concerning the investigations that had been done and the data that had been obtained. Interpretations of the data and expressions of opinion regarding the cause of the settlement were not allowed. A majority of the members of the jury reportedly did not believe that it was possible to freeze soil and did not find credible the defence attorney's claim that the settlement was due to the thawing of frozen ground. The verdict was 9 to 3 in favor of the insurance company, which was awarded damages from the city and the sewer contractor on the basis of the jury's finding that the damage to the building must have been caused by construction of the sewer.

Lessons learned

This case has provided a number of useful lessons, both technical and professional. Among them are the following.

(1) It is quite easy and accurate to measure ground temperatures with a thermistor in the tip of a cone penetrometer. It was expected that the friction during penetration might lead to inaccurate temperature readings. However, in the San Francisco Bay Mud, the temperatures measured during continuous penetration were virtually identical to those measured after stopping penetration of the cone and allowing time for the temperature of the cone to stabilize.

(2) Freezing Bay Mud quickly, without allowing time for drainage as the water expands, has the effect of completely remoulding the mud. When it thaws, it consolidates and compresses under the same load that it carried in equilibrium before freezing. The compression can be as much as 15%.

(3) There is no substitute for measuring what you need to know. Examples from the One Lombard case include the groundwater levels, vibrations due to sheet-pile driving, ground temperatures, and effects of freezing and thawing the Bay Mud.

(4) The most important thing to know about any piece of information is that it may be wrong. An example on this job was the information that no frozen ground had been encountered during renovation of the building. After the low ground temperatures had been measured, the writer was informed that the contractor who dug the pit for the elevator had in fact encountered frozen ground.

For a time following the lawsuit, the writer felt that a valuable experience had been ruined by the perverted jury verdict. However, with the passage of time, this feeling has mellowed. The illogical disposition of the matter in the eyes of the law will not alter that unique experience, on December 22, 1978, when the Bay Mud came up on the flight of the auger as cold as ice cream and the pleasure that came from unraveling the mystery and knowing the cause of the problem with a surety that geotechnical engineers seldom enjoy.

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