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SYNOPSIS Cracking and heaving of a Single Storey R.C. Building was initially perceived as settlement. This error led to unnecessary and costly remedial measures such as Piling for the Phase II Building which further aggravated the problem. The heaving was caused by a seemingly innocent decision during the construction stage to use Slag from a steel mill as the base course material. This Slag reacted with the highly corrosive groundwater which caused heaving of the Building and discomfort and morale problems to the Building occupants. Careful engineering study and investigation resulted in a very simple solution which saved the Building from abandonment and demolition.

INTRODUCTION

A Single Storey Precast Reinforced Concrete Research and Development Building was built in Two (2) Phases starting with the Phase I in October 1975. After the construction of Phase I, severe flooding in the area occured in October 1978. Severe cracks were observed in the Precast Post Tensioned Waffle Roof Slab and supporting Beams and Walls. Cracking and extreme waviness was also observed in the Floor Slabs, making office work very difficult. This initial cracking and distress became progressive over the years and "settlement" of the Building was suspected. Extensive structural epoxy adhesive repairs were made on the cracked portions by the original contractor. In addition full scale load tests were performed on the waffle roof slab.

Because of the suspected "settlements", it was decided by the owner to construct Phase II on Pile Foundations. Soon after construction, cracks were also observed in this Phase II portion but in contrast to the Phase I portion, more severe cracking occurred on the walls and not on the slabs.

In the meantime, cracking continued on the Phase I structural elements despite the structural repairs.

This condition was puzzling to the owners and several Engineers were consulted to look at possible remedial measures.

Because of the client's concern for the safety of its employees, abandonment and demolition of the Building were contemplated. It was at this point that our services were engaged to have a critical last look at the Building and to ascertain the cause/s of the problems. We were also asked to determine whether the progressive cracking can be arrested and the building rehabilitated with the safety of occupants being the foremost consideration.

DESCRIPTION OF THE BUILDING

The Research and Development Laboratory building was originally proposed as a two storey reinforced concrete building with precast post tensioned waffle slabs but after some distress was observed early on, the plan was abandoned.

The facility was built in a low lying area in the suburban town of Pasig in Metro Manila. The area is sometimes flooded when the Marikina River overtops its Banks during a 10 year flood.

A two meter Engineered Fill was placed to elevate the Building's Finished Ground Line from the surrounding area. A half meter layer of "heavy aggregate" base course was laid and compacted to support the slab on grade. This engineered fill and base course was laid to support the Parking, Driveway and the entire Building footprint to include the future Phase II addition. The filling and compaction for the whole area to include the proposed future Phase II addition were all done at the same time.

The center was constructed in two phases as follows:

Phase I

This phase was constructed starting October 1975 on continuous footings supporting column loads through socket pedestals loading on to the continuous footings. Founding elevation is approximately 2.8 meters below finished floor line. The columns are 0.35m x 0.35m precast concrete columns inserted into sockets in the footing.

The roof consists of approximately 1.0m x 1.0m precast waffle slabs joined together by cast in place concrete packing and post tensioning. A layer of water proofing was subsequently applied.

Perimeter walls consist of 150mm CHB units and plaster finished with protruding fins also of CHB. Interior walls were also of CHB resting on the slabs.

The floor is a 100mm thick reinforced concrete slab on "heavy aggregate" Base Course over the imported granular fill material.

Phase II

Phase II construction was started in August 1978 or approximately three (3) years after Phase I construction. The structural configuration is the same except that the new building was now supported on Pile foundations because of the observed distress and perceived "settlements" of the Building.

This new addition was constructed by another contractor.

The walls were now supported on Grade Beams with Flanges acting as continuous footings. The Grade Beams are in turn supported on Pile caps. The floor slab was still connected to the walls and columns by Dowels. Columns were embedded into the Pile caps.

OBSERVED DISTRESS

Two years after construction of the Phase I Building, Flooding occurred in October 1978. The flood waters rose to about 38 centimeters above the floor line of the Building. Although, minor cracking was observed in the Building even before October 1978, extensive cracks and more regular repairs reached its peak in 1982 and became a major problem and concern for the owner as well as the Building occupants.

The corridor slabs became so wavy that normal walking was difficult and passage of pushcarts of chemicals had to be done carefully to avoid spillages.

As earlier discussed, there were contrasting failure patterns and observed cracking between Phase I and Phase II construction.

For clarity, these are discussed in detail separately as follows:

Phase I Distress

Phase I was constructed in October of 1975 on continuous footings resting on well compacted Engineered Fill.

Severe cracking and extreme waviness were observed in the slabs. Maximum slab displacement is 130mm (5.21 inches) at the analytical laboratory. The 3D mesh plot of the slab deformations is shown in Fig. 1. The 2D Contour Plot is also presented in Fig. 2.

Cracks have been observed in the masonry walls but were not as severe as in the Phase II Walls.

A noticeable separation gap was observed between the roof and the wall with the exterior walls opening outwards.

The extreme waviness of the slabs has made normal office work difficult. Desks and cabinets needed to be periodically relevelled on stilts (See Fig. 3) to prevent rolling of pens and pencils from the desk top. Fulltime carpenters had to regularly realign doors and windows to allow proper closing and opening. Light Partition Walls separated from Floor Slabs (See Fig. 4)

However, the most serious effect was on the morale of the workers as they were constantly in fear that the Building is going to sink or collapse on them.

Phase II Distress

Soon after completion, the walls of the Phase II addition experienced more severe cracking than the corresponding walls of the Phase II portion. Waviness was detected in the slabs but somehow these were lesser in magnitude as can be seen in Figs. 1 and 2. The main indication that something was still wrong was in the extent and magnitude of cracking in the walls and constant adjustments on the doors and windows (See Fig. 3).

Cracks were mainly opening upwards but in addition, some cracks tended to indicate that the walls were trying to separate from the columns (See Fig. 4).

Leaks in the Precast Waffle Slab occurred, indicating movement of the roof slab. The floor slabs had perceptible bulges at the center of the panels but were not as pronounced as in the Phase I Construction.

Some Engineers consulted have even ventured as far as to say that the Piles have somehow "reduced the settlements" but no explanation could be given for the more severe cracking of the walls.

These two highly contrasting distress manifestations baffled the client and the occupants of the Building. However, the general conclusion still was that the building was "settling" and that all remedies have been exhausted. Abandonment and demolition of the Building was therefore being contemplated.

INVESTIGATION

In early 1984, we were contracted by the client's Corporate Engineering Department to undertake an investigation to unravel the seemingly conflicting failure patterns in the two buildings. Explanations were needed as to why despite substantial expenditures in Piled Foundations, the Phase II portion of the Building was still "settling" and cracking with more severe cracks in the walls than were observed in Phase I.

The investigation programme consisted of the following phases:

1. Soil Borings along the periphery of Phase II in order to determine underlying soil properties in the area of the piled foundation.

2. Test pits inside and outside of the building to retrieve soil samples and determine character of fill material in the area.

3. Laboratory soil classification and strength tests of soil and physical characteristics.

4. Laboratory chemical testing on soil leachate samples and water samples in the building.

5. Interviews with R&D Laboratory personnel and document review of various tests conducted for the R&D Laboratory Building relevant to the investigation.

6. Measurements of Ground Heave inside and outside of the building and the preparation of the subsequent Heave Contour.

7. Recording of observed cracks and structural features including photographs and their subsequent mapping to aid in the structural rehabilitation and repair of the building.

8. Analyses of possible loadings imposed on the soil by the foundation elements of the building and corresponding settlement analyses.

9. Understanding of construction plans furnished by the client insofar as it would assist in interpreting the responses of the various building elements to the heave forces.

The findings obtained in the foregoing investigation together with the results of various tests served as bases for the correlation and understanding of the mechanisms contributing to the observed problems in the building and outside of the building.

No effort was spared to investigate possible causes of the cracks in the attempt to conclusively isolate the forces that are triggering the observed distress in the building.

Immediately after our commissioning, we made exhaustive investigation and conducted interviews with Building occupants to reconstruct and piece together the chain of events. Almost all the Building occupants from the scientists to the Building Manager were of the opinion that the building was "sinking " and that nothing further could be done to save the Building.

Morale was so low that some employees interviewed thought that the investigation was another delaying tactic by the management to postpone abandonment of the Building because of the vital research studies being made at the time. All of these were proved to be untrue after a very challenging investigative work which in the end tied together all the loose ends and helped us arrive at a simple solution which saved the building.

Early at the start of field work and testing, it was already clear to us that the crack patterns manifested were caused by heaving and not by settlements.

What was not clear to us at the onset were:

* What was causing the heaving ?
* What was the explanation for the differing crack patterns in the two phases of the building ?

Potentially expansive soils were not prevalent in the general area nor was the imported fill expansive, since it was essentially silty fine sand and therefore the agent causing the heaving had to be identified and isolated.

SOIL INVESTIGATION

The initial investigation program consisted of three boreholes around the Phase II Building to a depth of 20.0m average and several test pits outside the Building footprint. The borings were done to determine underlying soil strength parameters and also to detect the presence of potentially swelling soils. Since initially we suspected that the expansive soil was not the Engineered Fill, concentration of the soil borings was focused on natural ground about two meters below. Nevertheless, regular sampling and field classification was done starting with the base course, the Engineered Fill and the natural ground. The "Base Course" material was initially and innocently classified by the Field Engineer as "gravel base course".

It was only when we dug the test pits that we learned that this was no ordinary "gravel base" course as initially identified, since these were extremely heavy and there were large chunks that were like huge flakes in the test pit. Picks cannot even indent the material and finally, Saw cutting with a carbide blade showed that it was iron.

What was also surprising to us initially was the presence of dark gray fluffy cotton like materials in the heaved portions.

SLAG USED AS BASE COURSE

Further investigation revealed to us that a well meaning and cost cutting decision was made during construction to use SLAG wastes from a steel mill as the base course material since it was free for the taking and it compacted readily. This "base course" was laid to a thickness of 0.30m to 0.50m in some places and was spread in all the proposed built-up areas including the future addition and the driveway.

The gray fluffy cotton like material turned out to be SLAG that has fully expanded after corrosion (See Fig. 5 & Fig. 6). The expansion potential can be gaged from the size of the cavity and magnitude of heaving that it has caused.

More numerous test pits were therefore recommended to be undertaken inside the Building footprint to verify the extent of the slag.

All the additional test pits showed the uniform presence of the slag base course and the degree of expansion and corrosion that has occured underneath (See Fig. 7 & Fig. 8). Most of the test pits were excavated under the heaved areas and also some in the unaffected areas. In both cases, slag was present in varying conditions of expansion and corrosion.

Levelling to determine the slab contours was also done inside the Building with the vertical Benchmark made outside the affected areas. The levelling was done using liquid level hoses because of the numerous partitions rendering optical levelling next to impossible. The results are depicted in Fig. 1 and Fig. 2.

RESULTS OF CHEMICAL TESTS ON SOILS AND WATER-R&D CENTER BUILDING

In some of our interviews, complaints were heard regarding the water from the deep well that was causing stomach problems and sometimes Diarrhea.

Subsequently, we made recommendations to test the water from the deepwell and also in some of the adjacent Buildings and Factories being served by similar deep wells.

The results are shown in Tabular Form in Fig. 9. The results show that most of the water from the deepwells in the area have corrosive potential as indicated by their Langelier Saturation Index (LSI) values.

Chemicals tests were performed on several soil sample Leachates and water from the Deepwell of the R&D Building. The objective of the tests is to determine corrosion potential after test pits showed the presence of slag (iron) in the general area investigated. The Langelier Saturation Index (LSI) was obtained by computation from the test parameters. The soil leachates were obtained by mixing one part of soil to one part of distilled water. The mixtures were shaken for two hours at 200 oscillations per minute and allowed to set for 24 hours.

The resulting extracts were analyzed for:

- pH
- Conductivity
- Alkalinity
- Total Hardness
- Sulfates (SO_4)
- Chloride
- Acidity

Fig. 9 tabulates the values of the various chemical tests conducted on water samples in Soil Leachates at the R&D Laboratory.

Several conclusions can be inferred therefrom as follows:

- Water from R&D Laboratory and surrounding areas have corrosive tendencies. Of the thirteen (13) samples whose corrosion potential were measured using the LSI, seven (7) samples exhibited corrosive tendencies.

- Chloride content for R&D well water is excessively high (about 800 to 900 ppm).

- Sulfate (SO4) content of the slag is very high (975 ppm).

- pH values indicate slightly basic to slightly acidic values for most of the water samples tested.

POSSIBLE MECHANICS OF CORROSION

Several possibilities could trigger the corrosion of the slag and its consequent expansion during the corrosion process.

The resulting expansion has been found to increase the volume of the steel or iron by as much as 10 times its original volume, in the process generating large expansive pressures when confined.

Slag

The use of slag as a fill material proved to be detrimental as the material could corrode even in ordinary tap water given the proper environment.

The slag obtained from most electric arc furnaces is slightly basic in character but contains large amounts of sulfates, manganese and other impurities from the steel making process. This is borne out by the very high sulfate content obtained in sample 5-14 of Fig. 9 from Test Pit No. 1. Because of the nature of the slag formation in the mill, vesicles were formed containing entrapped air. The large particle size (gravel to cobble size) of the slag also allowed air entrapment during the compaction process. The entrapped air promotedor accelerated corrosion because of the presence of oxygen.

Groundwater

As earlier stated, the groundwater is generally corrosive (Langelier Saturation Index Negative). In addition, chloride content is high which can trigger pitting and corrosion in the slag.

The foregoing primary factors alone would already indicate the highly favorable environment to initiate and sustain corrosion. Since the total corrosion decomposition of steel or iron would be a long time dependent process, its simulation in the laboratory would for the purposes of this investigation be too long. However, samples extracted from the test pits showed varying degrees of decomposition and oxidation stages when tested in the laboratory using a NaCl solution.

In order to fully understand the mechanism, the following definitions are extracted from ASTM 6-15-79a "Standard Definitions of Terms Relating to Corrosion Testing".

Corrosion - the chemical or electrochemical reaction between a material, usually metal and its environment that produces a deterioration of the material and its properties.

Graphitic Corrosion - the deterioration of metallic constituents in gray cast iron which leaves the graphitic particles intact.

The corrosion of ferrous metals is caused by the tendency of iron (Anode) to go into solution in water as ferrous Hydroxide and displaced Hydrogen, which in turn combines with dissolved oxygen to form more water. At the same time, the dissolved ferrous hydroxide is converted by more oxygen to the insoluble ferric oxide thereby allowing more iron to go into solution.

Corrosion therefore requires liquid water (as in damp air) and oxygen (which is normally dissolved in water).

Corrosion occurs only in the presence of an ionizing medium. The most universal ionizing medium is water. No corrosion will occur in the total absence of water. The rate of corrosion is affected by the amount of dissolved oxygen present.

The dissolved oxygen could react in either of two ways:

1. By combining with the hydrogen film to expose the surface of the metal (which the film protects).

2. By combining with the dissolved ferrous hydroxide to form insoluble hydrated ferric compound and thereby allow formation of more ferrous Hydroxide.

The chloride ion solution tends to dissolve the protective coating already formed and tend to prevent new coatings being laid down thus further accelerating corrosion.

Having understood the probable corrosion mechanisms, the following can be theorized:

1. The corrosive groundwater as it was elevated by flooding or during the rainy season immersed the metallic slag in solution causing decomposition. Sufficient dissolved oxygen is existent in the soil and trapped in the large voids present in the slag.

2. The R.C. slab acted as an impermeable membrane which ensured entrapment of moisture keeping the slag in at the very least a moist environment. This ensured progressive corrosion. Because of the confinement of the surrounding soil on the slab, the slag exerted an upward pressure which offered the least resistance causing the slab to heave.

3. In addition to the foregoing and as can be shown in the subsequent sections, possible leakages in the pipes, more specifically in the acid and waste chemical lines could have aggravated the corrosion.

4. Inspection of the photographs and test pit logs (See figs. 11 & 12) clearly show that the slag layers have expanded upward and heaved the concrete pavement.

OBSERVATIONS ON THE RELATIVE MAGNITUDE OF CRACKS

With reference to the slab displacement contour map (Fig. 1 and Fig. 2), it can be shown that Phase I has heaved or displaced more than the Phase II. Although the two are supported by different foundation elements (continuous footing vs. pile foundation for Phase I and Phase II respectively), this would not really explain why there is less heaving and cracks in Phase II because if heaving of the same magnitude have occured, more damage would have resulted because of the rigid restraint offered by the piles.

It is only possible then that because the slag fill have been laid out all at the same time, that substantial unconfined or unrestrained heave has already occured over time in the Phase II area before construction could take place. Unlike in Phase I, where the slab offered confinement and trapped moisture as to cause progressive heave under restraint.

In addition, although it could be observed that there are relatively fewer cracks in Phase II, it can also be shown that in contrast to Phase I, the walls in Phase II are more damaged compared to the floor slab where displacements are minimal.

The foregoing is explained by the fact that while substantial heaving has already transpired, the residual heave after construction, though not as large as Phase II displacements, have cracked the walls because of the relatively more rigid restraint or pullout capacity of the piles. Thus the walls were affected more than the floor.

Fig. 4 which was taken along the corridor near the interface between Phase I and Phase II showed a unique but typical crack pattern in Phase II that is not manifested in Phase I.

The crack pattern shows propagation from the floor intersecting the column line diagonally on both sides. This shows that the wall is flexing but because of the rigid restraint of the walls, has failed the wall in shear instead, because of the upward pressure on the wall footings.

Several conclusions can be made on these observations:

- o There is less displacement for Phase II simply because the slag has already partly expanded before Phase II was constructed.
- o It is not true that the pile foundation had in some way contributed to reduction of cracks. On the contrary, if the Phase II portion would have been subjected to the full heave potential of the slag as in Phase I, more damage would have occured because of the more rigid restraint.

EFFECT OF WATER AND CHEMICAL LINES

Closer inspection of the displacement contour map would show that the following areas were the most affected by the heaving in descending order.

- o Experimental Section
- o R&D Office
- o CENLAB Office
- o Technical Library

These areas have one thing in common, and this is the presence of water lines and chemical lines near the heaved areas.

It is suspected that the lines have leaked or burst due to corrosion from the groundwater or galvanic corrosion with the slag (dissimilar metals in contact) or have been broken by initial heaving thus contributing to acceleration of the corrosion process.

Even without the foregoing, leakage of chemicals has been detected in the PVC connections of the chemical sinks in the Experimental Section.

This condition probably contributed more corrosive chemicals under the slab as to cause the extensive Heaving in the Experimental Section.

RECOMMENDATIONS MADE FOR REMEDIAL ACTION

After satisfactorily proving to the owner that the Building was actually rising due to heave and not "sinking" as originally perceived, we set out to make recommendations on remedial measures that need to be undertaken.

Since the Building was not on the verge of collapse nor seriously damaged by the heaving, we submitted a three staged rehabilitation program. This was necessary as critical research work is ongoing at the time and total or major disruption could not be allowed for the time being.

The following were the remedial stages as recommended:

Stage I : Release of Floor Slab from wall

The floor slabs which were originally dowelled into the perimeter walls and interior walls were recommended to be saw cut using a diamond saw. This has the effect of releasing the walls from any uplift pressures acting on the slab. This will in turn reduce the cracking on the walls and other structural elements.

Stage II : Removal of Slag Base Courses

As soon as facility work load permits, the slabs that were released by diamond saw cutting shall be removed and the slab excavated and replaced by compacted clean granular Fill.

All water utilities (Drainage & Sewage) as well as chemical lines shall be inspected for damage or corrosion and if need be, replaced by PVC Pipes or Compatible Plastic Pipes in the case of the chemical lines.

The columns should be inspected to determine if any pullout from the socket footings has occurred so that this could be repaired.

The granular Engineered Fill Subgrade shall be tested in case any residual acidity is present and this shall then be neutralized with lime milk before the granular base course is placed and compacted.

Stage III : Monitoring and Crack Repair

We recommended installation of a permanent reference Benchmark to monitor further movements in the Building after Stage I and Stage II repairs have been implemented. In case movements have ceased, epoxy repairs of all cracks should be undertaken after thorough cleaning of all cracks.

CONCLUSION

The owner has implemented Stage I and Stage II for the Phase I structure and Stage I for the Phase II structure. In the case of the latter, the freeing of the Sabs was already sufficient to arrest further cracking of the walls. Since swelling was preinduced before Phase II Construction, the resulting heave after construction was very much less than the heaving experience in Phase I Construction.

Stage III was subsequently carried out and to this time no further distress or cracking has been reported in any of the Building Elements.

The paper illustrates how a seemingly innocent decision to use "good aggregate" in the form of slag as a base course nearly caused the abandonment and demolition of a building.

It also illustrates how the initial but erroneous perception of movement of the structure as being downward or "settling" has caused additional but unecessary expenditures in the form of Piled foundations for Phase II Construction. The use of Piled foundations aside from adding to the cost and giving false hopes, only aggravated the problem by increasing restraints on the walls causing more serious cracking in the latter.

The investigative procedures employed led to the isolation of the slag as the agent causing the heaving of the Building and the cracking of various structural elements. The resulting simple remedial measures employed, which consisted of removal of the slag and freeing of the slab connections from to the walls, saved the Building from abandonment and demolition.

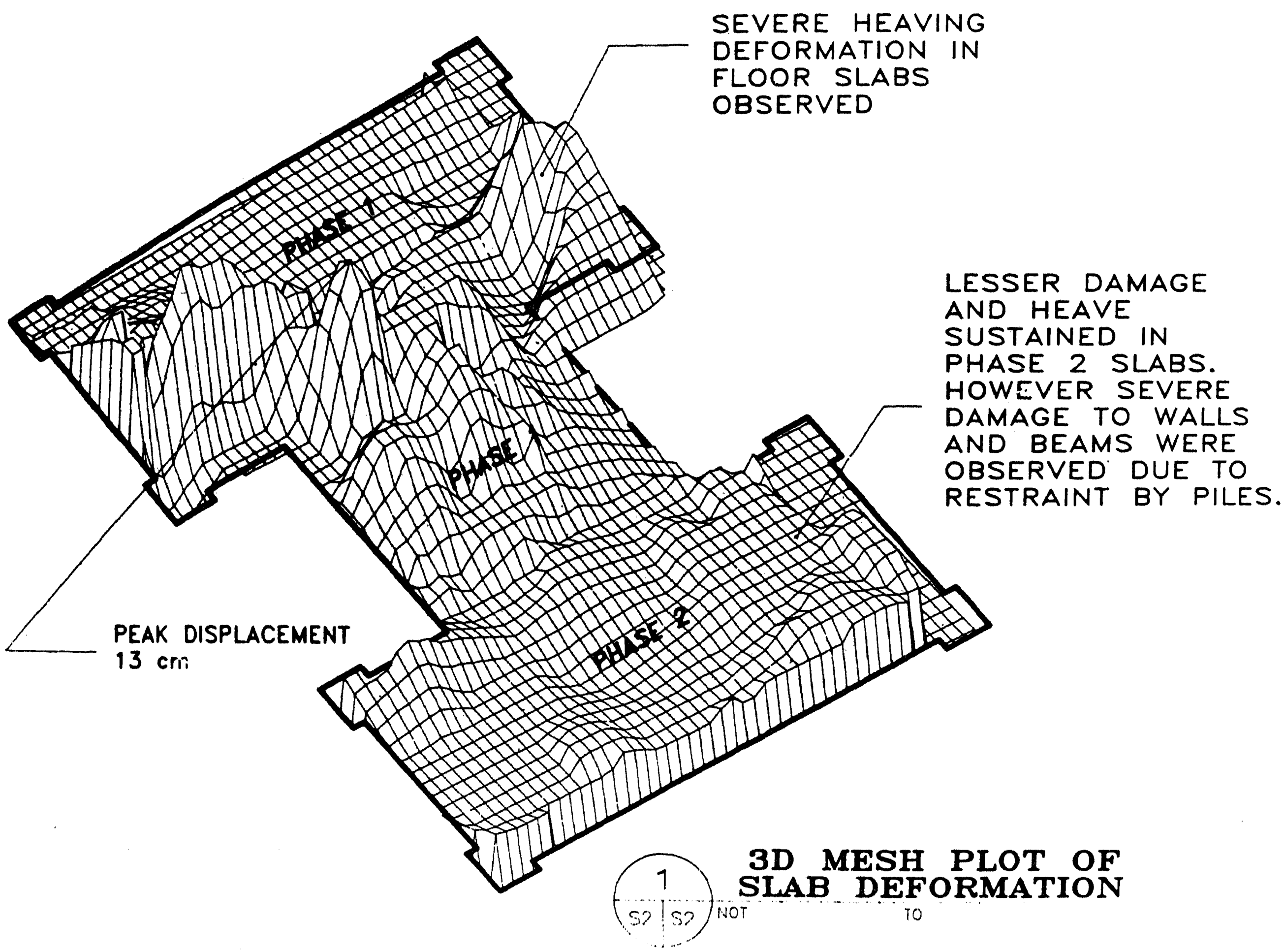


Fig. 1: Slab Deformation 3D Mesh Plot

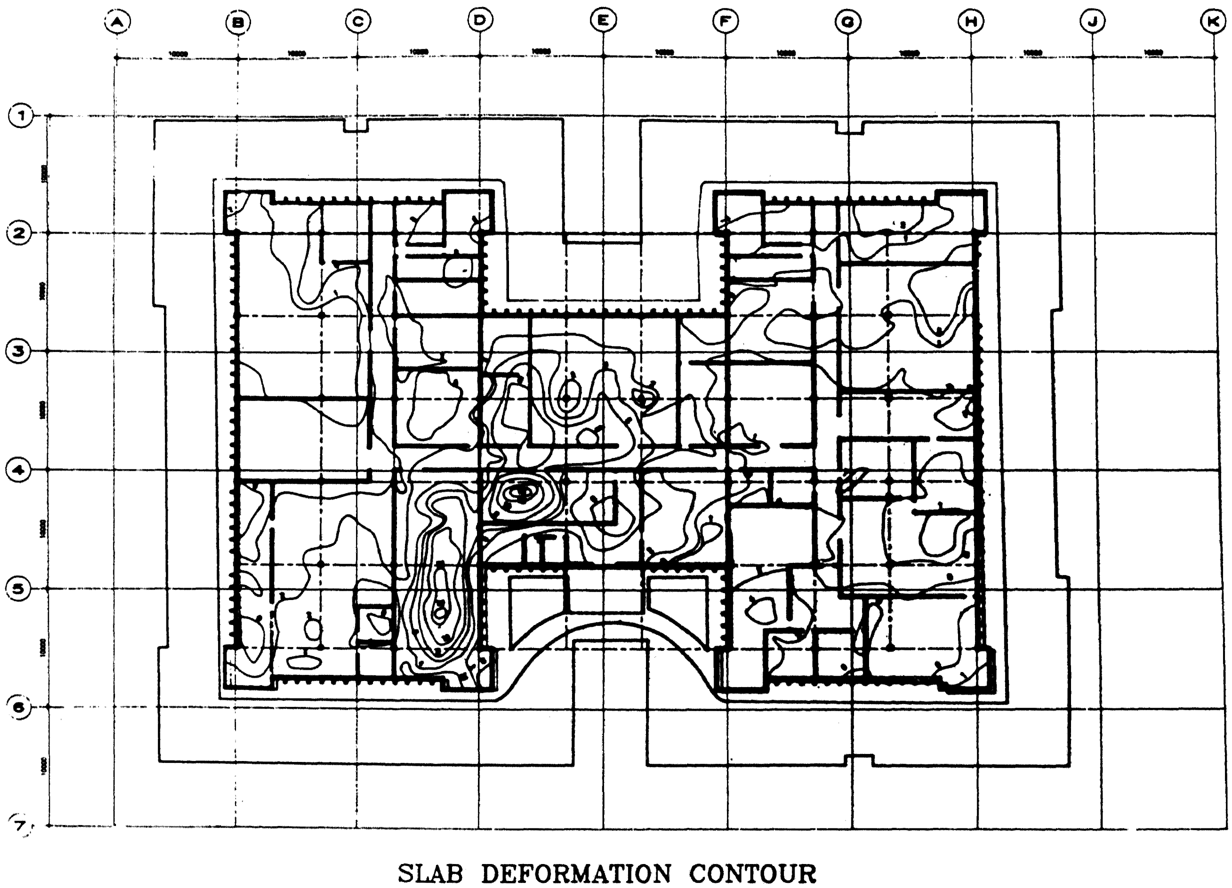


Fig. 2: Slab Deformation 2D Contour Plot

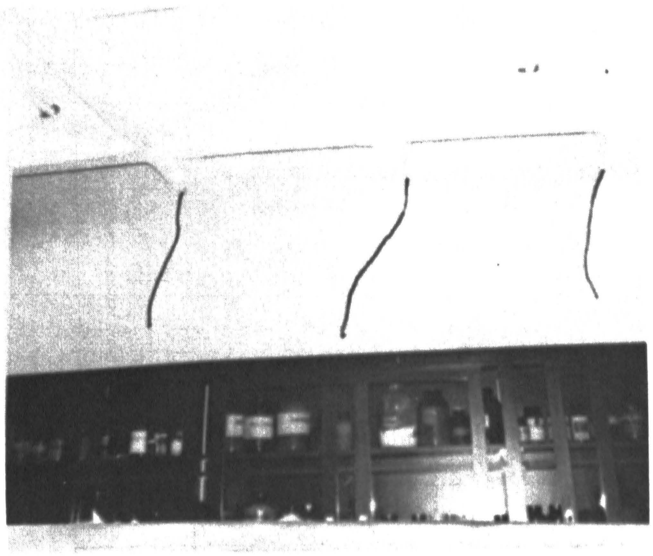


Figure 3:

Shows cracks at wall to Waffle Slab Intersections at Phase II portion of the Building.

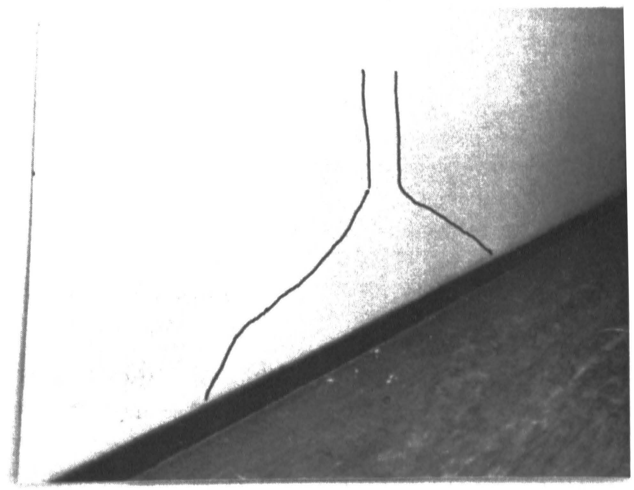


Figure 4:

Shows unusual cracking pattern at Wall-Column Interface. The Wall is being restrained from upward movement by the column which is in turn restrained by the Pile Foundations (Cracks highlighted for clarity).

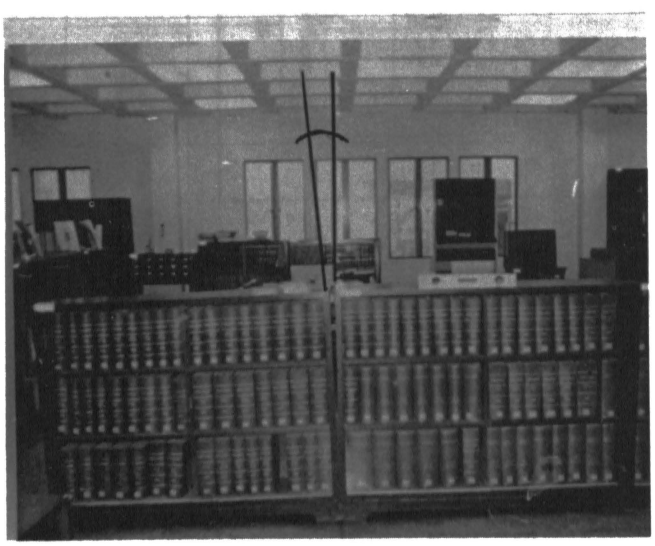


Figure 5:

The magnitude of heaving in some Slabs is illustrated by Rotation of two (2) adjacent bookshelves.

Figure 6:

Light partitions heaved at some locations lifted-off from their bracket connections from the Floor Slab.

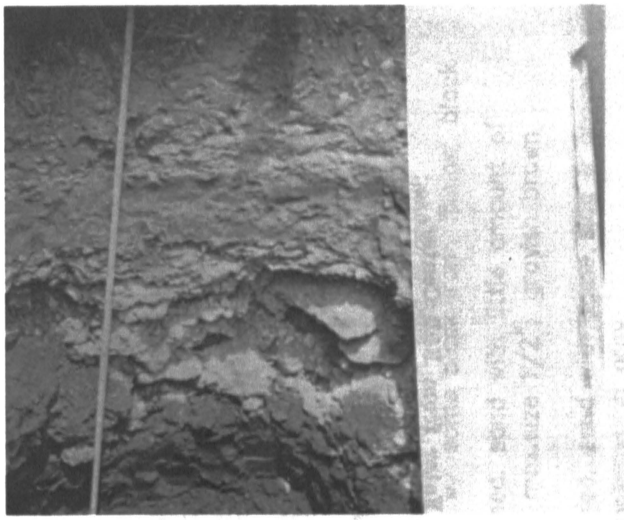


Figure 7:

The Test Pit shows expanded Slag (whitish material) and imported Fill. Scale is approximately one meter.

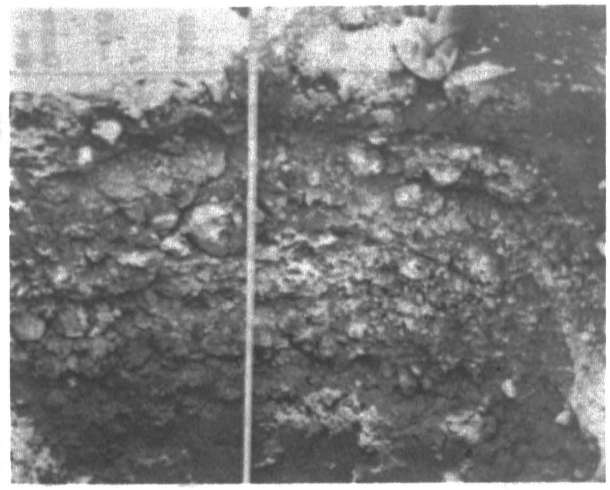


Figure 8:

Expansion in the Slag is clearly evident in this picture at the top portion. Note some cavities formed in the process.

Figure 9:

Expanded and Unexpanded Slag (White Portion) is clearly shown. Note the magnitude of expansion shown in the lower portion of the Slag layer.

SOIL/WATER TESTS FOR CORROSION POTENTIAL
R&D BUILDING

PARAMETERS		S1*	S2	S3	S4	S5*	S6*	S7	S8	S9	S10	S11*	S12	S13*	S14*	S15*	S16*	S17	S18	S19
pH		7.1	7.4	6.8	7.6	6.8	–	8.3	6.7	6.8	7.5	7.2	7.4	7.1	10.5	–	6.24	7.38	10.38	6.9
Specific Conductance	mmhos /cm	–	–	–	–	–	–	–	–	–		–	–			–				
Alkalinity	ppm	0	0	0	0	0	0	0	0	0	0	0	0	0		–	174.4			
Acidity	ppm	–					–	–	–	–	–	–	–		0	–				
Sulfate	ppm	19.2	22.3	6.8	37.4	16.3	–	4.6	33.4	32	19.2	29.5	26	26	975	101 105 134		566	53.8	650
Chloride	ppm	71.8	680	98	441	40.7	931 921	35.4	20.8	34	815	980	452	855	0	–		177	182	100
Total Hardness	ppm	289	725	306	431	235.6	–	48.9	175.6	253.5	1000	1194	406	1079	1361	–	264.9	314	62.8	262
Langelier Saturation Index (LSI)[1]	–	+0.05	–	–0.2	+0.71	–0.3	–	+0.66	–0.55	–0.14	+1	–	–		+4.1	–	–0.85	–0.22	+2.56	–0.6
Remarks		Scale For-ming	–	Corro-sive	Scale For-ming	Corro-sive	–	Scale For-ming	Corro-sive	Corro-sive	Scale For-ming				Scale For-ming		Corro-sive	Corro-sive	Scale For-ming	Corro-sive

[1] Langelier Saturation Index (LSI) values are based on Total pH, total Dissolved Solids, Alkalinity and Hardness of the Leachate. LSI Values < 0 indicate a corrosive tendency while LSI values > 0 indicates a Scale Forming Tendency.

SAMPLES SOURCES:

S1 – Chlorinated well water from R&D Domestic Water Nov. 3, 1976

S2 – One Sample from Bo. Ugong Pasig, Feb. 6, 1976

S3 – Chemical Plant, Bo. Ugong Pasig, March 2, 1976

S4 – Pharmaceutical Plant, Bo. Ugong Pasig, March 2, 1976

S5 – R&D Center Well Water, April 21, 1977

S6 – R&D Center Well Water Taken at Depths 500 + 360 Feet Average

S7 – Three Samples from Bo. Ugong, May 19, 1976

S8 – – ditto –

S9 – – ditto –

S10 – – ditto –

S11 – One Gallon Well Water from R&D Center, June 3, 1976

S12 – One Gallon Well Water from Pharmaceutical Plant, June 3, 1976

S13 – One Gallon

S14 – Pulverized Slag Passing No. 200 Sieve Samples G Analysis

S15 – Test Pit Samples from TP-1 designated 1A, 1B, & 1C Analysis

S16 – Water from Garden Faucet R&D Building

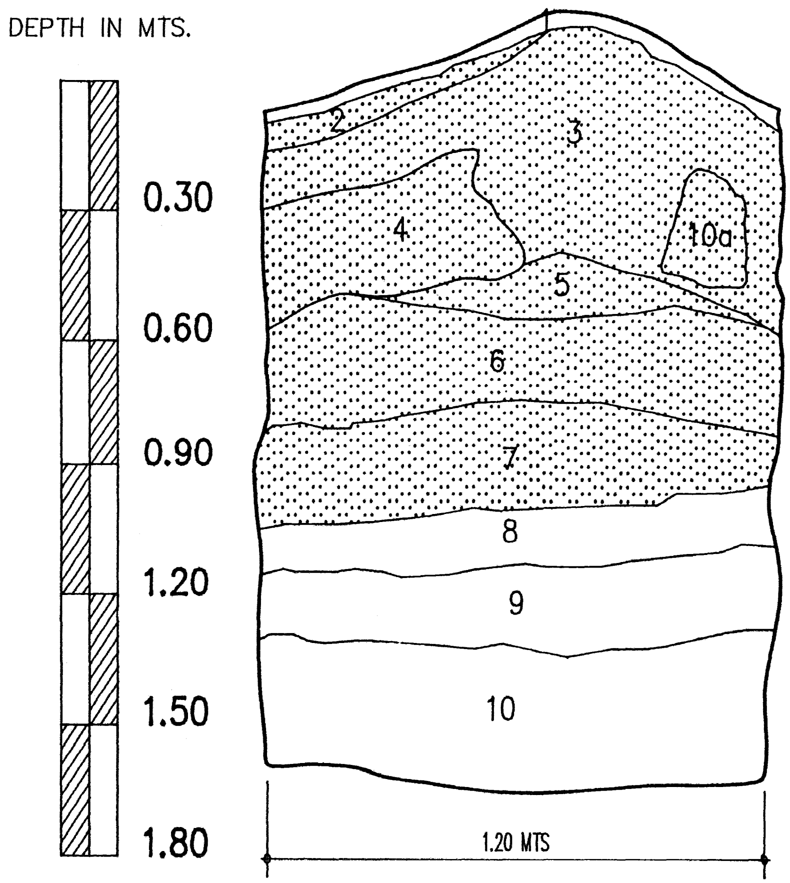
S17 – Soil Samples from Test Pits R&D Building

S18 – – ditto –

S19 – – ditto –

Fig. 10: Table 1

TEST PIT CROSS-SECTION



MATERIALS DESCRIPTION

1 – 2.0cm Asphalt pavement

2 – Silty fine to med. sand with slag and traces of gravel; max.size 1/2" ; grayish brown

3 – Slag with traces of gravel and coarse sand

4 – Coarse to med. sand with slag & gravel; max.size 1/2" w/ some black iron fillings; black

5 – Silty fine to med. sand with little amount of slag & gravel; max.size 1/2"; grayish brown

6 – Silty fine to med. sand with some slag & gravel; max.size 1/2"; brownish gray

7 – Silty fine to med. sand with some slag & gravel; max.size 1/2"; grayish

8 – Clayey silt with traces of fine gravel and little amount of sand; med. plastic; gray

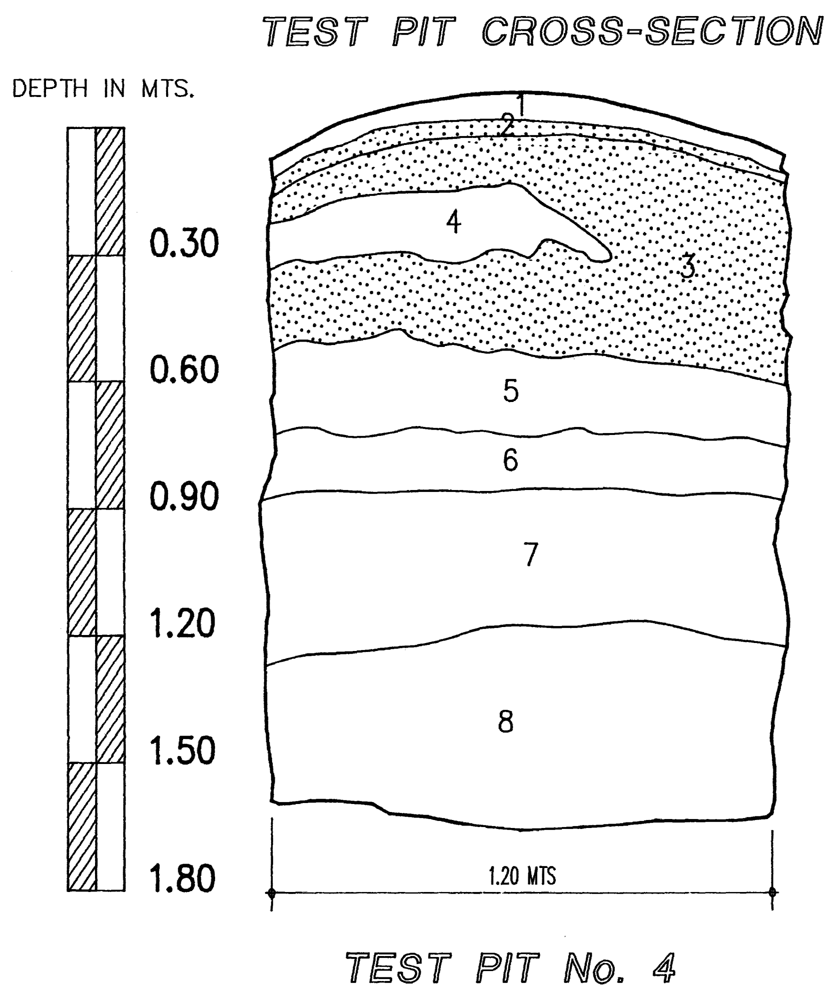
9 – Clayey silt with traces of fine sand; medium plastic; brownish gray

10 – Clayey silt with some fine sand; medium plastic; brownish

10a– Highly oxidized slag (spongy)

TEST PIT No. 1

Fig. 11: Log of Test Pit No. 1



MATERIALS DESCRIPTION

1 – 8.0cm Asphalt Pavement

2 – Clayey silt with pcs. of gravel traces of fine sand and slag

3 – Slag with pcs. of gravel; max. size 1/2"; and traces of silt; gray

4 – Gravel max. size 1" with traces of silt and fine sand; gray

5 – Clayey silt with traces of fine sand; grayish brown

6 – Clayey silt with traces of fine sand; brown

7 – same formation

8 – same formation

Fig. 12: Log of Test Pit No. 4