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ABSTRACT

The Logan Section of the City of Philadelphia, that encompasses 17 city blocks and includes 997 "row type" dwellings, was constructed in the early 1900s. It is reported that settlement of these structures has continued since their construction. In 1986, a Geotechnical Investigation, commissioned by the City of Philadelphia, revealed that a total of two to three feet of settlement, with as much as one to two feet of differential settlement, has taken place. Recent measurements indicated that settlement is still in progress. This settlement has resulted in severe structural damage and, in some cases, collapse of the buildings. One hundred (100) homes have been declared imminently dangerous, 110 homes have been declared dangerous, and the remaining homes are considered moderately damaged. This paper discusses the probable causes of settlement, and evaluates the geotechnical characteristics and properties of the ash and cinders. These characteristics are considered the prime cause of the problem at the Logan Section.

INTRODUCTION

Lippincott Engineering Associates (LEA) was retained by the City of Philadelphia, in the Spring of 1986, to investigate the settlement problems of the Logan Section of Philadelphia. The purposes of the investigation were to determine the causes of settlement, to make recommendations to arrest the settlement, and to provide remedial measures to rehabilitate the structural distress. (Figure 1 indicates type of differential settlement)

Figure 1 - House located at 920 Wyoming Avenue

SITE HISTORY

A study of historic maps indicated that the site is a reclaimed valley of the old Wingohocking Creek, which crossed the area in the early 1900s. As part of the Logan Section Development, the stream was contained in a 17 foot diameter brick storm sewer and the valley was filled with approximately 40 feet of loose ash and cinders. The dwellings were supported within the loose, uncontrolled, unengineered fill on shallow foundations. Construction of all dwellings was completed by 1920. There appears to be no evidence at this time indicating that the stream is flowing.

GEOLOGIC SETTING

The site, which is located on Roosevelt Boulevard in northeast Philadelphia, is underlain by metamorphic bedrock of the Wissahickon Schist formation. In general, the natural soil overlying the bedrock consists of residual soil and decomposed mica schist.

SUBSURFACE CONDITIONS AT THE SITE

A total of 38 test borings were advanced at the site. The SPT's was performed continuously through the fill. All borings were extended to or into the surface of bedrock. The boring results indicated that the site is covered with as much as 40 feet of loose ash and cinders overlying residual soil and decomposed mica schist. Based on test boring results, the following describes the on-site materials.

<u>Fill (F)</u>

A layer of grey-black ash and cinders cover the entire site and extends from zero, at the edge of the old creek valley, to 40 feet at the at the center of the old valley. The ash and cinders fill were found to be in an extremely loose condition, with blow counts of less than six per foot and in-situ densities of 55 to 60 pounds per cubic feet, being typical of conditions found.

Recent Alluvial Layer (RA)

A recent alluvial layer was occasionally encountered along the alignment of the old stream. The layer was two to five feet thick and consisted of sand, gravel and silty clay.

Residual Soil (RS)

Micaceous medium-stiff clay layers, formed by weathering of the mica schist bedrock, underlie the fill. The layers ranged in thickness from 10 to 15 feet.

Decomposed Rock and Bedrock (DR&R)

These were the last formations encountered in the borings. RQD of mica schist bedrock ranged from 7 to 30% in the areas where rock cores were recovered. (Figure 2 presents a general geologic section across the valley)

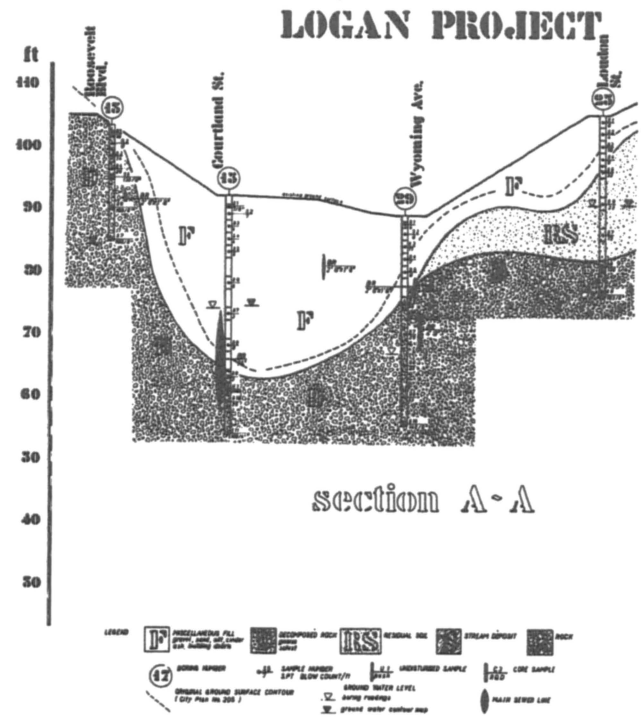

Figure 2 - Geologic Section

REVIEW OF LITERATURE

In order to determine the probable causes and mechanisms for structural distress, the engineering properties of ash and cinders have to be determined. A review of literature indicated that some work has been done in this area. It was noted that the engineering properties of these materials were influenced by the chemical components which varied from source to source. Hence, it was dicided to conduct laboratory and field tests on the on-site materials.

TESTS CONDUCTED

In order to determine the relevant engineering characteristics of the fill materials, the following types of tests were conducted:

1 - Laboratory Tests
2 - Laboratory Model Tests
3 - Field Tests

Laboratory Tests

This phase of testing consisted of Conventional Index and Mechanical Properties Tests, X-Ray Defraction, Chemical Testing, and Pin Hole Test (to study piping potential).

Evaluation of the laboratory test results revealed the following were characteristics of ash and cinders fill:

1 - The grain-size of ash and cinders resemble well graded sand and gravel with 17 to 30% fines. (See Figure 3.)

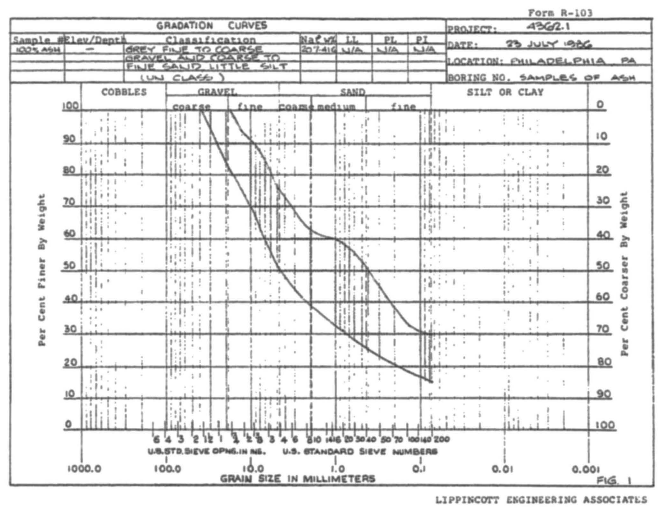

Figure 3 - Envelope of gradation analysis on Ash and Cinders

2 - The shear strength of loose ash and cinders is similar to that of loose granular materials. However; a greater, noticeable, drastic reduction of shear strength can be caused by flowing water.

3 - The maximum dry density is 88 PCF; the minimum density is 55 PCF.

4 - The specific gravity is 2.4.

5 - The consolidation characteristics are the same as granular soil coefficient of consolidation of one square foot per day was obtained. (See Figure 4)

6 - Ash and cinders are non-plastic materials.

7 - Loose ash and cinders are highly dispersive; compacted ash and cinders are not dispersive.

8 - The X-ray defraction indicated the primary constituent elements of the ash and

cinders are Al, Ca, Fe, and Si. Thirty-four percent of the sample was soluble in strong acid; 4% was soluble in tap water; however, 10% was soluble in weak acidic solution. (pH of 4)

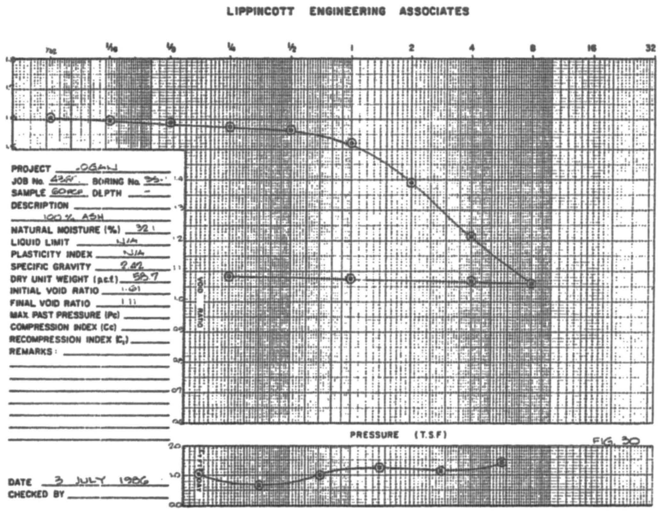

Figure 4 - Typical consolidation curve on Ash and Cinders near minimum density.

Laboratory Model Test

Based on the laboratory test results, it was felt that greater loss by piping, rather than consolidation, is the cause of the continuous settlement. To study this, a laboratory model was built and consisted of a 3 x 3 x 3 foot tank. A foot high layer of loose ash and cinders was placed in the bottom of the tank. The tank, then, was flooded several times with about one foot head of water. After the first flood, a reduction of 29% in volume was noticed. No further reduction was noted with further flooding. A second experiment was performed to study the piping potential of ash and cinders. In this experiment, a two inch diameter PVC pipe was buried in the middle of a two foot layer of ash and cinders. The pipe was perforated with 3/8 inch holes at six inch intervals, for the entire length of the pipe. Water was allowed to flow within the ash and cinder material. After one hour, the buried pipe was about half full of ash and cinders.

Field Plate Load Bearing Tests

To study the shear strength of the ash and cinders and the effect of water on shear strength, a plate load test was performed on ash and cinders in a test pit excavated to a typical foundation level. Standard plate load test procedures were followed with bearing pressure increased to 2000 PSF (estimate building bearing pressure). After one hour at 2000 PSF, a total settlement of approximately one inch was measured. To study the effect of water on the ash and cinders fill, the plate load test pit was flooded with a foot head of water, while the maximum bearing pressure was maintained on the plate; instantaneously as water was introduced into the test pit, the plate sunk four inches in the ash and cinders. A complete "loss of foundation supporting capability" was noted.

DISCUSSION OF TEST RESULTS

Based on the field and laboratory testing, these major observations were made:

1 - Primary consolidation of the loose ash and cinders probably resulted in four to twelve inches of settlement; however, settlement was completed within 12 to 24 months.

2 - Despite two to three feet of measured settlement, ash and cinders remain in a very loose state.

These two facts led us to rule out consolidation as a reason for continuous settlement. This, coupled with the result of the model testing and the pin hole test, led us to believe that ground loss by piping is the primary cause of the continuous settlement.

Our further investigation, which included house utility and city sewer line inspections ascertained that ash and cinders are piped through underground house utilities into the city sewer lines located in the city streets. This was confirmed by visual and television camera surveys of house utilities and city sewers and by the discovery of large quantities of ash and cinders within the city sewer system.

SEQUENCE OF EVENTS LEADING TO THE STRUCTURAL DISTRESS

Based on the discussion of the test results, the following is the probable sequence of events leading to structural distress in the dwellings:

1 - Initial settlement of four to twelve inches was experienced under the weight of the structures.

2 - This settlement resulted in breakage and opening of the joints in the underground cast iron and terra cotta utility pipes.

3 - Leakage of water from damaged pipes lead to continuous loss of shear strength of ash and cinders, leading to further breakage and opening of utilities.

4 - Ultimately, openings were large enough to allow piping to take place.

We expect the subsidence to continue indefinitely until repair work is done and all routes for piping are eliminated.

BUILDING DAMAGE

The two to three feet of total settlement and the one to two feet of differential settlement in the Logan Section has lead to severe damage to properties and has rendered some of the dwellings unsafe for occupancy. Three major types of distress resulted from the severe differential settlement; functional, structural, and architectural.

Functional Distress

This type of distress rendered several elements of the buildings unfit for their intended use. It is believed that most of the houses' underground utilities have suffered functional distress. Clogged or backed-up sewer lines are daily occurrences. In many homes, waste and waste matter drain directly into the fill below the houses and do not reach the sewer lines. Dye testing was performed by dropping dye in selected house toilets. Our observation indicated that the dye-marked water never reached the city sewers.

Severe differential settlement made living in the homes very difficult. This type of distress can be corrected.

Structural Distress

Based on the structural damage evaluation of the Logan Section dwellings, 100 homes were declared imminently dangerous. These homes were evacuated by the city. One hundred and ten (110) homes were declared dangerous. It was recommended that these homes be rehabilitated or demolished before reaching the imminently dangerous stage. The remainder of the homes were moderately dangerous and in need of rehabilitation before they progressed from dangerous to imminently dangerous.

Architectural Distress

The homes in the area visually exhibited the severe distress which the structures had endured. Most of the homes are leaning and tilting dramatically toward each other. Recent technological advances can be implemented to arrest further deterioration and possibly eliminate further movement; however, because of the age of the properties and the way in which the homes were constructed, there are no methods by which these homes can be made level. No matter how much money is spent on rehabilitation, the esthetics of the area will remain as is.

CONCLUSION AND RECOMMENDATIONS

From an economical standpoint, the cost of rehabilitation of the homes will probably outweigh the present value of the structures; however, as Engineers, we feel that the following steps, if adapted, will arrest further deterioration and settlement of the homes.

It is our opinion that ground loss and migration of ash and cinders by piping can be reduced drastically by rehabilitating the underground utilities for all structures in the area. Rehabilitation of the city sewers and an increase in the number of drain inlets in the streets would reduce the potential for flooding and greatly reduce runoff infiltration. However, due to the increase in seismic activities in the Philadelphia area in the recent past, and due to unforseeable weather conditions, recommendations were given to underpin all the houses that will be rehabilitated using pinpiles extending to bedrock surface.

ACKNOWLEDGMENT

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REFERENCES

There is very little literature written about the use of ash and cinders as controlled fill or about the geotechnical characteristics of ash and cinders; however, several papers on flyash were reviewed during the preparation of this report.

Chae, Yong S., and Snyder, James L., "Vibratory Compaction of Flyash".

Cunningham, June A., et al., "Impoundment of Flyash and Slag".

Collins, Robert J., "Highway Construction Use of Incinerator Residue".

Seal, Roger K., et al., "In-Situ Testing of Compacted Flyash".

All the above papers were presented in the "Geotechnical Practice for Disposal of Solid Waste Materials", June 13-15, 1977, University of Michigan, Ann Arbor.