ADSC: The International Association
of Foundation Drilling

The Effects of Free Fall Concrete in Drilled Shafts

by STS Consultants Ltd.
Northbrook, Illinois

A Report to the Federal Highway Administration

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– FORWARD –

The issue of how far and in what manner concrete can be placed by the free fall method in drilled shafts under dry conditions has been of great interest for many years.

In the early 1960s, a study of the free fall method of concrete placement was conducted by Clyde Baker and John Gnaedinger of STS Consultants. The results of that study extended the acceptable limits to over 90 feet and while some specifications have reflected these findings, free fall placement has not been universally accepted.

In order to once and for all determine the behavior of concrete placed by the free fall method, the ADSC and STS Consultants designed and conducted a comprehensive field test in late 1993. The test was conducted in such a way as to answer questions that may still have loomed in the minds of some engineers.

Funded in part by ADSC Members, The Millgard Corporation, Livonia, Michigan; Richard Goettle, Inc., Cincinnati, Ohio; Case Foundation Company, Roselle, Illinois; the Hugh B. Williams Industry Advancement Fund; and the Federal Highway Administration, this study has left little doubt as to the acceptability of the free fall method of concrete placement in drilled shaft construction. In fact, the findings went further than merely confirming the original 1960s assumptions. In reviewing the following test description and results, you will find that it is likely that the free fall method of concrete placement in drilled shaft construction results in increased concrete strength rather than in any segregation or loss of integrity.

The research reflected a combined effort of some very special individuals, as well as companies. Many thanks to ADSC Past Director, Earl "Bud" Stebbins, for the test design configuration; to Clyde Baker for his original approach; to the Chairman of the ADSC's H.B.W. Research Committee, Jim Melcher, Tri-State Drilling, Inc., Hamel, Minnesota; to ADSC Past President, Tom Buzek, Richard Goettle, Inc., Cincinnati, Ohio; and to ADSC President, Richard Millgard, The Millgard Corporation, Livonia, Michigan.

A special thanks is due to the FHWA and its forward thinking geotechnical Research and Development group. The FHWA continues to lead the nation in supporting much needed research directed at providing the American public with the most reliable, cost-effective highway transportation system in the world.

S. Scot Litke
ADSC Executive Director
April, 1994

February 1, 1994

Mr. Scot Litke
ADSC
P.O. Box 280379
Dallas, Texas 75228

RE: The Effects of Free Fall Concrete in Drilled Shafts -- STS Project No. 27618

Dear Mr. Litke:

The caisson installation, access shaft construction, observation and core strength testing for our joint research project on Free Fall Concrete in Drilled Shafts has been completed. This report describes the procedures used to construct the drilled shafts, provides as-built drawings of the actual field installations, presents the results of strength tests on cylinders and full length concrete cores, discusses our visual observations of the sides of the drilled shaft through the access windows, and provides our conclusions on the suitability of the use of free-fall concrete in drilled shafts.

We conclude that the free-fall placement method of concrete into properly constructed clean and dry shafts can be performed to depths of 120 feet or greater without meaningful loss of strength or segregation of the concrete aggregate.

Our observations indicated that all of the drilled shafts were fully formed with no zones of voided or honeycombed concrete, or exposed rebar. This was true regardless of the placement method, the rebar spacing, or the aggregate size over the ranges tested. Our review of the concrete core strength data indicated that all concrete lifts cored varied from their cylinder strengths within a range of -16% to +21%. Only a single lift had an uncharacteristically low strength of 3,100 psi, and we believe it was due to a long waiting time and addition of excessive water for that lift. All remaining core strengths varied from 5,100 to 7,400 psi. (Mix design strength was only 4,000 psi, and core strengths have been corrected per ACI by dividing test values by 0.85).

It has been a true pleasure working with you on this interesting and challenging project, and we hope that the research we have conducted helps to put to rest the "controversy" surrounding the use of free fall concrete in caissons.

Respectfully,

STS CONSULTANTS, LTD.

Tony A. Kiefer, P.E.
Senior Project Engineer

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Senior Principal Engineer

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1.0 INTRODUCTION

1.1 Background

The Association of Drilled Shaft Contractors has long been interested in the subject of free fall concrete placement in drilled shafts. Experienced drilled shaft contractors and many knowledgeable engineering specialists in the field have believed for many years that concrete does not segregate during free fall and that free fall placement can be accomplished without adverse effect on the concrete. However, the question of whether the free fall of concrete adversely affects the concrete strength and integrity in drilled shafts has persisted in the minds of some engineers and building officials despite past efforts to answer the question and dispel the concern. A report prepared on this subject more than 30 years ago by STS Consultants described research demonstrating that concrete does not segregate during free fall, provided that the concrete does not hit the sides of the shaft or the reinforcing cage (1). This was illustrated through pictures and through subsequent coring of the shaft. However, while some engineers have accepted this view in theory, they remain concerned that the concrete will either hit the sides of the shaft or the rebar cage, and therefore, they write specifications prohibiting free fall of concrete entirely, or limiting the height of free fall to what they believe are reasonable heights, typically in the neighborhood of 5 to 25 feet. These limitations have significant economic effects on the industry. For this reason, the Association of Drilled Shaft Contractors in cooperation with the FHWA has sponsored this current research project on the subject.

1.2 Research Goals

The objective of the research program is a definitive report answering the following four main questions:

Q1. Does concrete segregate or lose strength as a result of extended free fall through air? And, does slump, maximum aggregate size, height of drop, or addition of super-plasticizer clearly influence the results?

Q2. Does significant segregation and loss of strength occur if the concrete hits the rebar cage during free fall placement? And, does slump, maximum aggregate size, height of drop, or addition of super-plasticizer significantly influence the results?

Q3. Does rebar spacing within normal limits affect whether concrete flows readily through and around the rebar, and what is the effect of slump, aggregate size, or height or method of placement?

Q4. Does vibration of a well designed concrete mix affect the concrete strength and integrity?

Thus, the basic variables addressed in the research program include the following:

1. Height of Free Fall. In some places in the Country, such as Chicago, free fall placement of concrete is permitted to any depth, even as much as 150 feet. Current FHWA limitation is 25 feet. A reasonable maximum depth for practical test purposes selected in this research program was 60 feet. Similar mix designs were placed at different depths within a shaft to test the depth variability, if any.

2. Height of Fluid Pressure in the Tremie Pipe or Pump Concrete Lines, and/or the Height of Fluid Pressure in the Placement Concrete whether by Free Fall Methods or Tremie Placement. Experience has indicated that as the height or depth of fluid concrete increases, there can be a perceptible increase in the density of the deeper concrete which has a positive effect on the strength of the concrete and on the friction developed against the shaft walls.

3. Spacing of the Reinforcement Bars in the Reinforcing Cage. The closer the rebar spacing, the more difficult it is for concrete to flow uniformly around the bars and achieve full bond and also to exert full fluid pressure against the shaft walls. Current specifications usually require the spacing to be no closer than three times the maximum aggregate size. Rebar spacings of 3 inches and 6 inches were used to include this normal minimum current specification spacing.

4. Maximum Size of Aggregate. The maximum size of aggregate affects the flowability of the concrete and may affect the question of segregation of concrete that hits the rebar cage. A maximum aggregate size range of 5/8 inch and 1-1/4 inch was included in this program as is currently used in the industry.

5. Slump. The importance of proper slump in drilled shaft construction is becoming increasingly recognized. The current thinking is that the greater the slump for a given design strength, the better. The normal range in the industry today of 4 to 5 inches for dry placement and 7 to 8 inches for wet tremie placement was included in this research program.

6. Super-Plasticizer. The increasing use of super-plasticizer to obtain higher slumps may affect the concrete strength and segregation. The research program included the effects of super-plasticizers by adding WRDA-19 to the low slump mixes to produce high slump mixtures for comparison.

7. Hitting the Rebar Cage during Free Fall Placement. In the past, it has been assumed that if the falling concrete hits the rebar cage, it is likely to segregate. Whether this happens in reality was to be determined by the test program for both the fine aggregate mix and the coarse aggregate mix.

8. Vibration. Some specifications still call for vibration of concrete, even though the mechanical vibration of concrete in deep shafts is impractical. The anticipation is that impact vibrations from the falling concrete achieve adequate densification. but this still leaves questions about tremie placed

> concrete where there are no or limited impact vibrations. The current ACI Standard Specification for Drilled Piers calls for vibrating the top 5 feet. The test program addressed whether vibration is really required at all with a properly designed concrete mix, by vibrating the top 2 to 3 feet of each shaft.

The basic properties which were important to test or observe during the research program were the compressive strength of the concrete, the density of the concrete, and the visual observation of the aggregate spacing and mortar quality.

1.3 Research Plan

In order to accomplish the research goals in a cost effective way, four 60 foot long, 3 foot diameter shafts evenly spaced and tangent to a central 5 foot diameter access shaft were planned. The four proposed test shafts were divided into six 10 foot sections with one of four different concrete mixes placed in each section. The slump, maximum aggregate size, and placement procedures were varied. The low slump mixes where also placed with and without super-plasticizer. The three placement procedures were free fall central drop with careful control to see the concrete didn't strike the rebar cage, free fall sloppy drop with effort actually made to see that the free falling concrete did hit the rebar cage, and tremie placement with a tremie pipe extended all the way to the concrete placement level.

The concrete mixes were numbered 1 through 4, providing the total slump range of from 4 to 8 inches. Two different maximum aggregate sizes of 1-1/4 inch and 5/8 inch were used. The 10 foot sections were used in order to allow for the possibility of interface mixing where the mix designs changed and still have sufficient concrete at the middle of the section which was unaffected by the adjacent mixes.

The influence of both concrete fluid pressure on density and strength, as well as the influence of the height of concrete free fall placement and resulting impact vibrations was checked by having the same mix and placement procedure appear at different levels in the shafts with an effort made to maximize the vertical distance apart of these similar mixes and placement procedures. By varying the amount of reinforcement in the shafts, where the shafts touch the access shaft, it was possible to see how the rebar spacing affected concrete flow.

In order to compare the effects of vibration versus unvibrated shafts, only the top 2 to 3 feet of each shaft called for vibration to permit direct comparison with the immediately underlying concrete which was not vibrated.

The research plan called for taking standard 6 inch reference cylinders of each concrete lift placed and then comparing these reference cylinder strengths with 4 inch diameter cores to be taken after the concrete was adequately cured.

The entire construction process was documented through the use of video tape and photographs. In addition, all cores were photographed and stored for future reference.

2.0 CONSTRUCTION METHODOLOGY

2.1 Site Description

Construction of the four test drilled shafts and access shaft took place at the STS Consultants laboratories at 1869 Techny Road in Northbrook, Illinois. Installation occurred approximately 20 feet from a soil boring which had been drilled to a depth of 65 feet. The soil boring indicated that miscellaneous fill soils existed to a depth of approximately 7 feet, with a very stiff to hard clay extending to 15 feet. A saturated sandy gravel layer was encountered from approximately 15 to 18 feet below existing grade. Below the sandy gravel and extending to a depth of approximately 45 feet, stiff to hard silty clay with traces of gravel, sand and occasional cobbles and boulders was encountered. Under the silty clay, the soils became more silty with a clayey silt to silt extending to a depth of approximately 52 feet. The remainder of the boring encountered hard silty clay to hard clayey silt (hardpan) extending to the termination of the boring at approximately 65 feet. The water level was encountered at a depth of approximately 14 feet, coinciding with the sand and gravel layer at that depth. The boring logs for the site are included in the Appendix, and the location of the caisson installation is shown in Figure 1.

The plan view of the proposed drilled shafts installation and access shaft are shown in Figure 2. Four 3 foot diameter drilled shafts were drilled to nominal depths of 60 feet below grade with an edge to opposite edge spacing of approximately 6.5 feet. This allowed room for a 5 foot diameter access shaft to be drilled within the center of the four drilled shafts. The four test shafts were labeled north, south, east and west. The layout of the shafts indicating the tight pacing is shown in Photo 1.

2.2 Drilled Shaft Construction

Four drilled shafts were constructed within a three day period from June 29 to July 1. 1993. Corrugated liners inside of temporary steel casings were required in the upper portion of the shaft, in order to seal off the sand and gravel layer to a depth of approximately 20 feet. Despite these measures, water infiltration was a continuing problem, both from below the temporary casing, and from a depth of approximately 57 feet where a sand and gravel layer was encountered though not observed at the boring location. Installation of the casing and temporary liner is depicted in Photos 2 through 4.

A 60 foot long full length rebar cage was placed in each drilled shaft. This rebar cage consisted of ten No. 8 vertical bars with No. 4 ties placed horizontally at a spacing of 24 inches. The horizontal spacing of the vertical rebar was varied across the side of each test shaft which was tangential to the access shaft. One side of the rebar cage had vertical bars spaced at 3 inches on center, while the other side had a 6 inch center to center spacing. A diagram of the rebar cages is shown in Figure 3, and the as-built cages are shown in Photos 5 and 6.

The rebar cage of the East drilled shaft was also provided with three 1-1/2 inch diameter steel access tubes. The tubes were capped on each end and wired to the rebar cage at three locations as shown in Figure 3. The purpose of the steel tubes was to provide access for future nondestructive testing. The nondestructive testing was not performed as part of this research.

2.3 Concrete Mix Designs

In order to evaluate the effects of slump, aggregate size, addition of superplasticizer, placement method, and the use of vibration, four different mix designs were selected to be placed within the shafts in approximate lifts of 10 feet. The 60 foot depths of the shafts permitted six distinct lifts to be placed in each shaft. The variables associated with each mix design and the placement procedures for each shaft are shown schematically in Figure 4.

The mix designs selected were commercially available mixes typically used for drilled shaft construction. The low slump mixes were designed for a 4 to 5 inch slump range, while the high slump mix was designed for a 7 to 8 inch slump. Maximum aggregate sizes of 1-1/4 inch were selected for two of the mixes, while 5/8 inch maximum aggregate size was used for the other two mixes. Superplasticizer WRDA-19 was added to some of the low slump mixes in order to determine the effect of superplasticizer. The plasticizer was added to obtain a slump in the range of 7 to 8 inches which would compare to the high slump mixes without superplasticizer. The design strength for all the concrete mixes was 4,000 psi at 28 days. The mix designs are included in the back of the Appendix.

2.4 Concrete Placement Methods

The main goal of the research project was to determine the effect of different placement methods on the strength, integrity and segregation of the shaft concrete. To evaluate this, three different placement methods were used. These methods were termed central drop, sloppy drop, and tremie placement.

Each mix was placed by a central drop method where the concrete was back-chuted directly down the center of the shaft. Higher than normal care was exercised to insure that the rebar cage would not be struck by the falling concrete. As can be seen in Photos 7 and 8, depending on the slump, the concrete either flows like a viscous fluid or clumps together. For either case however, the concrete was easily placed down the center of the 30 inch rebar cage from a full drop height of 65 feet without hitting the cage.

The central drop procedures contrasted highly with the sloppy drop method of concrete placement. During sloppy drop, the concrete chute was directed into the rebar cage and the side of the drilled shaft. This method resulted in a considerable amount of ricocheting of aggregate, movement of the rebar cage, and complete coating of the rebar and corrugated liner with cement paste. For the most part, the sloppy drop concrete was directed at the top portion of the rebar cage on the side which was later observed through the access shaft window. Sloppy drop placement of two different mixes is shown in Photos 9 and 10.

A 12 inch diameter rigid, steel tremie pipe was utilized as the third method of placement, to act as a "control" for the other placement methods. Concrete was placed under the true tremie method with the pipe end remaining embedded within the concrete lift at all times. Once the concrete level reached the desired elevation, the tremie pipe was subsequently removed. Only 7 to 8 inch slump mixes were placed by tremie in accordance with general practice. The tremie procedure is shown in Photos 11 and 12.

Finally, the top 2 to 3 feet of each drilled shaft was vibrated using a portable concrete vibrator. The purpose of the vibration was to allow a comparison to be made between the vibrated concrete at the top of the shaft and the remainder of concrete within the top lift. The vibration process is shown in Photos 13 and 14.

2.5 Concrete Placement Difficulties

A number of difficulties were encountered during the shaft construction which had an impact on the quality of the test results. The main concern was water infiltration from gravel layers during the shaft construction. Gravel layers were encountered from 18 to 20 feet and below 57 feet in some of the shafts. Since these layers were deeper than the available length of temporary casing, water did collect at the bottom of the straight shafts. Also, since no bells were constructed, the quality of clean-up of loose soil by auger at the bottom of the shafts was not as good as desired for a typical production job. Various methods were used to remove the water; however, up to 8 inches of water was measured in the bottom of some of the shafts prior to placement of concrete. Also, the West Caisson was constructed 2 feet shorter in an attempt to reduce the water infiltration. The as-built length of each shaft, actual slumps, quanity of water in the shaft at concrete placement, and construction notes are shown in Figures 4 through 10.

The staging of the construction was also quite difficult in comparison to actual production jobs. Stopping a concrete pour after 10 feet to change trucks, install or remove the tremie pipe, add super-plasticizer and take slumps allowed for more time for water infiltration or soil ravelling to occur than would be allowed on a production job. Some concrete mixes waited over two hours on-site until poured.

2.6 Access Shaft Construction

A unique feature of this research program was construction of a 65 foot long, 5 foot diameter access shaft placed between the four constructed caissons. Two foot by 2 foot square "windows" were cut in the casing roughly at the mid-height of each concrete lift. Platforms were subsequently provided at each level so that direct observation of the sides of the four test shafts could be made. A drawing depicting the access shaft concept is shown in Figure 11.

A five foot diameter hole was augered between the four completed test shafts as shown in Photo 15. Alignment and drilling of the shaft was quite critical, since only approximately 1 foot of clearance was available between the access shaft and caisson sides. Due to the amount of water infiltration which was experienced during construction of the caisson shafts, dewatering of the access shaft became a real problem. In order to minimize the amount of water infiltration through the access windows, it was decided to grout the full length of the access casing. To accomplish this, the 28 access windows were precut at the ground surface, with a small amount of metal retained at two corners of the window to hold the metal in place. Following completion of the access shaft, the entire casing was lifted and set into place as shown in Photo 16. Upon setting of the casing in the proper orientation, the 3 inch thick annulus was grouted for the full length of the casing with a fast setting sand/cement grout.

Following the initial set of the grout, work was begun to remove the steel windows, break through the grout, and remove the soil and temporary liner to expose the side of each caisson. This work was considerably more difficult than initially expected and required nearly two weeks on-site. Removal of the windows is depicted in Photos 17 and 18.

Upon final removal of the window spoil, a deep well pump with associated wiring and piping was installed. The pump operated on 120 volt electricity and had the capacity of approximately 10 gallons per minute. Finally, an access ladder, standing platforms and a cover for the structure were constructed and installed. The view inside the completed access shaft at Levels 4 and 6 are shown in Photos 19 and 20 respectively.

3.0 TESTING PROGRAM AND RESULTS

Quality control for the research project consisted of performing slump tests on each truck load of concrete prior to placement, casting of reference cylinders and the determination of 7 and 28 day strengths. The in-place concrete was tested by obtaining full length, 4 inch diameter cores of each caisson shaft for visual observation, density testing and compressive strength testing; visual observation of the sides of each caisson shaft through the access windows, and Schmidt hammer testing of the sides of the caisson shafts.

3.1 Access Shaft Observations

Upon the completion of the access shaft construction, each window location was examined, photographed and tested. The visible portions of each caisson shaft were inspected for roughness, voids, honeycombing, variations in texture due to rebar spacing, and Schmidt hammer strengths where possible. The photographs obtained from the seven access windows for the West Caisson are shown in Photos 21 through 27.

The top three window locations contained generally smooth well-consolidated concrete, since the caisson shafts at these levels were formed by a 36 inch diameter corrugated liner. The top two window levels were dry, but all window levels below approximately 15 feet were wet. Water infiltration to the access shaft was occurring primarily at the third window level due to the upper water table, at the lowest window level, and the caisson bottom. The rate of water infiltration was estimated to be approximately 1 to 2 gallons per minute. Thus, it was possible for the water level within the caisson to rise between 10 and 20 feet in a 16 hour period, as was common at night when the pump was turned off. Despite the difficult working conditions, all locations were inspected and photographed. Summary descriptions of each window observation are shown in Figures 12 through 15.

In general, the window observations indicated that all of the caisson shafts were fully formed at all levels regardless of the type of concrete, placement method, rebar spacing, or slump. Some minor variations in the roughness of the surface concrete from right to left was discernible at some locations. The very rough and deformed condition of the concrete in the lower two access windows was a result of the soil and water conditions in the test shaft, rather than the concrete parameters. The silty nature of the soil below a depth of approximately 45 feet, as well as the observed gravel layers or pockets at some of the windows led to shaft wall instabilities which resulted in somewhat enlarged shafts at these locations.

3.2 Coring Operations and Testing

Quantitative test results on the strength and density of the caisson concrete was obtained by drilling a single 4 inch diameter core through the center of each of the 60 foot long test caissons. The cores were obtained using a truck mounted drilling rig and a diamond bitted core barrel. The cores were obtained in 10 foot runs and placed in sturdy wooden core boxes. The entire length of each core was subsequently photographed, examined and logged. The visual observations included the logging of each crack within the core, noting any aggregate segregation, sizes and locations of voids, if any, and a general description of the quantity of bugholes. Summarized observations for these logging activities are depicted for each caisson core on Figures 12 through 15.

Following the completion of the logging and photographing, representative sections of the core were cut to obtain 4 inch by 8 inch cylinders suitable for compressive strength testing. Typically between three and four cores were obtained from each 10 foot concrete lift, with the core selected near the center of each lift away from possible interface mixing effects. Due to the length of time required for the access shaft construction and coring operations, it was not possible to obtain 28 day core strengths as desired. Rather, strengths were obtained varying from 36 to 41 days after initial placement of the caisson concrete. Based on current theory, the strength gain resulting from aging the cores beyond 28 days would amount to only 3% to 4%. For this reason, the core strengths were not corrected for this effect. In accordance with ACI Code, however, the compressive strengths were divided by 0.85 to account for sample disturbance during the coring operations. The compressive strengths thus attained are summarized on the core logs in Figures 12 through 15. The individual core strengths are averaged and compared to cylinder strengths for each caisson in Tables 1 through 4. The actual core strength test results including unit weights and core dimensions are included in the Appendix. The twenty cores which were obtained and tested from the North Caisson are shown in Photographs 28 through 33.

In general, visual observations of the full length cores for all four caissons indicated that only two zones of segregated concrete were noted. These segregated zones were noted in Lift 1 of the North Caisson and Lift 5 of the East Caisson. Segregation was noted to be vertical encompassing approximately one half of each core over a length varying from 1 to 3 feet. Both of these lifts were placed with Mix No. 2 which consisted of 1-1/4 inch maximum aggregate size, 7 inch slump concrete placed by tremie methods. It appears reasonable to conclude that this vertical segregation was caused by the removal of the tremie pipe. It seems likely that the void created by the removal of the tremie pipe wall was more readily filled by cement paste and fine aggregate, while the 1-1/4 inch aggregate was left in place.

Additional anomalies occurred at the bottom of each test shaft. Typically, open or clayed filled voids as large as 4 inches were noted to extend as high as 10 feet above the bottom of the caisson, with a more typical height of 5 feet above the bottom of the caisson. These voids or clay pockets were clearly the result of water and poor cleaning conditions at the bottom of the shaft, in addition to possible ravelling of the shaft walls prior to and during concrete placement. Compressive strengths were determined from intact portions of the core which was free of voids or clay where possible.

Other anomalous occurrances included the coring of rebar within the West Caisson, where rebar was encountered from a depth of 42 feet, 6 inches to 50 feet. The horizontal 3/8 inch diameter rebar was encountered every 2 feet within this portion of the core and did affect some of the compressive strengths. Subsequent inclinometer readings of the corehole in the West Caisson however, indicated that the drilling procedures drifted by only a few inches. As a result, it appears that a portion of the rebar cage either collapsed or shifted considerably during construction for this caisson. Compressive strengths which were influenced by the inclusion of rebar were ignored.

An additional anomaly was noted at a depth of 32 to 33 feet within the West Caisson. At this level, a 2 to 3 inch zone of very low strength concrete paste was encountered overlying cracked and broken concrete. This occurred at the center of a lift which was placed by tremie procedures. The zones of concrete above and below this anomaly were intact exhibited high break strengths. Thus, the cause of this segregated zone or pocket is not obvious. It is likely the result of soil ravelling or possibly the result of improper removal and replacement of the tremie pipe. However, no improper procedures were noted.

3.3 Cylinder Testing

A standard set of four 6 inch by 12 inch cylinders was cast for each of the truck mixes which came on-site. Typically, a slump test was performed just prior to the placing of the concrete. Where necessary, water was added at the site to adjust the slump into the required 4 to 5 or 7 to 8 inch slump range. Super-plasticizer was also added at the site just prior to placing of the concrete lifts which required this admixture. Typically, between 1 and 2.5 gallons of WRDA-19 was added to obtain slumps in the 7 to 8 inch range.

Following the slump test, cylinders were cast in accordance with ASTM Standard C-42, and placed in a curing room after initial set. Compressive strength tests were performed on one cylinder at 7 days, and two cylinders at 28 days. The results of all tests are included in the Appendix of this report, while the 28 day strengths were averaged and are summarized on the core logs shown in Figures 12 through 15. The cast-in-place slumps were also summarized on these figures.

3.4 Schmidt Hammer Test Results

In order to obtain some analytical data from the sides of the caisson shafts, Schmidt hammer tests were attempted. Due to the difficult conditions, and bugetary constraints, horizontal coring or Windsor probe tests were not attempted. Also, Schmidt hammer tests were attempted primarily on the top three window levels only. This was due to the fact that the caisson concrete was quite rough at all those levels where no corrugated liner was used. No attempt was made to grind or smooth the lower window test locations which would have been very difficult in any case because of seeping soil and water.

Results of the Schmidt hammer tests are summarized in Table 5. The core strengths were determined from the rebound number in accordance with the graph shown in Figure 16. The Schmidt hammer results indicated relatively little variation between the caissons at the upper three window levels. The correlated compressive strength values were considerably lower than the strengths which were obtained by compressive strengths on cores taken from the centers of the caissons. Due to the lack of variation in the Schmidt hammer test results, as well as the difficulty in interpreting the data, no conclusions were drawn.

4.0 ANALYSIS AND DISCUSSION

4.1 Core Strength Summary

As noted previously, all collected core strength data, cylinder strength data and Schmidt hammer strength data is summarized for each caisson in Tables 1 through 4. Also, written descriptions of the full length caisson cores and observations through the access shaft windows are summarized on the core logs in Figures 12 through 15. Based on the results of twenty cylinder strength tests and nearly eighty compressive strength tests on the cores, it can be concluded that (with the exception of Level 5 in the East Caisson), the measured core strengths varied from the reference cylinder strengths by -16% to +20.7%. These variations in twenty-three out of the twenty-four lifts placed are quite small considering the many variables involved and the difficult placement conditions. Further, the measured compressive strengths for twenty-three out of the twenty-four lifts placed greatly exceeded the 4,000 psi design strength. The measured average core strengths varied from 5,100 psi to 7,060 psi. Thus, variations in placement method, drop height, slump, aggregate size, and addition of super-plasticizer did not significantly affect the strength or unit weight of the caisson concrete.

The single exception to the above general conclusion occurred within the East Caisson at a depth of 30 to 40 feet. This lift displayed an average core strength of only 3,100 psi, and average unit weight of 143.3 pounds per cubic foot, with an uncharacteristically low average cylinder strength of only 4,790 psi. The lift was placed utilizing Mix No. 3 at a slump of 5.5 inches by the sloppy drop procedure. The resulting core strengths were 35.3% less than the already low cylinder strength, resulting in the only underdesigned concrete.

We believe that the low strengths and unit weights for this single concrete lift was not the result of the placement procedures, but rather was the result of excessive waiting time and the addition of water on the site. Only a single lift of Mix No. 3 was placed within the East Caisson. Thus, a truck mix of only 3 cubic yards was required. This truck actually arrived first at the site and was required to wait in excess of 2 hours while the rebar cages, steel access tubes, and the lower two tremie lifts were placed. In addition, 14 gallons of water were added prior to the placement of the concrete in order to increase the slump to 5.5 inches due to the long waiting period. Also, this lift was placed on top of 20 feet of previously placed tremie concrete. Eight inches of water which had been measured at the bottom of the caisson shaft was displaced up to a level of 40 feet by the tremie procedure. Subsequent bailing and attempted removal of the water and contaminated concrete was performed. While the height of water was measured to be approximately 2 inches following the bailing procedure, the actual success of this procedure may have been questionable. In addition, the compressive strength tests on the three core samples from this lift all indicated that minimum aggregate shear occurred in the cores. This weak bonding between the aggregate and cement paste is consistent with the concrete mix which had waited for a long period of time and had a considerable quantity of water added.

4.2 Access Window Observations

The most interesting observations made through the access shaft windows occurred through window levels 4 and 5 at a depth of 20 to 40 feet. These portions of the caissons were below the permanent corrugated liner, but were formed within competent silty clay soils which should not have ravelled or leaked water. At these two levels, some vertical ribbing was noted at all four of the test shafts. At some of the locations, this ribbing appeared to have the distinct shape and spacing of the vertical rebar. While the causes of the vertical ribbing are speculative, it was noticed that in every case, the more pronounced ribbing occurred on the side of the caisson shaft which contained the 3 inch vertical rebar spacing. Thus, it appears that the 3 inch rebar spacing may have had a greater effect on the roughness of the concrete at the shaft surface than the 6 inch spacing. No conclusions could be drawn regarding the slump or maximum aggregate size of the various mixes, since the vertical ribbing was evident over a wide range of slumps and aggregate sizes with no pattern apparent. Thus, it appears that the ribbing were not related to the flowability of the concrete, but was likely the result of the flexibility of the rebar cage and the concrete placement procedures.

Due to the flexibility of the rebar cage, it appears likely that the cage was pressed into the clay walls of the shaft during the placement procedures. These indentations were subsequently filled with concrete resulting in the noted ribbing. These indentations would be more likely to occur on the sides of the caisson shaft where a greater quantity of rebar could come in contact with the soil walls. It is also possible that the vertical ribbing was a result of the sloppy drop placement procedures. It should be noted that all of the lifts which exhibited ribbing were located above other lifts which had been placed by sloppy drop procedures. During the sloppy drop procedure, concrete was typically directed into the rebar cage and side of the caisson shaft at the location of the access windows. The resulting flow of concrete down the side of the shaft could possibly result in erosion of the clay walls to form vertical channels. These vertical channels would likely be more pronounced at the locations of the closer spaced rebar.

4.3 Comparison of Placement Procedures

Even though all placement procedures and mix designs tested resulted in greater than required design strength concrete, it is still possible to draw some general conclusions by comparison of the methods. Comparison of lifts in the same batch of concrete with all variables removed except for placement methods provides the best data. In general, it was noted that the only segregation of concrete occurred within two of the tremie lifts. Also, additional anomalies also occurred within a tremie lift in the West Caisson possibly as a result of water infiltration or improper tremie procedures. Direct comparison of tremie to central drop placement indicates that in three out of the four direct comparisons that can be made, tremie placement resulted in higher strength concrete than central placement. Tremie strengths varied from 9% less to 14% more than the central drop procedures.

A similar comparison made between the sloppy drop methods and central drop methods indicates that the sloppy drop core strengths were greater than the central drop core strengths in six out of seven of the direct comparisons which can be made. The sloppy drop strengths varied from 5% less to 8% greater than the central drop strengths. Based on this research, it appears that the general expectation that striking of the rebar cage will cause segregation or weakened concrete is invalid. It may, however, result in displacement of the cage.

4.4 Effect of Super-Plasticizer

The effect of super-plasticizer within Mixes 1 and 3 can be assessed by examining three cases where nearly direct comparison can be made. Comparing lifts S3 and S5, lifts E4 and W4, and lifts W2 against W3 leads to the conclusion that concrete which was placed without super-plasticizer had strengths which varied from 0% to 14% higher than the comparable mix with super-plasticizer. In no case was the mix with super-plasticizer stronger than a mix without. While the number of direct comparisons is small, these lifts provide the least amount of additional variables which could affect the results. Further, the variation of 0 to 14% is small even for concrete off the same mix and batch.

5.0 CONCLUSIONS

The goals of this research program were to answer four questions which were posed at the beginning of this report. Subject to the limitations of the procedures used and the quantity of data obtained as discussed in previous sections, the following conclusions can be drawn.

Q1. Does concrete segregate or loose strength as a result of extended free fall through air? And, does slump, maximum aggregate size, height of drop, or addition of super-plasticizer clearly influence the results?

None of the lifts placed by central drop free-fall procedures within the research program exhibited any signs of aggregate segregation. The design strengths of all centrally dropped lifts varied from 13% less to 20% more than the reference cylinder strengths. The lowest centrally dropped compressive core strength was recorded to be 5.510 psi while the highest strength was 7,060 psi. All of the strengths were well above the intended 4,000 psi design strength.

Due to the small variation in the compressive core strength and lack of aggregate segregation, no definitive effect of slump, aggregate size, height of drop, depth of fluid pressure, or addition of super-plasticizer was discerned. A slight increase in compressive strength and unit weight was noted with depth for the North Caisson however, thus indicating the possible beneficial effect of greater fluid concrete height or drop height.

Though the maximum height of fluid pressure or drop height for the research program was 60 feet, we believe that free-fall placement of concrete can be extended to 120 feet or more provided that the shaft walls or rebar cage are not contacted by the falling concrete. Since the concrete was easily placed within the 2.5 foot diameter rebar cage to 60 feet, extrapolation based on geometry would allow a 120 foot drop in a 5 foot diameter shaft. Caissons are routinely constructed to depths of up to 150 feet in the Chicago area by free-fall methods. Full length cores of over 100 of these caissons over the past 30 years have never indicated segregation or weakened concrete (2).

Q2. Does significant segregation and loss of strength occur if the concrete hits the rebar cage during free fall placement? And, does slump, maximum aggregate size, height of drop, or addition of super-plasticizer significantly influence the results?

Surprisingly, in six out of seven direct comparisons made between sloppy drop and central drop placement procedures, the sloppy drop methods actually resulted in higher average compressive core strengths than equivalent central drop procedures. Also, no segregation of aggregate was noted for any of the sloppy drop mixes placed. Thus, based on this research, it is concluded that striking the rebar cage or corrugated liner at the side of the caisson shaft does not have a detrimental effect on the strength or integrity of the concrete.

Due to the high strengths and lack of segregation which was apparent in all of the sloppy drop lifts, the effects of aggregate size, slump, height of drop, height of fluid pressure, and addition of super-plasticizer did not appear to affect the results in a meaningful way for the well-designed concrete mixes.

Even though sloppy drop procedures were not found to affect the strength or segregation of the concrete, it is not intended that contractors should begin to place concrete in a haphazard fashion. The sloppy drop procedure adversely affected the placement of the rebar cage and also caused additional concrete contamination as a result of traveling down the soil sides of the caisson shaft.

Q3. Does rebar spacing within normal limits affect whether concrete flows readily through and around the rebar, and what is the effect of slump, aggregate size, or height or method of placement?

Observations of the sides of the caisson shafts indicate that the spacing of the rebar cage did affect the roughness of the caisson surface at a depth of 20 to 40 feet, when concrete was not placed within a corrugated liner. The vertical ribbing which was noticed appears to be the result of concrete flowing down the sides of the caisson shaft during the sloppy drop procedures for lifts below the affected levels. This roughness of the shaft did not appear to be more or less pronounced as a result of variations in aggregate size or slump.

In all cases, the caisson shafts were fully formed and no honeycombing, voiding or exposed rebar was evident. Nevertheless, the roughness of the caisson surface at some of the lifts indicates that the rebar spacing should not be less than 3 inches edge to edge for any concrete mix, and more importantly, adequate embedment depth and position control of the rebar cage should always be maintained.

Q4. Does vibration of a well designed concrete mix affect the concrete strength and integrity?

The number of comparisons which could be made between vibrated and unvibrated concrete for this research program were minimal. Only two cores of vibrated concrete were obtained for comparison to unvibrated concrete. The results of these two comparisons indicate that vibrated concrete (which had been placed by tremie procedures) was 7% higher in strength for both cases than the underlying unvibrated concrete. The unit weight of the vibrated concrete varied from 3 pcf less to 1 pcf higher than unvibrated concrete. Thus, based on the limited number of cores in this research program, vibration does have a beneficial effect on the strength of the concrete, but the unvibrated strength of the concrete was still significantly higher than the required 4,000 psi design strength. Thus, while the vibration was beneficial within the research program, it was not necessary.

In summary, we conclude that the free-fall placement method of concrete into properly constructed clean and dry shafts can be performed to depths of 120 feet or greater without meaningful loss of strength or segregation of the concrete aggregate.

6.0 REFERENCES

1. Baker, C.N., Jr., and Gnaedinger, J.P., "Investigation of the Free-Fall Method of Placing High Strength Concrete in Deep Cassion Foundations", Report Prepared for Case Foundations Company, 1960, (available through the Association of Drilled Shaft Contractors, Dallas, Texas)

2. Baker, C.N., Jr., and Gnaedinger, J.P., "History of Chicago Building Foundations 1948-1983", Chicago Committee on High-Rise Buildings, November 1984

TABLES

Table 1
Summary of Concrete Strengths for the North Caisson

NORTH CAISSON

		Core Samples						
Level	No. of Core Samples	Avg. Strength* @ 36 days (psi)	Avg. Unit Weight (pcf)	Avg. of Two Cylinder Strengths @ 28 Days (psi)	% Difference	Schmidt Hammer Strength (psi)**	Type of Placement	Mix No.
1	1	5540	149.1	6070	8.7% less	2350	Tremie (vibrated)	2
2	3	5100	151.8	6070	16% less	2350	Tremie	2
3	3	5730	152.9	6070	5.6% less	2500	Sloppy Drop	2
4	3	5630	152.8	6070	7.2% less	<1500	Central Drop	2
5	3	6000	153.3	6570	8.7% less	----	Tremie w/ Super P	1
6	3	7060	154.6	6570	7.5% more	----	Central Drop	1
7	3	6730 6170 +	154.1 153.0 +	6570 6570	2.4% more 6.0% less	----	Sloppy Drop	1

\+ Includes sample N7D. which contained several clay voids that caused an early fracture. The previous line excludes that sample.

* Core samples adjusted to compare with cylinder strengths by dividing the core strength by 0.85.

** ± 600 to ± 725 psi variance.

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Table 2
Summary of Concrete Strengths for the South Caisson

SOUTH CAISSON

		Core Samples						
Level	No. of Core Samples	Avg. Strength* @ 35 days (psi)	Avg. Unit Weight (pcf)	Avg. of Two Cylinder Strengths @ 28 Days (psi)	% Difference	Schmidt Hammer Strength** (psi)	Type of Placement	Mix No.
1	1	6110	145.3	5060	20.7% more	2300	Tremie (vibrated)	4
2	3	5750	144.3	5060	13.6% more	3200	Tremie	4
3	3	6180	148.0	5660	9.2% more	3300	Central Drop w/ Super P	3
4	3	6290	149.3	5660	11.1% more	1600	Sloppy Drop w/ Super P	3
5	3	6820	146.7	5660	20.5% more	----	Central Drop	3
6	3	5520	145.2	5060	9.1% more	----	Central Drop	4
7	4 +	5920	146.9	5060	17.0% more	----	Sloppy Drop	4

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* Core samples adjusted to compare with cylinder strengths by dividing the core strength by 0.85.

\+ Note samples 7B, 7C, and 7D were 2 inch diameter cores.

** ± 600 to ± 750 psi variance.

Table 3
Summary of Concrete Strengths for the East Caisson

EAST CAISSON

		Core Samples						
Level	No. of Core Samples	Strength* @ 41 days (psi)	Unit Weight (pcf)	Avg. of Two Cylinder Strengths @ 28 Days (psi)	% Difference	Schmidt Hammer Strength** (psi)	Type of Placement	Mix No.
1	0[a]	---	---	6580	---	2200	Sloppy Drop (vibrated)	4
2	3	6280	147.4	6580	4.5% less	3100	Sloppy Drop	4
3	3	6200	147.6	6580	5.7% less	3100	Central Drop	4
4	3	5100	151.7	5910	13.7% less	---	Sloppy Drop w/ Super P	1
5	3	3100 +	143.3	4790	35.3% less	---	Sloppy Drop	3
6	3	5340	151.4	5830	8.6% less	---	Tremie	2
7	3	6300	148.2	6580	4.3% less	---	Tremie	4

\+ Minimum aggregate shear in cores E5A, E5B and E5C.

* Core samples adjusted to compare with cylinder strengths by dividing the core strength by 0.85.

** ± 700 to ± 750 psi variance.

a No samples obtained within the upper 2 feet of the caisson.

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Table 4
Summary of Concrete Strengths for the West Caisson

WEST CAISSON

		Core Samples						
Level	No. of Core Samples	Ave. Strength* @40 days (psi)	Ave. Unit Weight (pcf)	Avg. of Two Cylinder Strengths @ 28 Days (psi)	% Difference	Schmidt Hammer Strength** (psi)	Type of Placement	Mix No.
1	0 [a]	---	---	5810	---	2700	Central Drop w/Super P (vibrated)	1
2	3	5730	147.8	5810	1.4% less	2700	Central Drop w/Super P	1
3	3	5730	146.3	5810	1.4% less	3050	Central Drop	1
4	3	5780	151.9	5810	0.5% less	---	Sloppy Drop	1
5	3	6470	143.5	6310	2.5% more	---	Tremie w/Super P	3
6	3 2	4840 + 5510	151.4 + 150.4	6310	23.3% less 12.7% less	1500	Central Drop w/Super P	3
7	4 3	5270 ++ 6050	147.5 ++ 149.6	6310	16.5% less 4.1% less	---	Sloppy Drop w/Super P	3

+ Includes sample W6C which contained a piece of rebar near the top of the sample. which caused an early fracture. The following line excludes that sample.

++ Includes sample W7D. which contained several clay voids that caused an early fracture. The following line excludes that sample.

* Core samples adjusted to compare with cylinder strengths by dividing the core strength by 0.85.

** ± 725 to ± 750 psi variance.

a No samples obtained in the upper 2 feet of the caisson.

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Table 5
Summary of Schmidt Hammer Results on Caisson Shafts Through Access Windows

Caisson	Window Level	Average Rebound Number	Number of Readings	Correlated Compressivex Strength (psi)	Comments
NORTH	1	26.8	10	2350	
	2	27.3	10	2350	
	3	28.2	10	2500	
	4	20.3	10	< 1500	Rough Concrete
	5	---	0	---	No Measurements
	6	27.0	6	---	Large Scatter
	7	---	0	---	No Measurements
SOUTH	1	26.8	10	2300	
	2	31.5	10	3200	
	3	32.0	10	3300	
	4	22.5	8	1600	Rough Concrete
	5	---	0	--	No Measurements
	6	17.8	6	< 1500	Rough Concrete
	7	---	0	---	No Measurements
EAST	1	26.4	10	2200	
	2	30.6	10	3100	
	3	31.1	10	3100	
	4	---	0	---	No Measurements
	5	---	0	---	No Measurements
	6	12.8	5	< 1500	Soil Film & Rough Concrete
	7	---	0	---	No Measurements
WEST	1	28.4	10	2700	
	2	28.7	10	2700	
	3	30.7	10	3050	
	4	---	5	---	Rough Concrete & Soil All Measurements < 10
	5	---	0	---	No Measurements
	6	21.7	7	1500	Rough Concrete
	7	---	0	---	No Measurements

* ±650 to ±750 psi variance depending on the correlated strength. See Figure 16 for actual variance.

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PHOTOS

Photo 1 Layout of the four caissons and center access shaft at the project site. The 3 foot diameter shafts and 5 foot diameter access shaft were placed to maintain an approximate 1 foot edge-to-edge clearance.

Photo 2 Augering through the rubble fill for the West caisson to set oversize temporary casing.

Photo 3 Placement of a 48 inch diameter temporary oversize casing through fill soils for the South caisson.

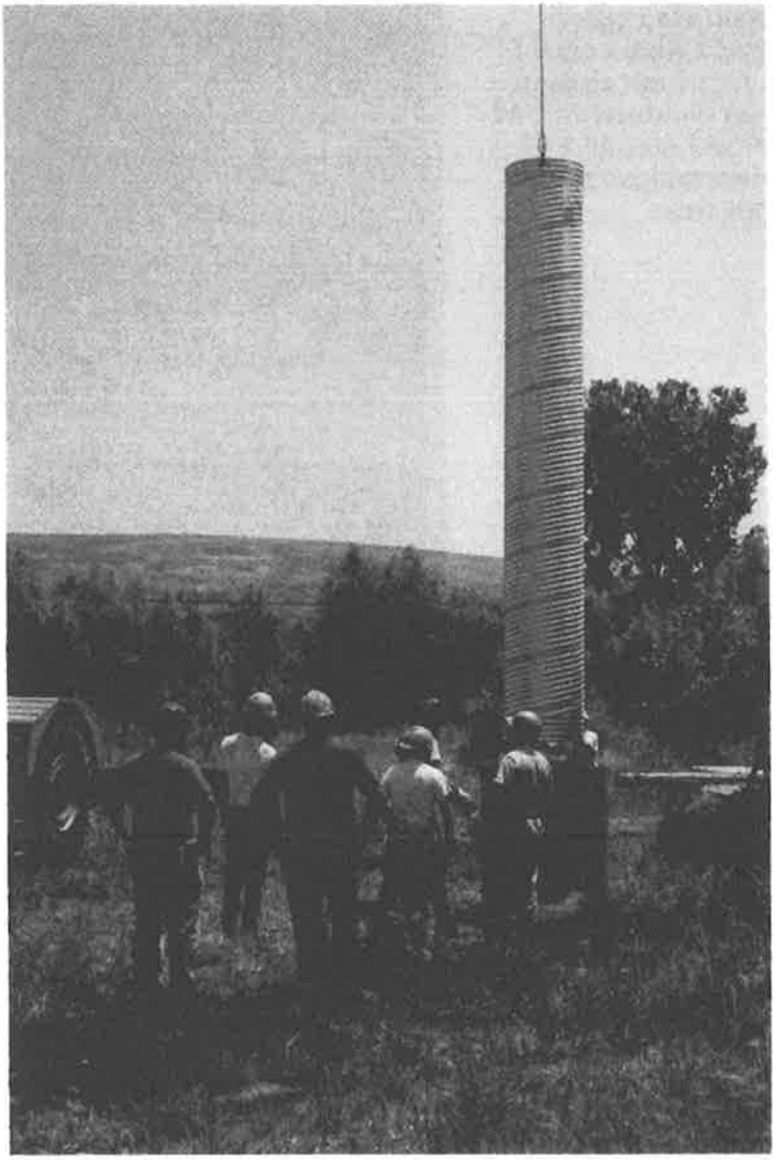


Photo 4 Installation of a 22 foot long by 36 inch diameter corrugated permanent liner in the North caisson as required by the site conditions. The permanent liner extended through the top two concrete lifts.

Photo 5 60 foot long by 30 inch diameter full-length steel reinforcing cages placed within each of the four test caissons. Cages consisted of #8 vertical bars and #3 horizontal bars tied with wire.

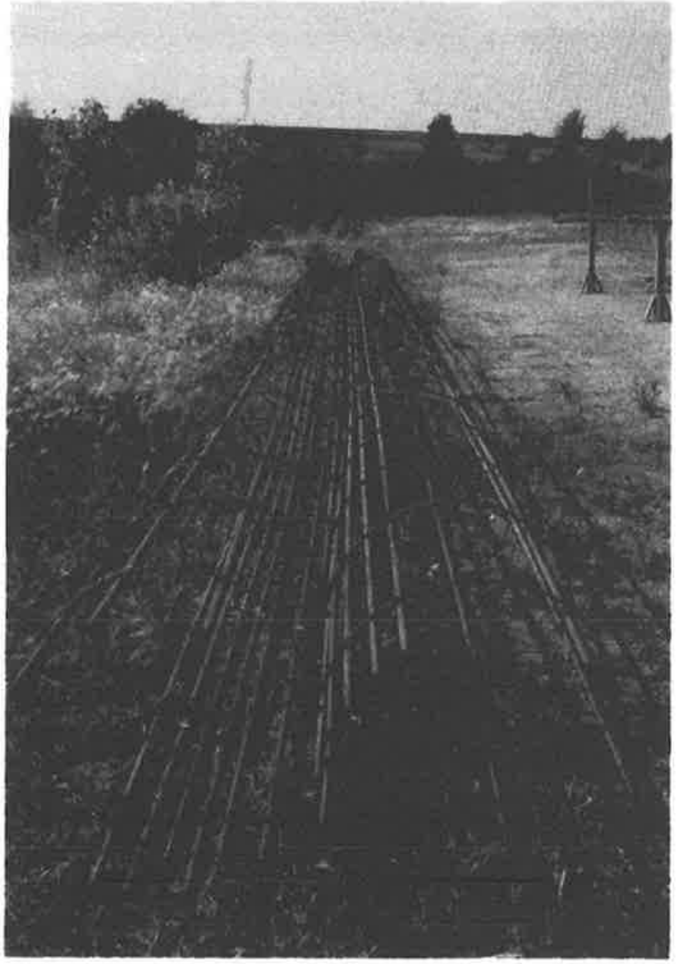


Photo 6 3 inch and 6 inch spacing of the vertical rebar on the side of the cage which faced the windows of the access shaft.

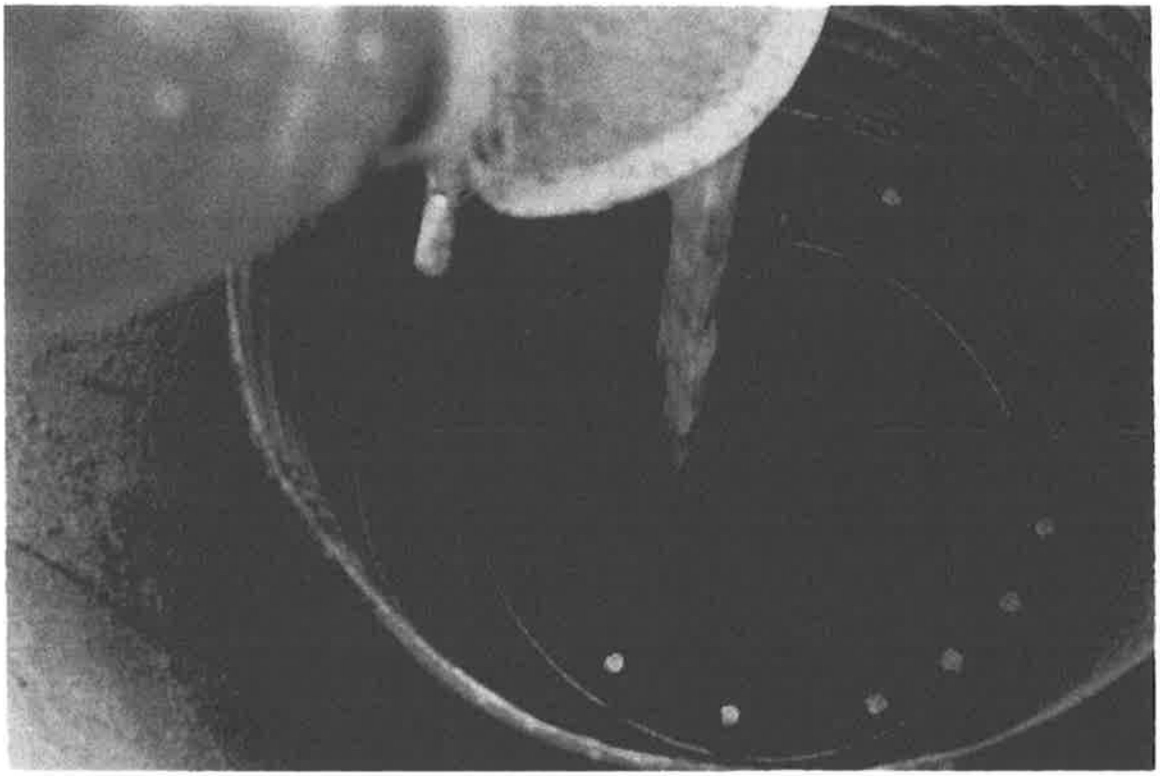


Photo 7 Concrete being placed by the central drop method into the East caisson at a depth of 12 to 22 feet. Mix #4 with a 7 inch slump and 5/8 inch aggregate size was backchuted directly down the center of the shaft.

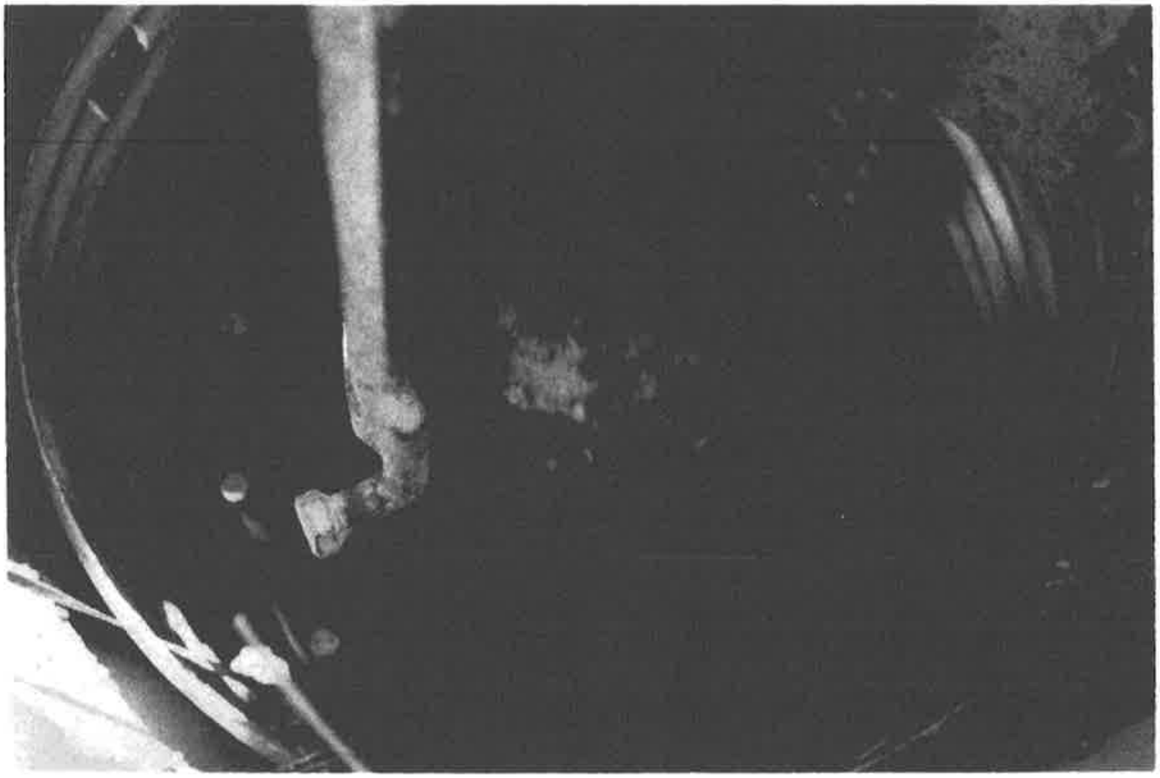


Photo 8 Central drop free-fall of concrete into the North caisson at a depth of 43 to 51 feet using Mix #1 with a slump of 4.5 inches and an aggregate size of 1-1/4 inch. Note how the lower slump concrete clumps together rather than flowing in a continuous sheet as above.

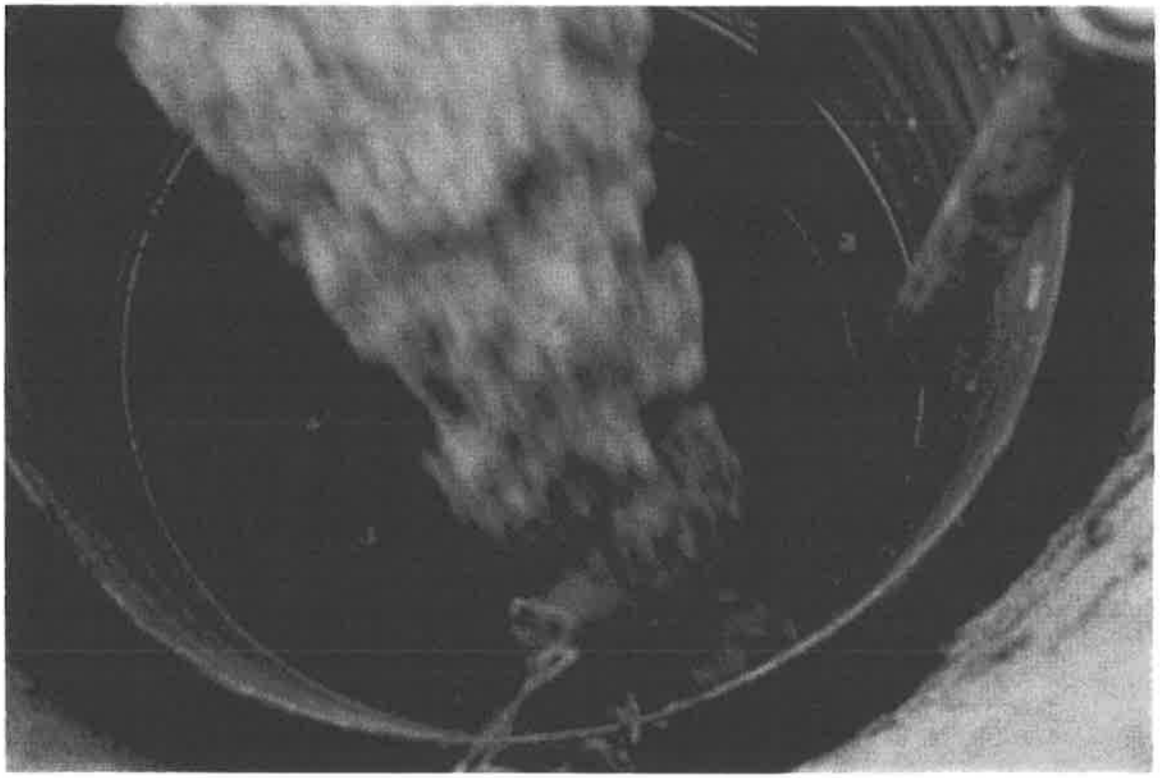


Photo 9 The "sloppy-drop" free fall method of concrete placement with Mix #3 (5/8 inch aggregate and 5.5 inch slump) at a depth of 32 to 43 feet in the East caisson. Note the ricocheting of the concrete as it is purposefully directed into the rebar cage and corrugated liner.

Photo 10 Sloppy-drop free fall of concrete in the East caisson at a depth of 22 to 32 feet using Mix #1 (8.25 inch slump, 1-1/4 inch aggregate and superplasticizer). Note the complete coating of the rebar cage and permanent liner.

Photos
11 & 12 Concrete placed by the tremie method into the East caisson at a depth of 53 to 65 feet using Mix #4 with a 7 inch slump. A 12 inch diameter rigid steel tremie and hopper were used. The bottom of the tremie pipe remained embedded within the fluid concrete at the bottom of the lift during the pour.

Photo 13 The top of the East caisson just prior to the start of vibrating to a depth of about 2.5 to 3 feet. The top lift was Mix #4 with a 7 inch slump and 5/8 inch aggregate.

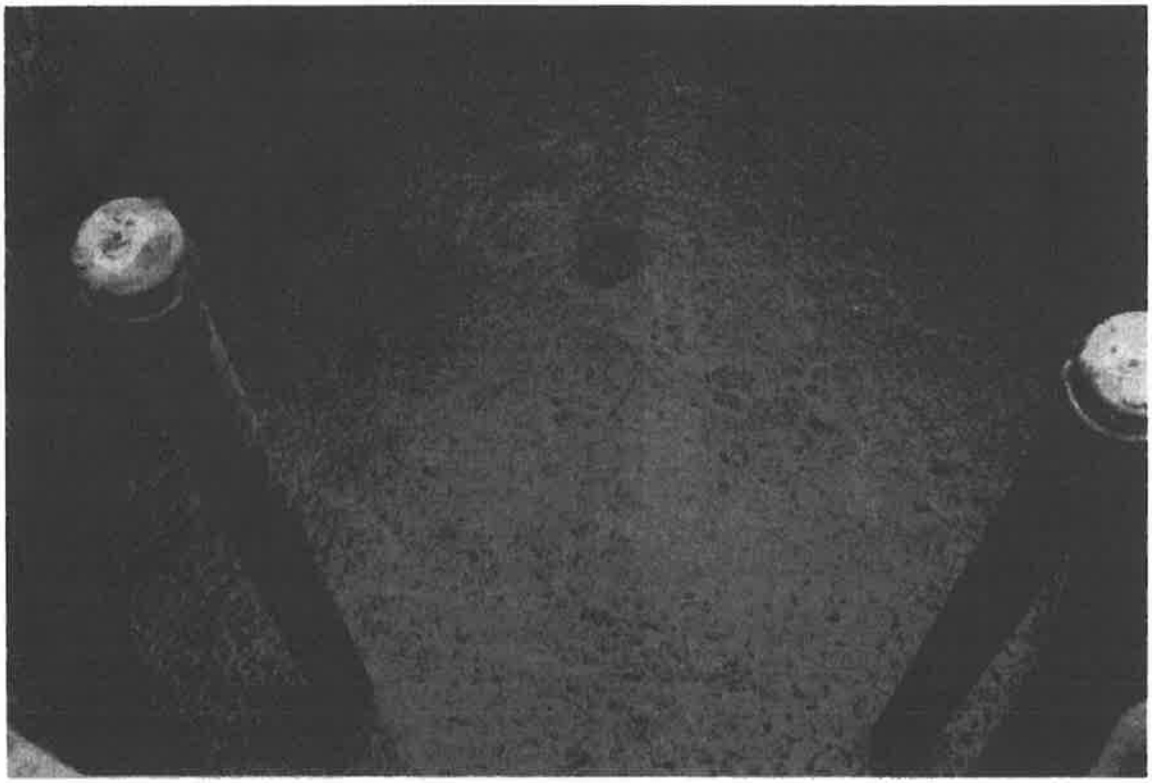


Photo 14 The top of the East caisson after the completion of the vibrating.

Photo 15 Lining up and leveling of the 5 foot auger to drill the access shaft between the four completed caissons. This view looking south shows the North caisson in the foreground.

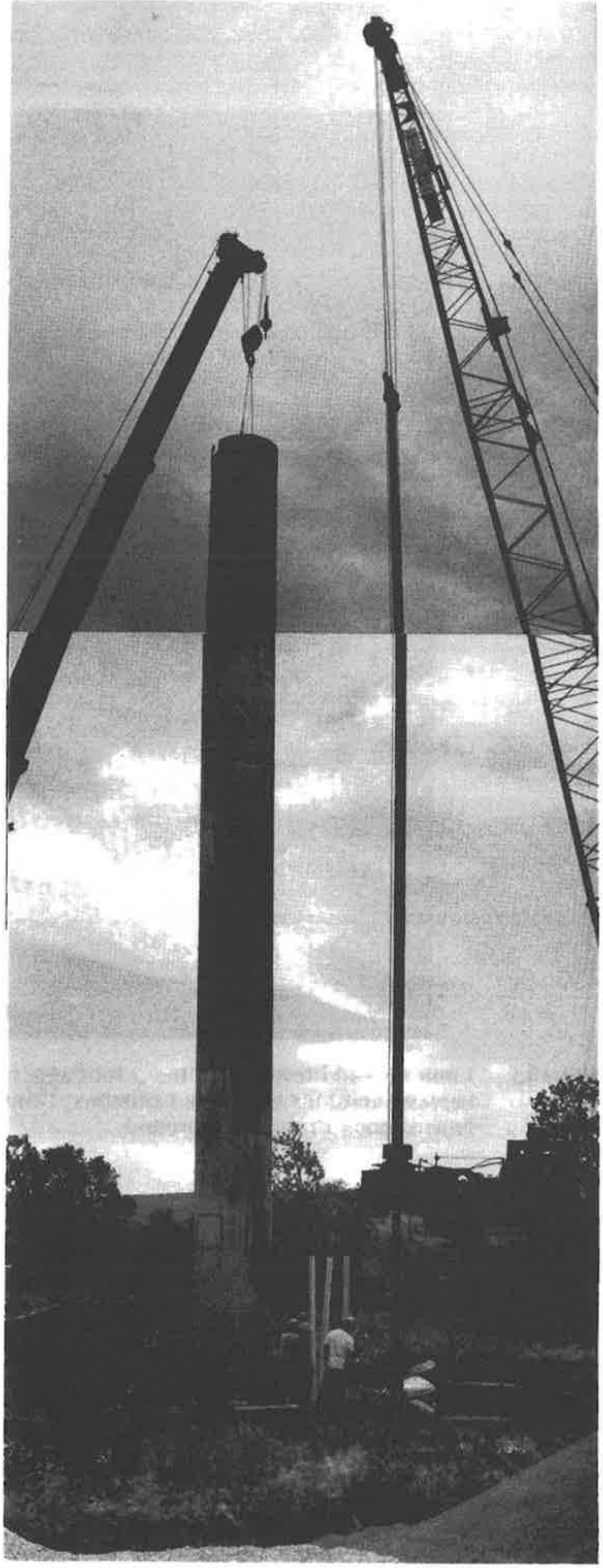
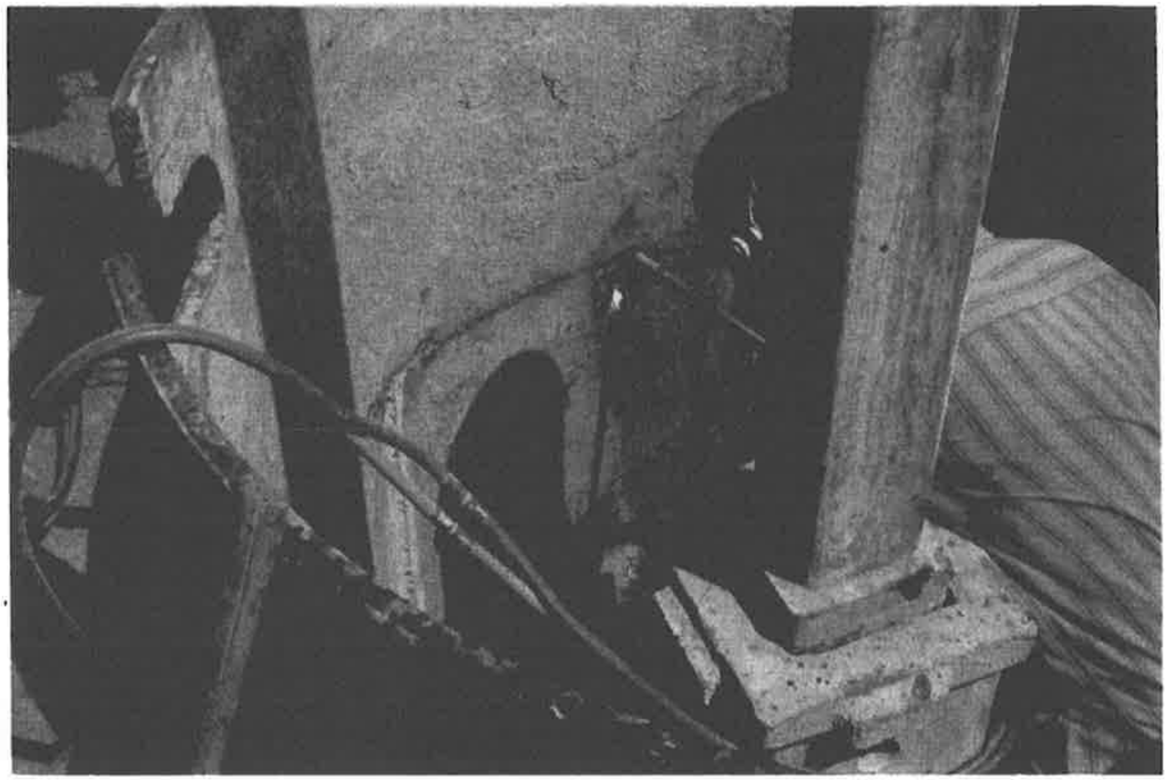


Photo 16 Installation of the 58 inch diameter by 65 foot long access casing. The 2 foot square access windows were pre-cut, but held in place at the corners for subsequent removal downhole. One window faced each caisson at the approximate center of each 10 foot thick high concrete lift. The bottom 5 windows facing the West Caisson were cut 2 feet higher due to the shorter depth of that caisson.



Photos 17 and 18
Removal of the access windows and revealing of the cement grout which was placed outside the access casing to a depth of 60 feet to minimize groundwater infiltration during construction and observation.

Photo 19 The view inside the access shaft looking down from the platform at window Level 4 at a depth of 30 feet below the surface. after the installation of the ladder, deep well pump, and working platforms. The four windows at Level 5 are visible as is water at the base of the shaft.

Photo 20 Inside the access shaft at Level 6. Total water infiltration from the upper windows was approximately 1-2 gallons/minute. Here, the water level was pumped down just below the bottom of the Level 7 window. The depth of water was about 6 inches.

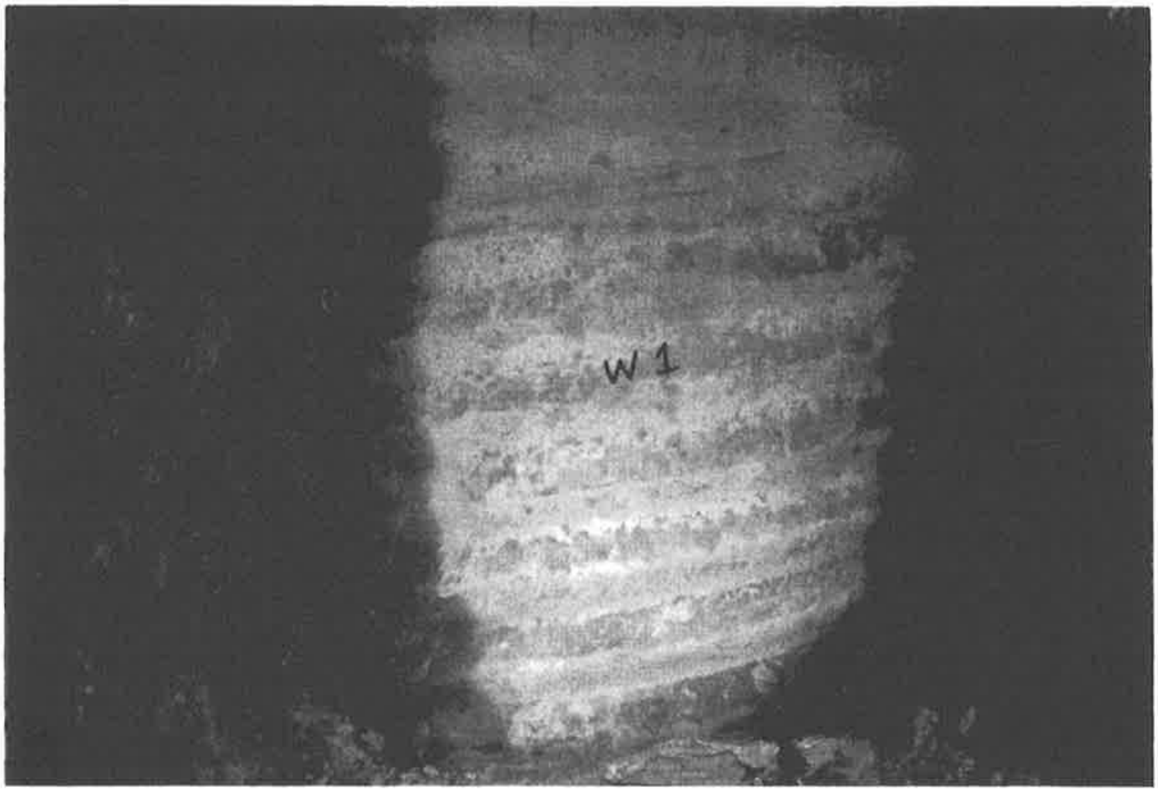


Photo 21 Exposed concrete for the West Caisson at Window Level No. 1, 3.5 feet below the top of the access casing, following the removal of grout and the corrugated liner. White residue on the concrete surface was a result of the surface coring operation.

Photo 22 Exposed concrete for the West Caisson at Window Level No. 2, 7 feet below the top of the access casing. Chipping of surface was caused by removal of the corrugated liner.

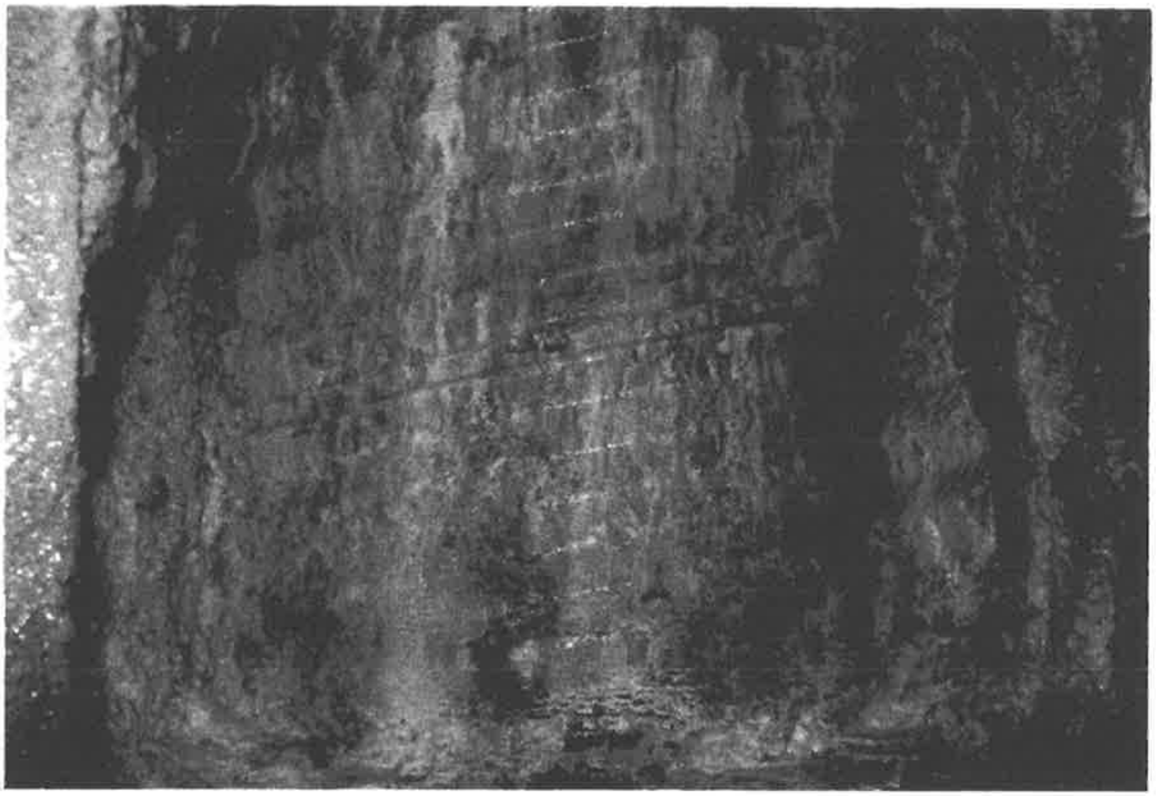


Photo 23 Exposed concrete for the West Caisson as seen through the access shaft Window #3 at a depth of 15 feet below the top of the access casing. Note the wet condition.

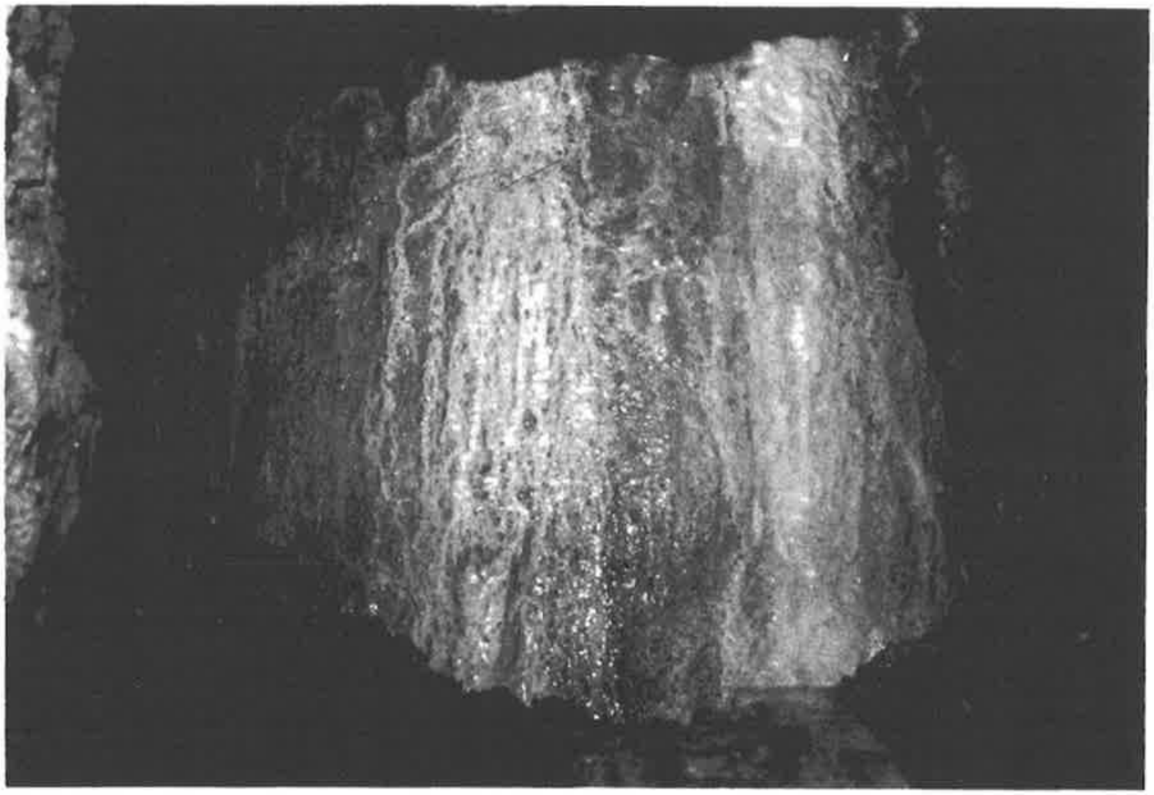


Photo 24 Exposed concrete for the West Caisson at Window level #4 at a depth of 25 feet below the top of the access casing. The concrete is fully formed while somewhat rough. No segregation, voids or honeycombing is evident.

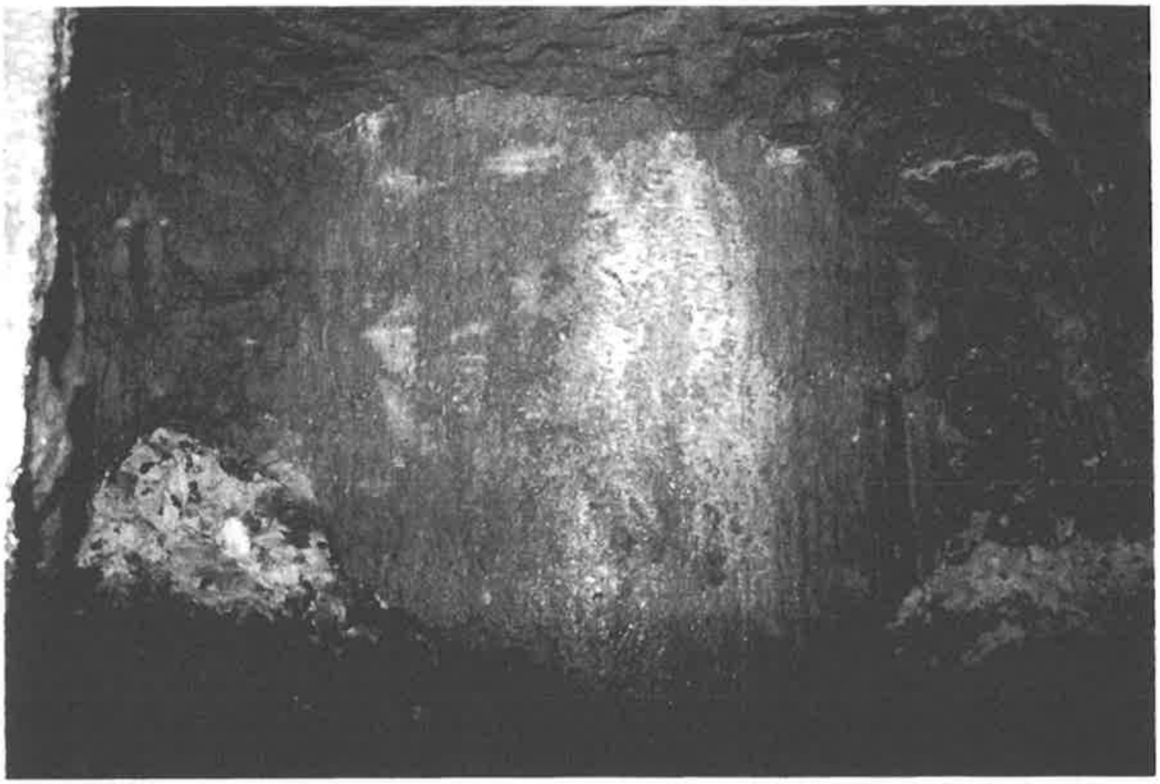


Photo 25 Exposed concrete for the West Caisson at Window Level #5 at a depth of 35 feet below the top of the access casing. Chips in the concrete surface were caused by removal of the soil. A roughly horizontal seam is apparent within the concrete at the mid-height of the window culminating in an exposed wire tie at the right.

Photo 26 Exposed concrete for the West Caisson at Window Level #6 at a depth of 45 feet below the top of the access casing. The white muck on the surface are concrete cuttings from the coring operation at the surface. The concrete is rough and was chipped during removal of the soil. however, no voids or honeycombing are evident.

Photo 27 The view through the Level #7 access window at a depth of 54 feet below the top of the access casing for the West caisson showing the exposed concrete. Concrete is rougher than other levels, but fully formed. The surface was chipped during the soil removal.

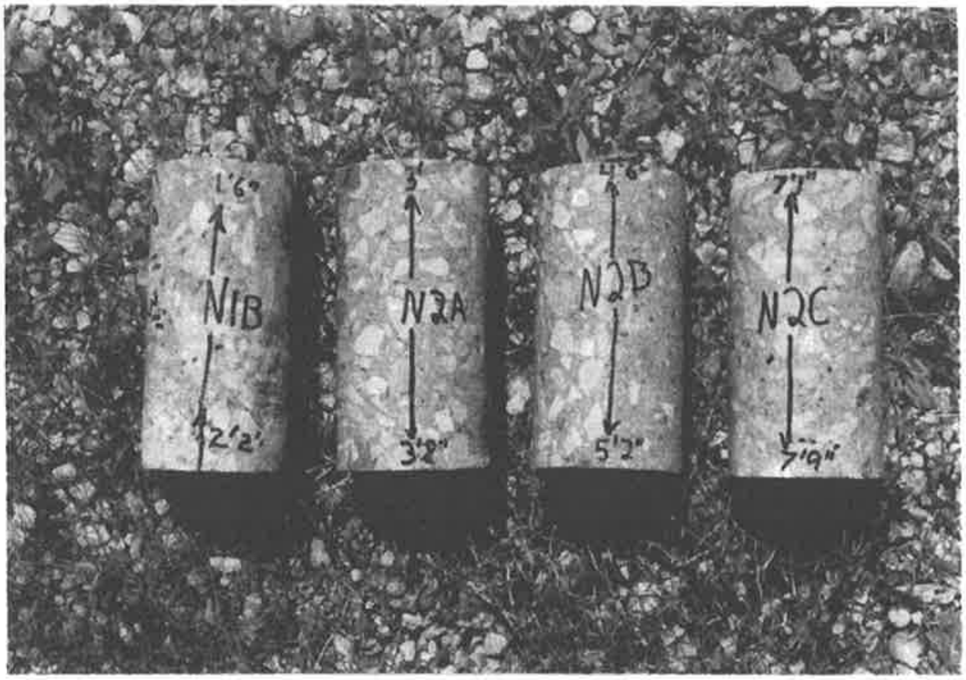


Photo 28 Core samples N1B, N2A, N2B and N2C from Lift #1 of the North Caisson. Note the vertical segregation of aggregate within core N2B. The concrete for these cores was placed by tremie using Mix #2. Core N1B was vibrated, while those below were not.

Photo 29 Core samples N3A, N3B, and N3C from Lift #2 of the North Caisson. Lift #2 was placed by sloppy drop procedures using concrete from the same truck as the lift above. No segregation is evident.

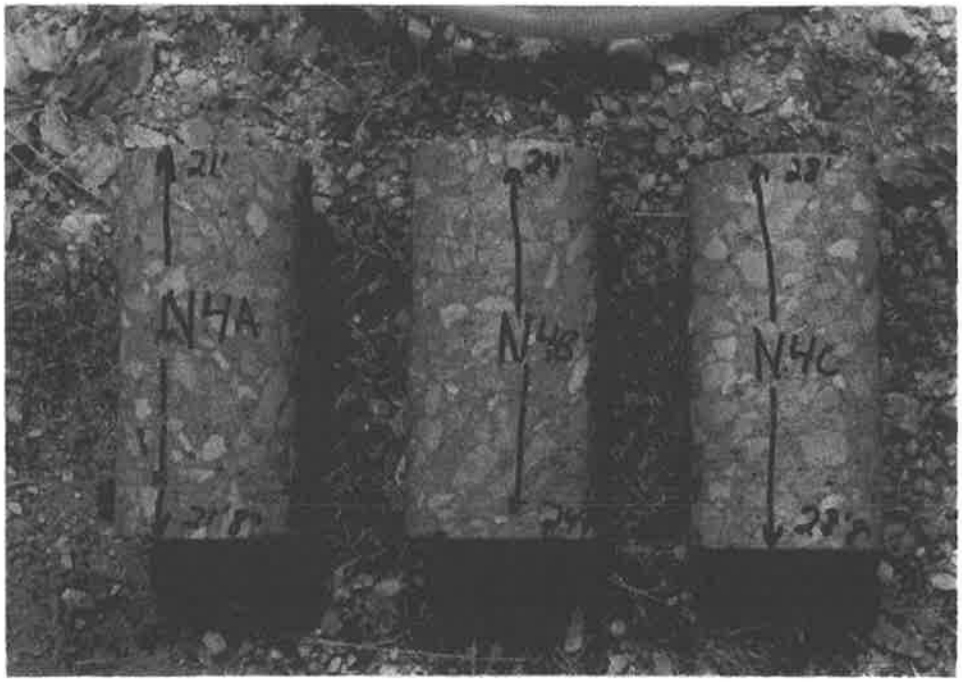


Photo 30 Core samples N4A, N4B and N4C from Lift #3 of the North Caisson. Lift #3 was placed by the central drop method with the same mix and slump as the two lifts above. No segregation of aggregate is apparent.

Photo 31 Cores N5A, N5B, and N5C were taken from Lift #4 of the North Caisson. Lift #4 was placed by tremie using Mix #1 with superplasticizer added. No aggregate segregation within the cores is apparent.

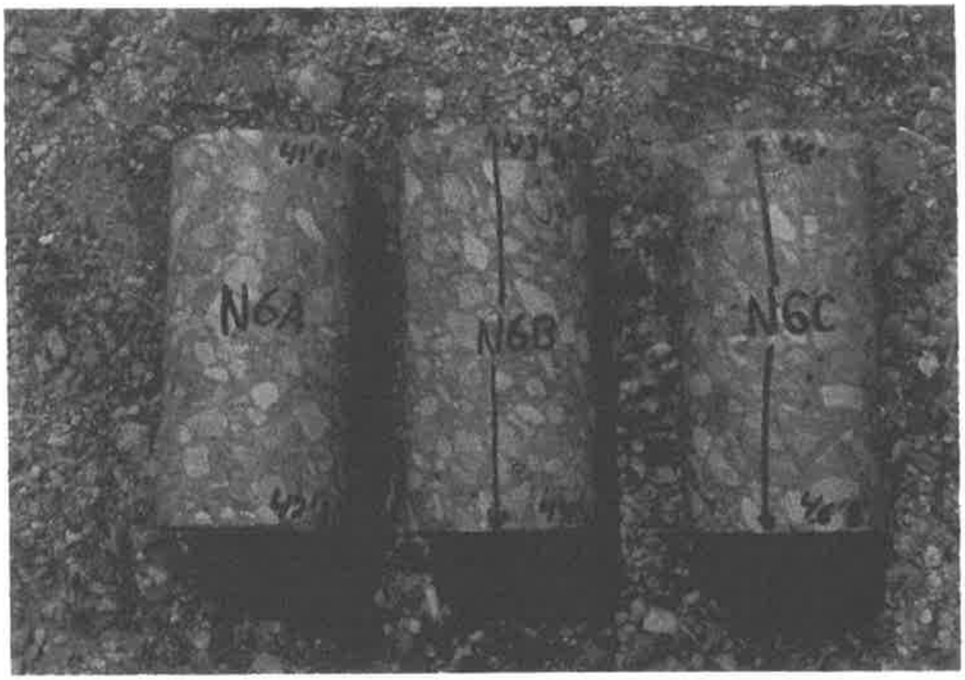


Photo 32 Core samples N6A, N6B and N6 taken from Lift #5 of the North Caisson. The lift was placed using Mix #1 by the central drop method. No segregation of aggregate was noted.

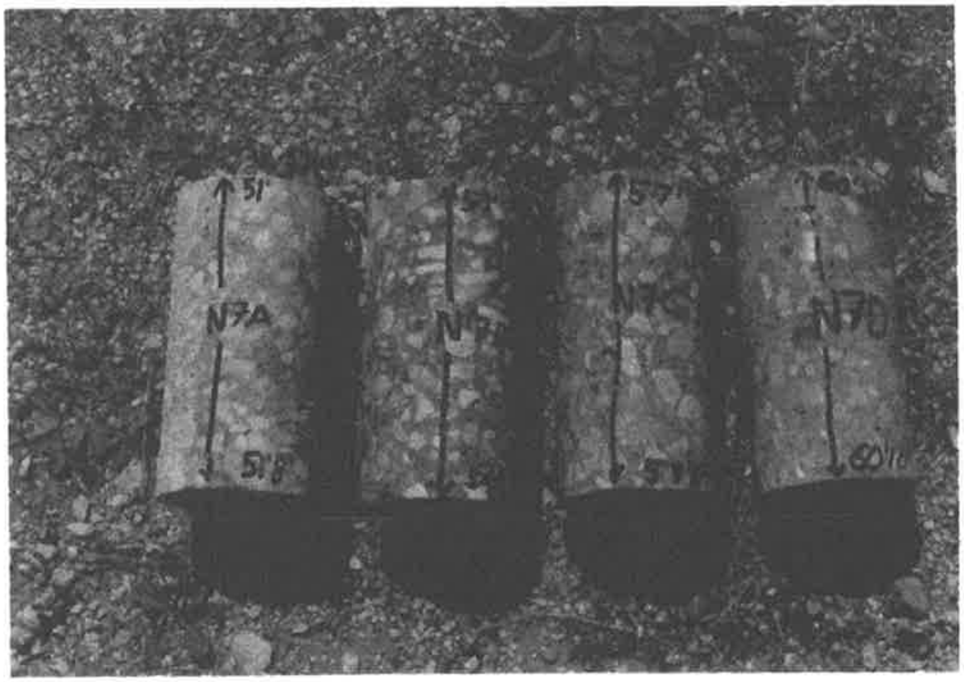
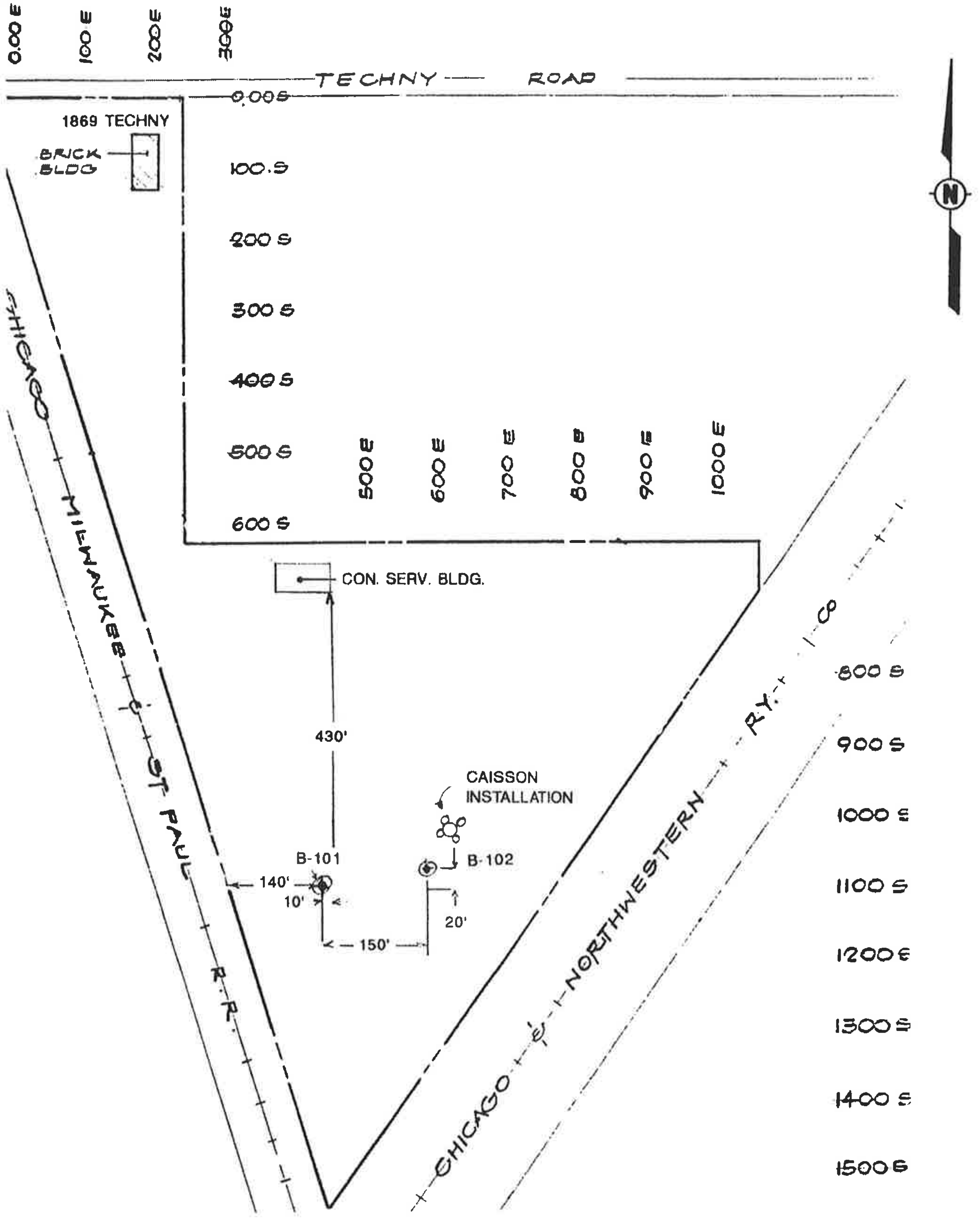


Photo 33 Core samples N7A, N7B, N7C and N7D from Lift #6 of the North Caisson. This lift was placed by the sloppy drop procedure with Mix #1. Some dark gray clay-filled voids can be seen in core N7D, however, no segregation of aggregate in the lift is apparent.

FIGURES



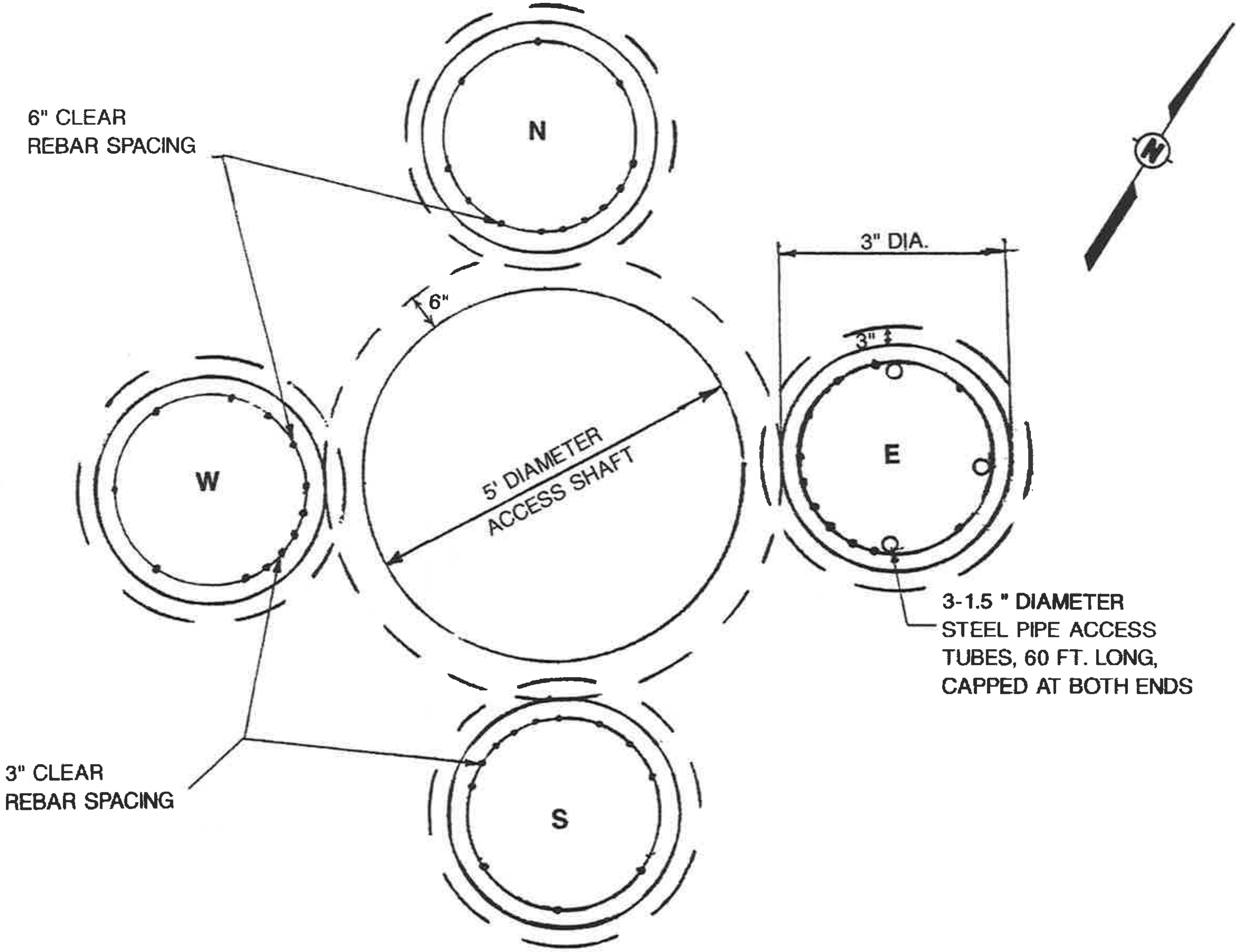
NOTE: DIMENSIONS AND SCALE ARE APPROXIMATE.

STS Consultants Ltd.
Consulting Engineers

PROJECT/CLIENT

LOCATION DIAGRAM
FREE FALL CONCRETE RESEARCH
STS CONSULTANTS LABORATORIES
NORTHBROOK, ILLINOIS

DRAWN BY	KKB	9-3-93
CHECKED BY		
APPROVED BY	TAK	9-3-93
SCALE 1"=200'±	FIGURE NO. 1	
STS DRAWING NO. 27618		



**RESEARCH ON THE EFFECTS OF
FREE FALL CONCRETE
IN DRILLED SHAFTS**

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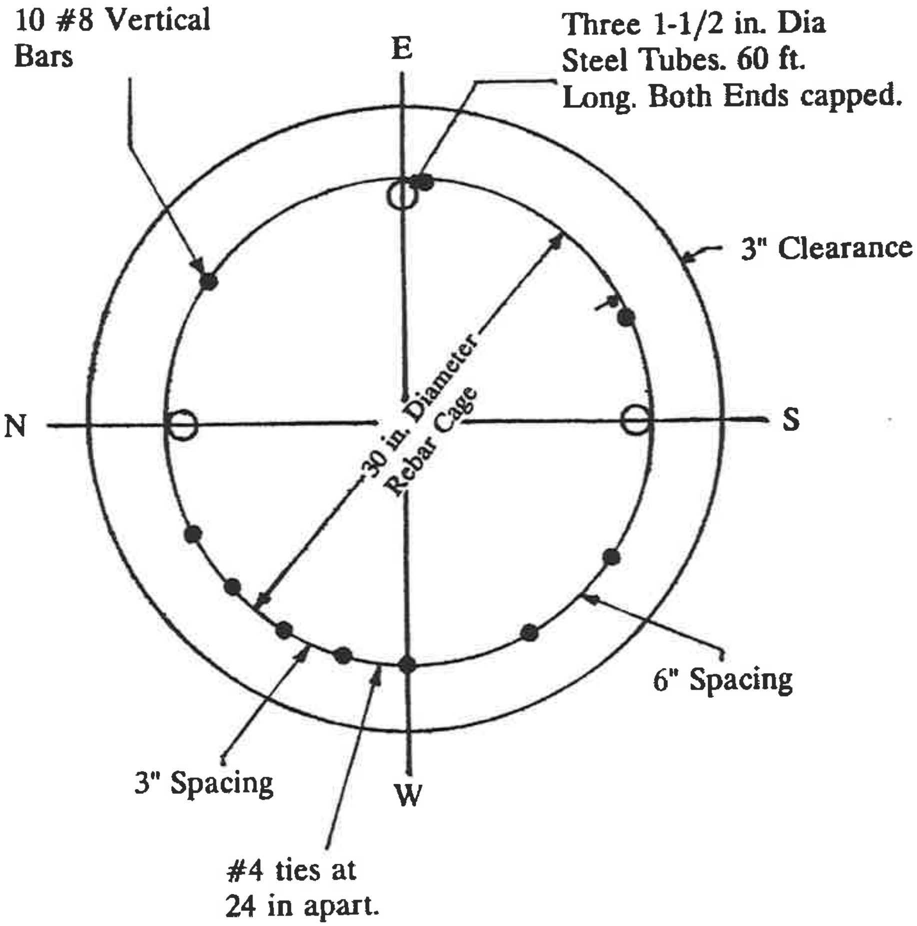
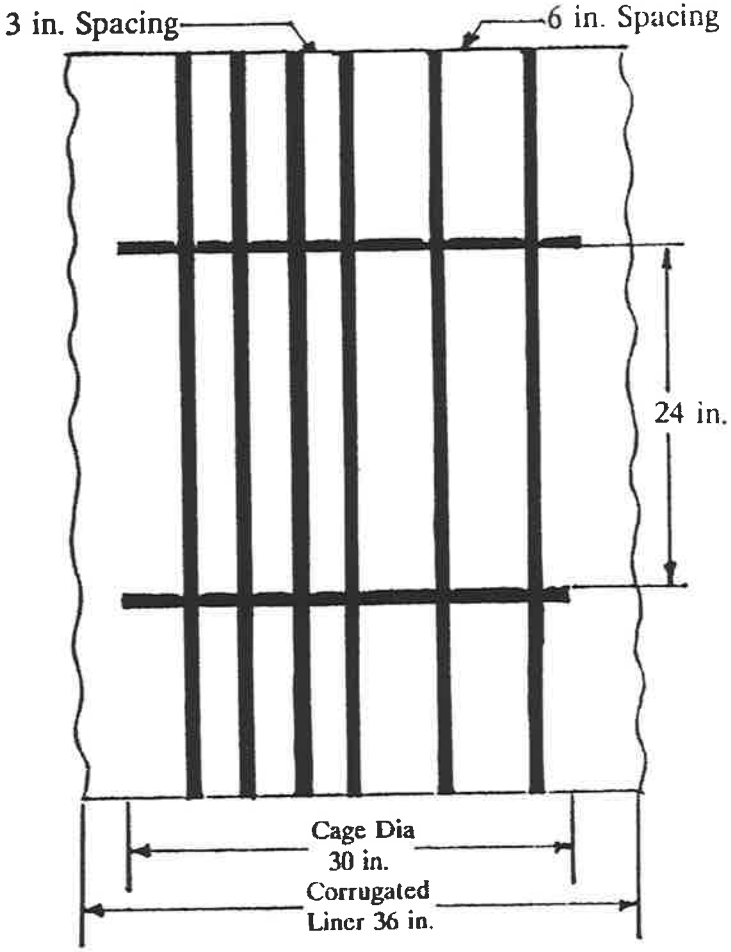
DRAWN BY	KKB	DATE	11-29-93
CHECKED BY		DATE	
APPROVED BY	TAK	DATE	11-29-93
CADFILE			

STS PROJECT NO. 27618
STS PROJECT FILE
SCALE NTS
SHEET NO. FIGURE 2

OVER HEAD VIEW



PROFILE VIEW



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RESEARCH ON FREE FALL CONCRETE REBAR CAGE

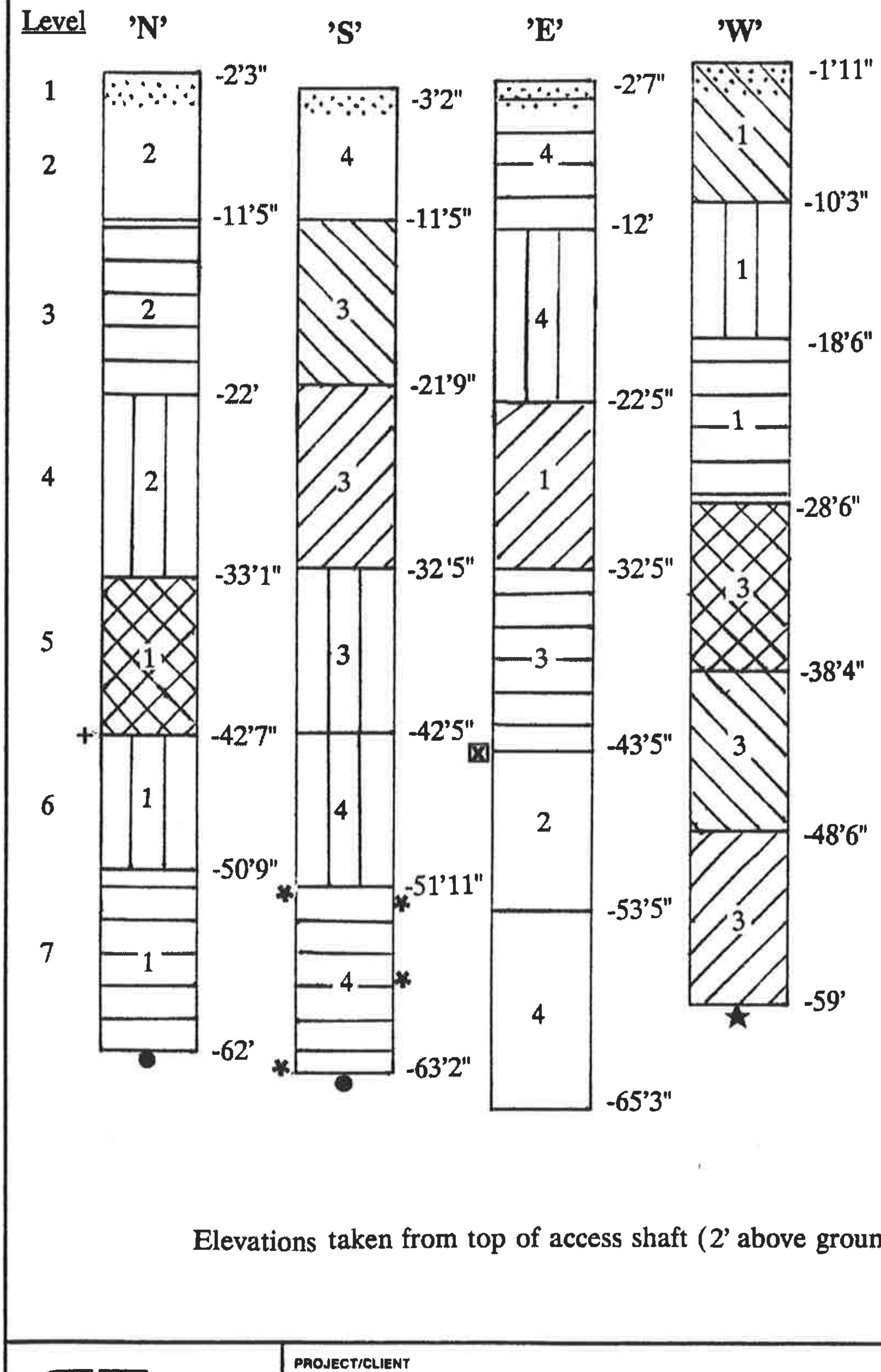
DRAWN BY	KKB	DATE	11-29-93
CHECKED BY		DATE	
APPROVED BY	TAK	DATE	11-29-93
CADFILE			

STS PROJECT NO. 27618

STS PROJECT FILE

SCALE NTS

SHEET NO. FIGURE 3



Mix No.	Slump	Max. Agg.
1	4-5	1-1/4"
2	7-8	1-1/4"
3	4-5	5/8"
4	7-8	5/8"

Central drop w/ plasticizer ▧

Sloppy drop w/ plasticizer ▨

Central drop no plasticizer ▥

Sloppy drop no plasticizer ▤

Tremie placement w/ plasticizer ▩

Tremie placement no plasticizer □

Vibrated concrete ░

Elevations taken from top of access shaft (2' above ground level)

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PROJECT/CLIENT

RESEARCH ON FREE FALL
CONCRETE
TEST CAISSONS
(As Built)

DRAWN BY	KBI	7/19/93
CHECKED BY	TAK	7/19/93
APPROVED BY	CNB	
SCALE NTS	FIGURE NO. FIGURE 4	
STS DRAWING NO.	27618	

NOTES

✱ In the south caisson from 50-60 feet, sloppy drop without plasticizer with mix No.4 was used. The slump test was unable to be taken before the contractor placed it. The slump turned out only to be 4.5 inches, so 15 gallons of water was added to raise the slump to 7 inches for the later lifts.

+ One gallon of water added to clean the hopper.

● Six inches of water in bottom of north and south caissons.

★ Bottom was able to be cleaned to 1.5 inches of water.

☒ Six inches of water on top of tremie placement.

Concrete

	Mix no.	Mix ID	Truck No.	Listed Slump	Actual Slump	Slump w/ Super P (WRDA-19)
North Caisson	#1	1231	1156	4-5"	4.5"	8.5" (1.5 gal)
	#2	1232	1176	7-8"	7" after 7 gal water added	----
South Caisson	#4	2995	601	7-8"	4.5"then after 15 gal water 7"	----
	#3	2994	901	4-5"	3" after 10 gal water added	7.5" (2.0 gal)
East Caisson	#4	2995	9101	7-8"	7"after 5 gal water added	----
	#2	1232	1178	7-8"	7.5"	----
	#3	2994	547	4-5"	5.5"after 14 gal	----
	#1	1231	1156	4-5"	----	8.25" (2.5 gal)
West Caisson	#3	2994	912	4-5"	----	7.5" (2.5 gal)
	#1	1231	1102	4-5"	5.5"	7" (1 gal)

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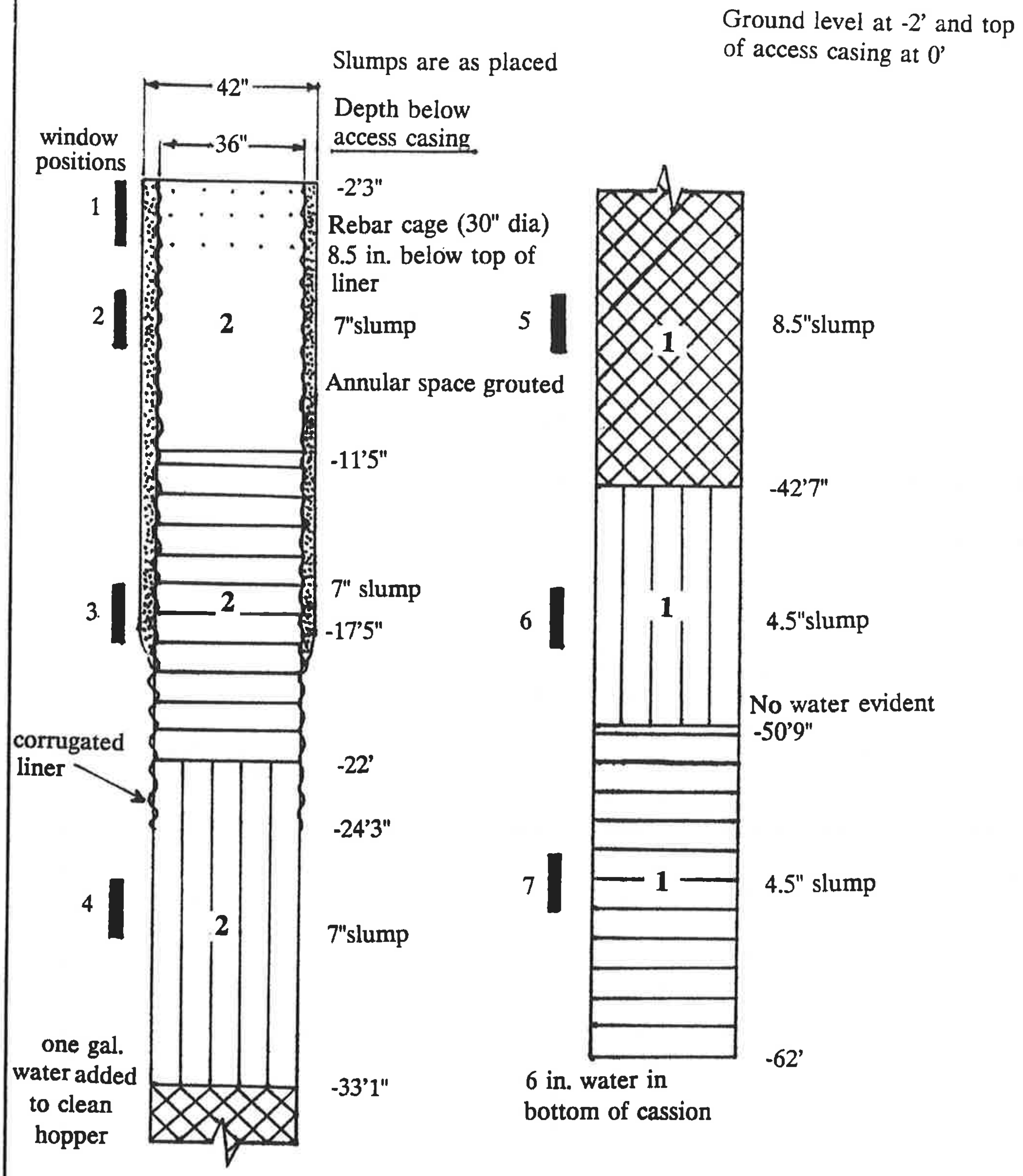
PROJECT/CLIENT

RESEARCH ON FREE FALL
CONCRETE
(Slump Summary)
"As Built"

DRAWN BY	KBI	7/19/93
CHECKED BY	TAK	7/19/93
APPROVED BY	CNB	
SCALE	FIGURE NO. 5	
STS DRAWING NO.		



Completed Tue. June 29, 1993

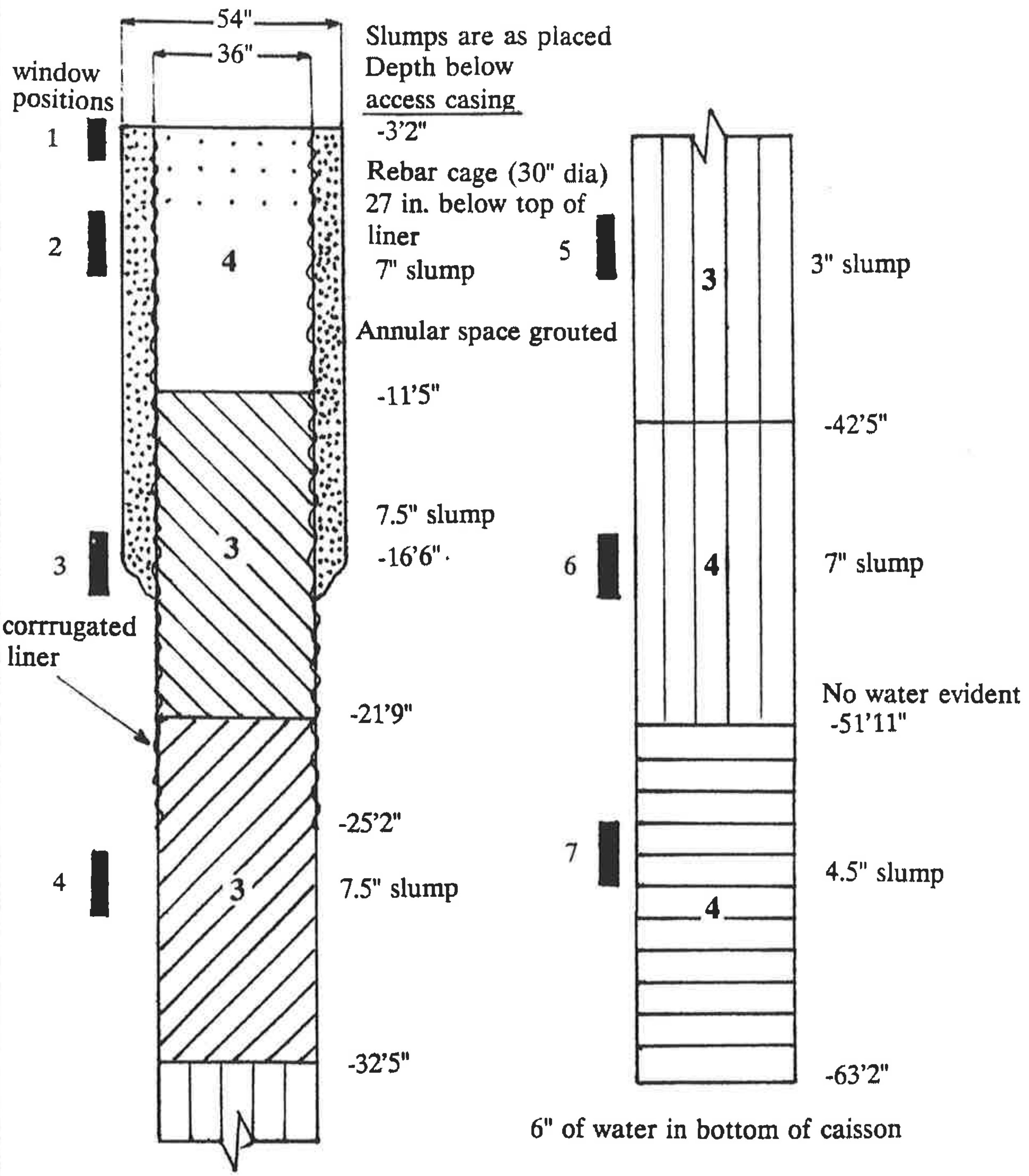
STS Consultants Ltd.
Consulting Engineers

PROJECT/CLIENT

RESEARCH ON FREE FALL
CONCRETE
NORTH CAISSON
(as built)

DRAWN BY	KBI	7/19/93
CHECKED BY	TAK	7/19/93
APPROVED BY	CNB	
SCALE NTS	FIGURE NO. 6	
STS DRAWING NO.		

Ground level at -2' and top
of access casing at 0'



6" of water in bottom of caisson

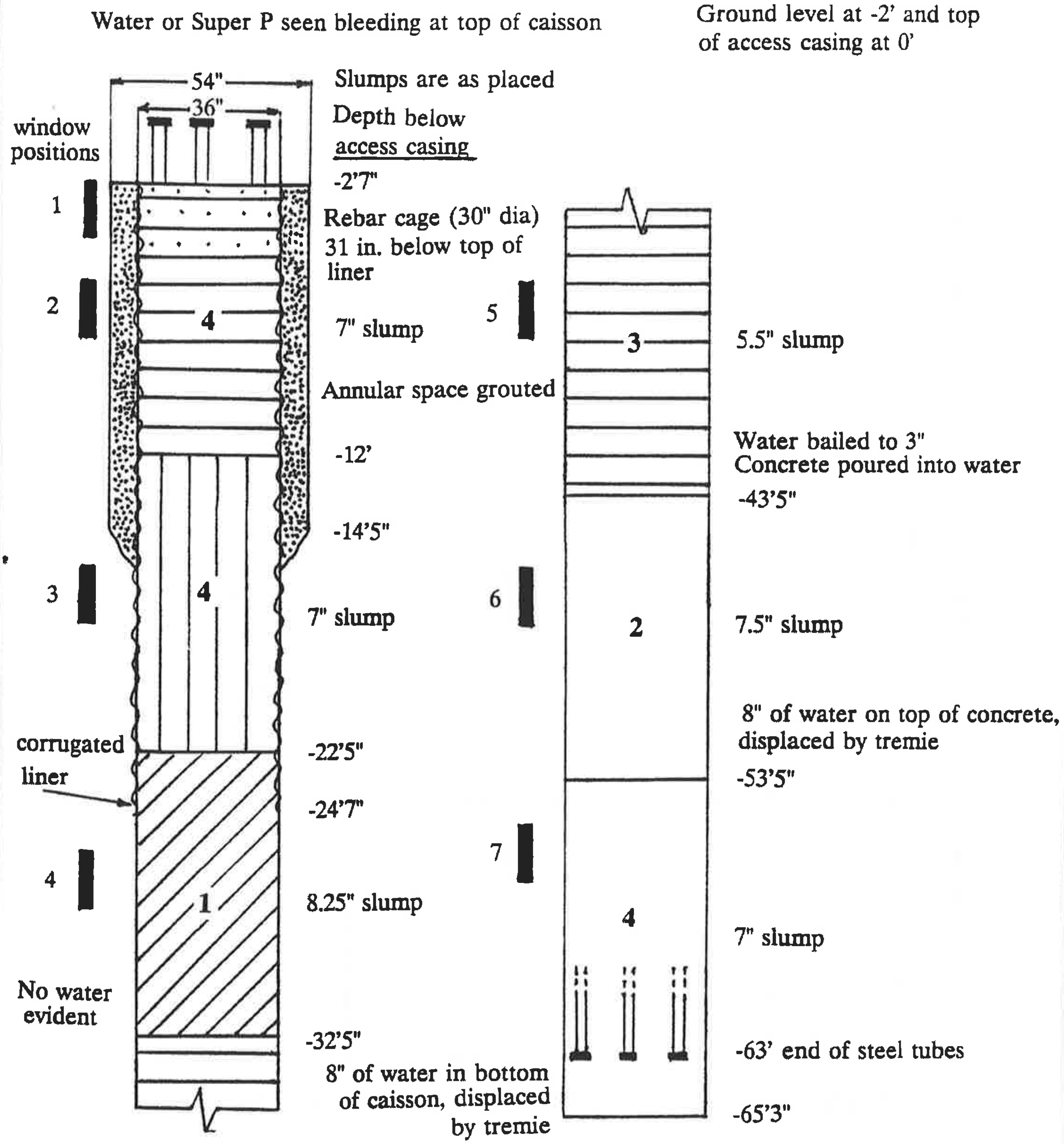
Completed Wed. June 30, 1993

STS Consultants Ltd.
Consulting Engineers

PROJECT/CLIENT

RESEARCH ON FREE FALL
CONCRETE
SOUTH CAISSON
"As Built"

DRAWN BY	KBI	7/19/93
CHECKED BY	TAK	7/19/93
APPROVED BY	CNB	
SCALE NTS	FIGURE NO. 7	
STS DRAWING NO.		



Steel tubes protrude 2' above top of caisson. Pipes are placed in the north, south, and east parts of the rebar cage, as shown in the specification.

Completed Thur. July 1, 1993

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PROJECT/CLIENT

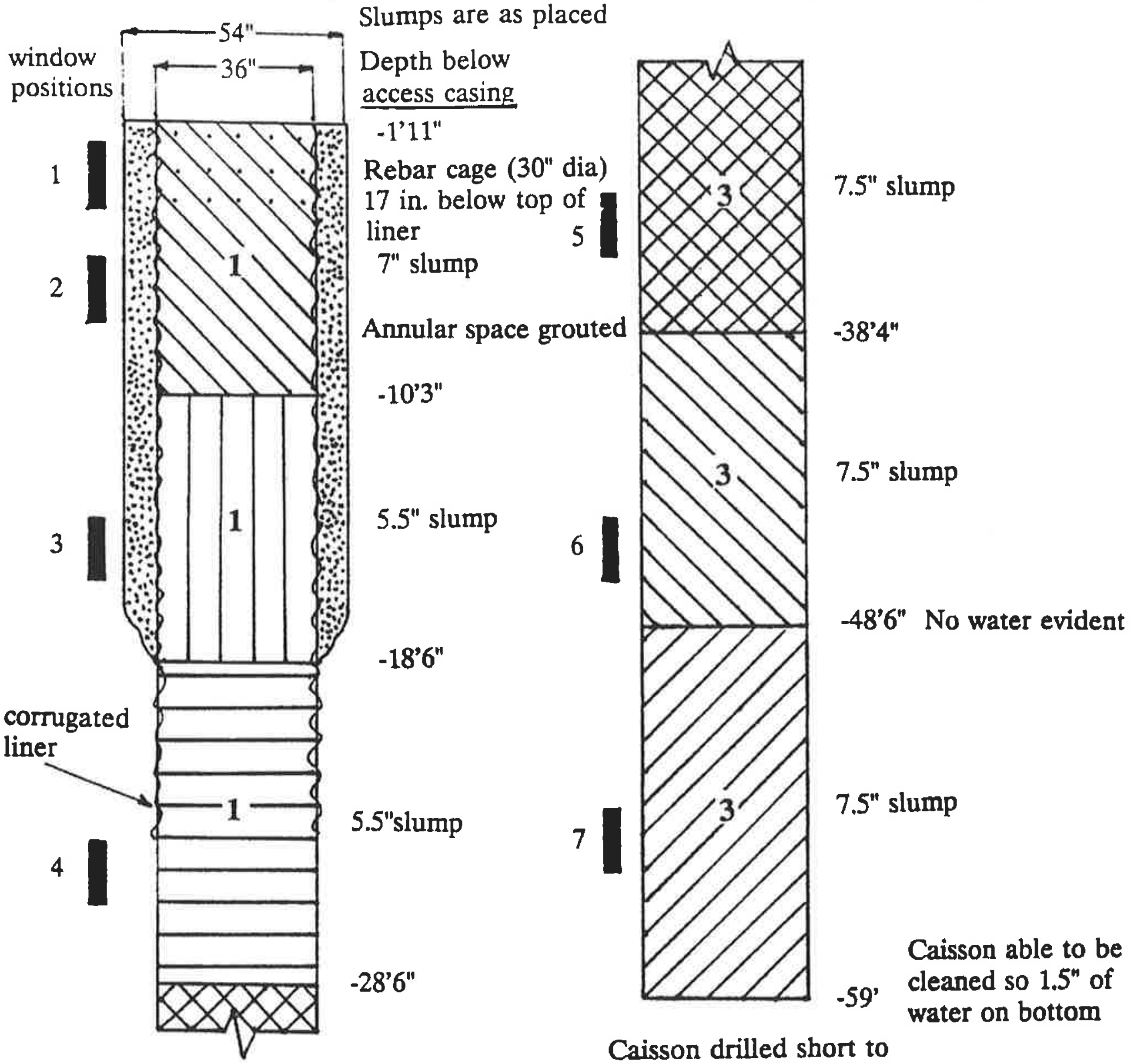
RESEARCH ON FREE FALL
CONCRETE
EAST CAISSON
"As Built"

DRAWN BY	KBI	7/19/93
CHECKED BY	TAK	7/19/93
APPROVED BY	CNB	
SCALE NTS	FIGURE NO. 8	
STS DRAWING NO.		

After setting for 1 day had plastic looking film on top

Ground level at -2' and top of access casing at 0'

Slumps are as placed



Caisson drilled short to avoid sand layer found in other shafts at approx. 59'

Windows for west caisson cut two feet higher (except for top two) because lift levels were altered due to shortened shaft

29" of rebar cage was removed from top

Completed Thur. July 1, 1993

STS Consultants Ltd.
Consulting Engineers

PROJECT/CLIENT

RESEARCH ON FREE FALL
CONCRETE
WEST CAISSON
"As Built"

DRAWN BY	KBI	7/19/93
CHECKED BY	TAK	7/19/93
APPROVED BY	CNB	
SCALE NTS	FIGURE NO. 9	
STS DRAWING NO.		

GENERAL NOTES

All caissons were grouted between temporary casing and permanent liners.

Steel access tubes in the East Caisson protrude 2 feet above ground level.

Wire in the rebar cage was cut as the cage was placed.

In the West Caisson, the rebar cage was shortened by 29 inches due to the shallower depth.

After 1 day of setting the top looked:
North caisson: normal
South caisson: mucky
East caisson: Small cracks on top (Super Plasticizer?)
West caisson: Plastic-like film on top

West side windows of the access shaft were cut 2 feet higher (except for top two windows) because the concrete lifts were placed higher.

Access shaft drilled to 59'10" below ground surface with a 60" auger. The 65' long casing was pounded to a depth of 63' to allow a 2' stickup. A 36" pilot was continued to 62'10".

STS Consultants Ltd.
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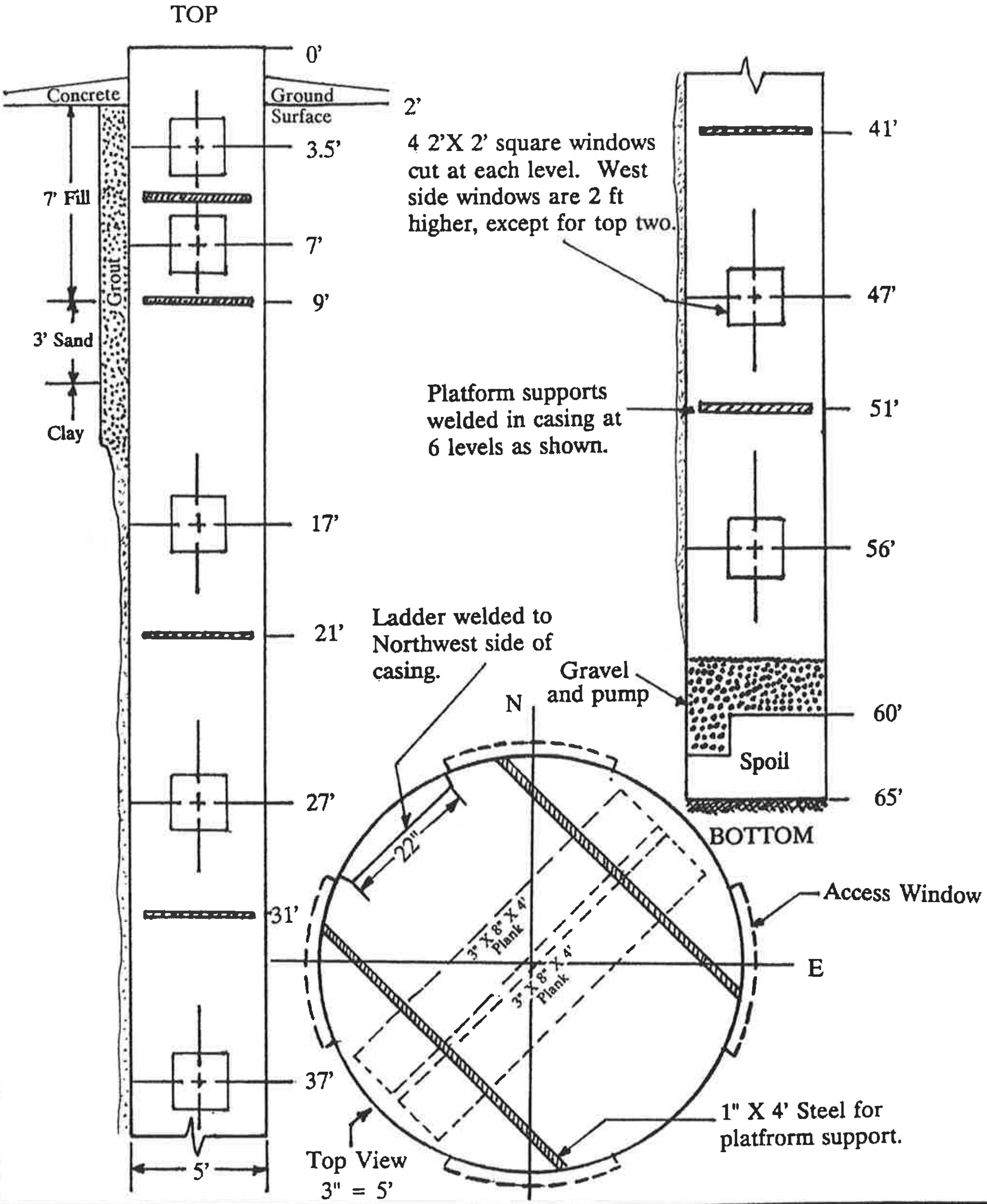
PROJECT/CLIENT

RESEARCH ON FREE FALL CONCRETE

"AS BUILT"

DRAWN BY	KKB	12-22-93
CHECKED BY	TAK	12-22-93
APPROVED BY	CNB	12-22-93
SCALE NTS	FIGURE NO. 10	
STS DRAWING NO. 27618		



4 2'X 2' square windows cut at each level. West side windows are 2 ft higher, except for top two.

Platform supports welded in casing at 6 levels as shown.

Ladder welded to Northwest side of casing.

Top View
3" = 5'

STS Consultants Ltd.
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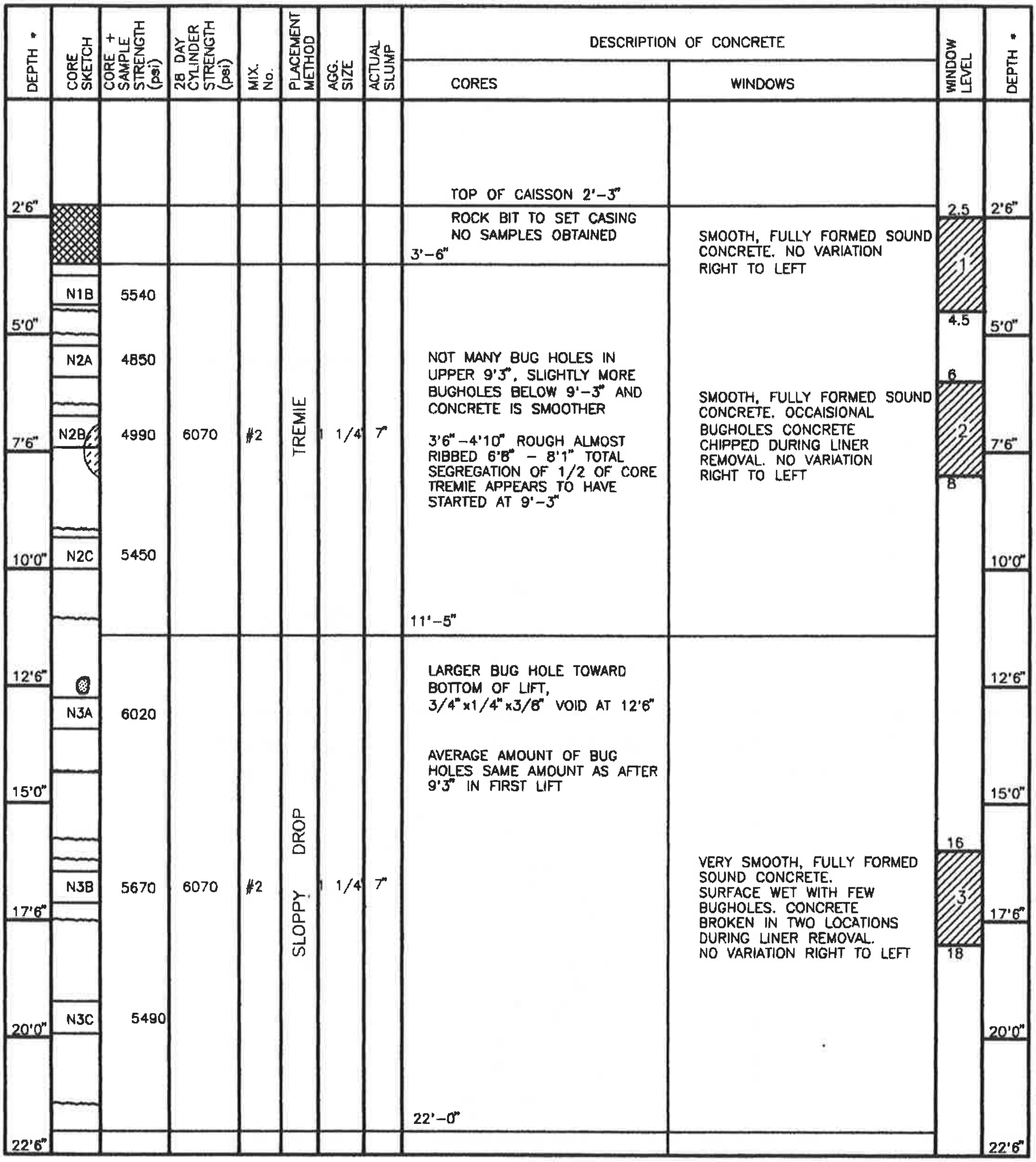
PROJECT/CLIENT

RESEARCH ON FREE FALL CONCRETE
ACCESS CASING

DRAWN BY	KBI	8/5/93
CHECKED BY		
APPROVED BY		
SCALE 1" = 5'	FIGURE NO. 11	
STS DRAWING NO.		



DEPTH *	CORE SKETCH	CORE + SAMPLE STRENGTH (psi)	28 DAY CYLINDER STRENGTH (psi)	MIX. No.	PLACEMENT METHOD	AGG. SIZE	ACTUAL SLUMP	DESCRIPTION OF CONCRETE: CORES	DESCRIPTION OF CONCRETE: WINDOWS	WINDOW LEVEL	DEPTH *
								TOP OF CAISSON 2'-3"			
2'6"								ROCK BIT TO SET CASING NO SAMPLES OBTAINED 3'-6"	SMOOTH, FULLY FORMED SOUND CONCRETE. NO VARIATION RIGHT TO LEFT	2.5 1	2'6"
	N1B	5540									
5'0"										4.5	5'0"
	N2A	4850								6	
7'6"	N2B	4990	6070	#2	TREMIE	1 1/4	7"	NOT MANY BUG HOLES IN UPPER 9'3", SLIGHTLY MORE BUGHOLES BELOW 9'-3" AND CONCRETE IS SMOOTHER 3'6"-4'10" ROUGH ALMOST RIBBED 6'8" - 8'1" TOTAL SEGREGATION OF 1/2 OF CORE TREMIE APPEARS TO HAVE STARTED AT 9'-3"	SMOOTH, FULLY FORMED SOUND CONCRETE. OCCAISIONAL BUGHOLES CONCRETE CHIPPED DURING LINER REMOVAL. NO VARIATION RIGHT TO LEFT	2 8	7'6"
10'0"	N2C	5450									10'0"
								11'-5"			
12'6"								LARGER BUG HOLE TOWARD BOTTOM OF LIFT, 3/4"x1/4"x3/8" VOID AT 12'6"			12'6"
	N3A	6020						AVERAGE AMOUNT OF BUG HOLES SAME AMOUNT AS AFTER 9'3" IN FIRST LIFT			
15'0"										16	15'0"
	N3B	5670	6070	#2	SLOPPY DROP	1 1/4	7"		VERY SMOOTH, FULLY FORMED SOUND CONCRETE. SURFACE WET WITH FEW BUGHOLES. CONCRETE BROKEN IN TWO LOCATIONS DURING LINER REMOVAL. NO VARIATION RIGHT TO LEFT	3	
17'6"										18	17'6"
20'0"	N3C	5490									20'0"
								22'-0"			
22'6"											22'6"

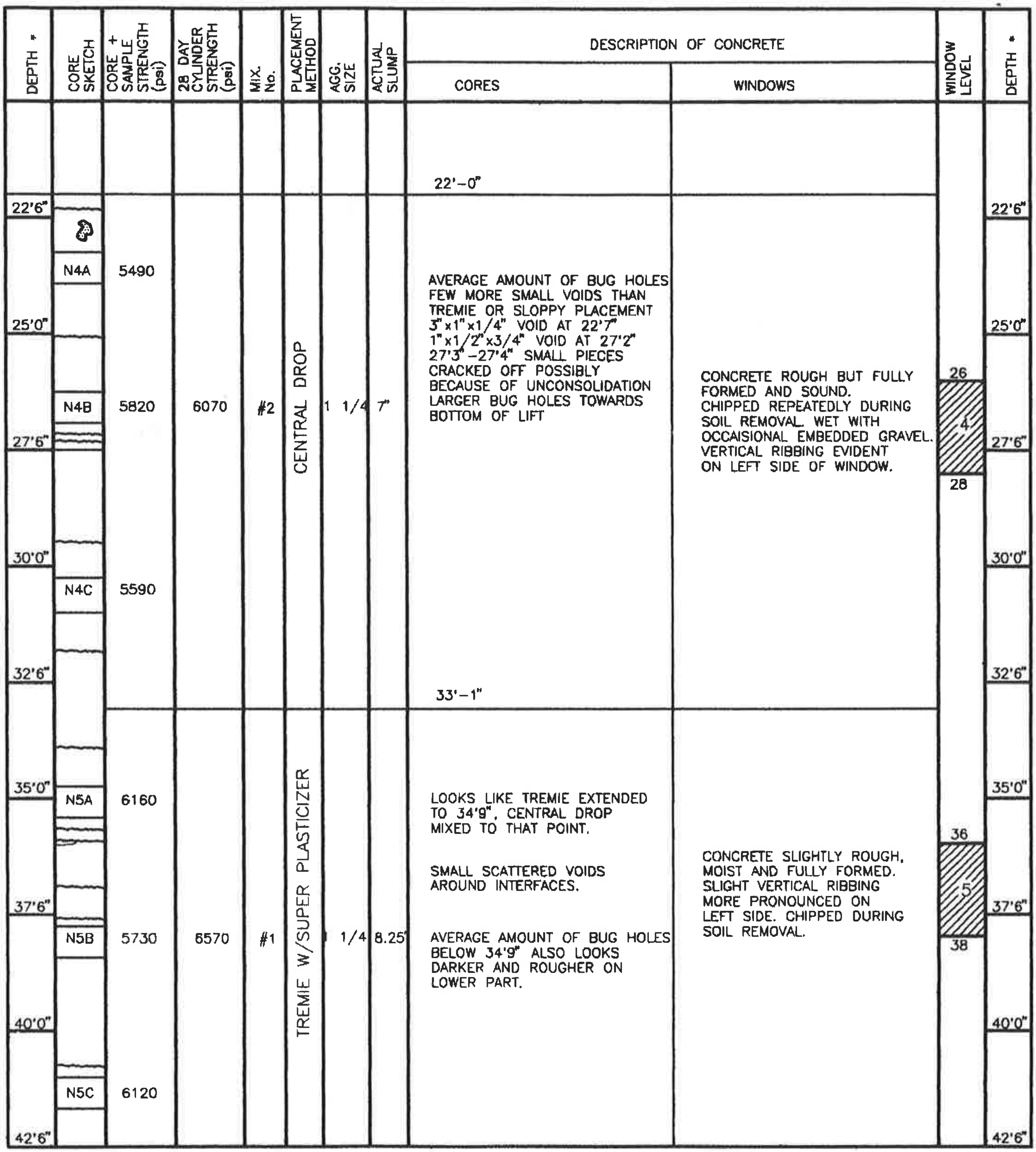
* BELOW TOP OF ACCESS CASING

+ f'c @ 36 DAYS CORRECTED FOR DISTURBANCE

NORTH CAISSON (LIFT 1 AND 2)

SCALE: 1"=3'

FIGURE 12



DEPTH *	CORE SKETCH	CORE + SAMPLE STRENGTH (psi)	28 DAY CYLINDER STRENGTH (psi)	MIX. No.	PLACEMENT METHOD	AGG. SIZE	ACTUAL SLUMP	DESCRIPTION OF CONCRETE: CORES	DESCRIPTION OF CONCRETE: WINDOWS	WINDOW LEVEL	DEPTH *
								22'-0"			
22'6" 25'0" 27'6" 30'0" 32'6"	N4A N4B N4C	5490 5820 5590	6070	#2	CENTRAL DROP	1 1/4	7"	AVERAGE AMOUNT OF BUG HOLES FEW MORE SMALL VOIDS THAN TREMIE OR SLOPPY PLACEMENT 3"x1"x1/4" VOID AT 22'7" 1"x1/2"x3/4" VOID AT 27'2" 27'3"-27'4" SMALL PIECES CRACKED OFF POSSIBLY BECAUSE OF UNCONSOLIDATION LARGER BUG HOLES TOWARDS BOTTOM OF LIFT	CONCRETE ROUGH BUT FULLY FORMED AND SOUND. CHIPPED REPEATEDLY DURING SOIL REMOVAL. WET WITH OCCAISIONAL EMBEDDED GRAVEL. VERTICAL RIBBING EVIDENT ON LEFT SIDE OF WINDOW.	26 4 28	22'6" 25'0" 27'6" 30'0" 32'6"
								33'-1"			
35'0" 37'6" 40'0" 42'6"	N5A N5B N5C	6160 5730 6120	6570	#1	TREMIE W/SUPER PLASTICIZER	1 1/4	8.25	LOOKS LIKE TREMIE EXTENDED TO 34'9", CENTRAL DROP MIXED TO THAT POINT. SMALL SCATTERED VOIDS AROUND INTERFACES. AVERAGE AMOUNT OF BUG HOLES BELOW 34'9" ALSO LOOKS DARKER AND ROUGHER ON LOWER PART.	CONCRETE SLIGHTLY ROUGH, MOIST AND FULLY FORMED. SLIGHT VERTICAL RIBBING MORE PRONOUNCED ON LEFT SIDE. CHIPPED DURING SOIL REMOVAL.	36 5 38	35'0" 37'6" 40'0" 42'6"

* BELOW TOP OF ACCESS CASING

+ f'c @ 36 DAYS CORRECTED FOR DISTURBANCE

NORTH CAISSON (LIFT 3 AND 4)

SCALE: 1"=3'

FIGURE 12 (CONT.)

DEPTH *	CORE SKETCH	CORE + SAMPLE STRENGTH (psi)	28 DAY CYLINDER STRENGTH (psi)	MIX. No.	PLACEMENT METHOD	AGG. SIZE	ACTUAL SLUMP	DESCRIPTION OF CONCRETE		WINDOW LEVEL	DEPTH *
								CORES	WINDOWS		
42'6"								42'-7"			42'6"
45'0" 47'6" 50'0"	N6A N6B N6C	7260 6680 7240	6570	#1	CENTRAL DROP	1 1/4	4.5"	DARKER LOOKING CONCRETE ABOUT 43'3" AVERAGE AMOUNT OF BUG HOLES FEW SMALL VOIDS SCATTERED AROUND INTERFACE (50'-50'6") 50'-9"	CONCRETE ROUGH AND WET BUT FULLY FORMED . RUST SPOT NOTED AT CENTER OF WINDOW DUE TO 1/2" REBAR POKING THROUGH SURFACE. CONCRETE CHIPPED DURING SOIL REMOVAL. NO VARIATION RIGHT TO LEFT AND NO VERTICAL RIBBING.	46 6 48	45'0" 47'6" 50'0"
52'6" 55'0" 57'6" 60'0" 62'6" 63'6"	N7A N7B N7C N7D	6780 7020 6400 4490	6570	#1	SLOPPY DROP	1/4	4.5"	BELOW AVERAGE AMOUNT OF BUG HOLES OCCAISSIONAL SMALL VOIDS. FROM 56'11" LARGER CLAY VOIDS NOTICED. 2 1/4"x1"x1/2" CLAY VOID AT 59' 4"x2"x1 1/2" CLAY VOID AT 60'9" 3"x3"x2" CLAY VOID AT 63' SMALL AMOUNT OF CLAY IN CORE N7D BOTTOM OF CAISSON	VERY ROUGH SURFACE, BUT FULLY FORMED. SURFACE CHIPPED BY SOIL REMOVAL. NO VARIATION NOTED RIGHT TO LEFT.	55 7 57	52'6" 55'0" 57'6" 60'0" 62'6" 63'6"

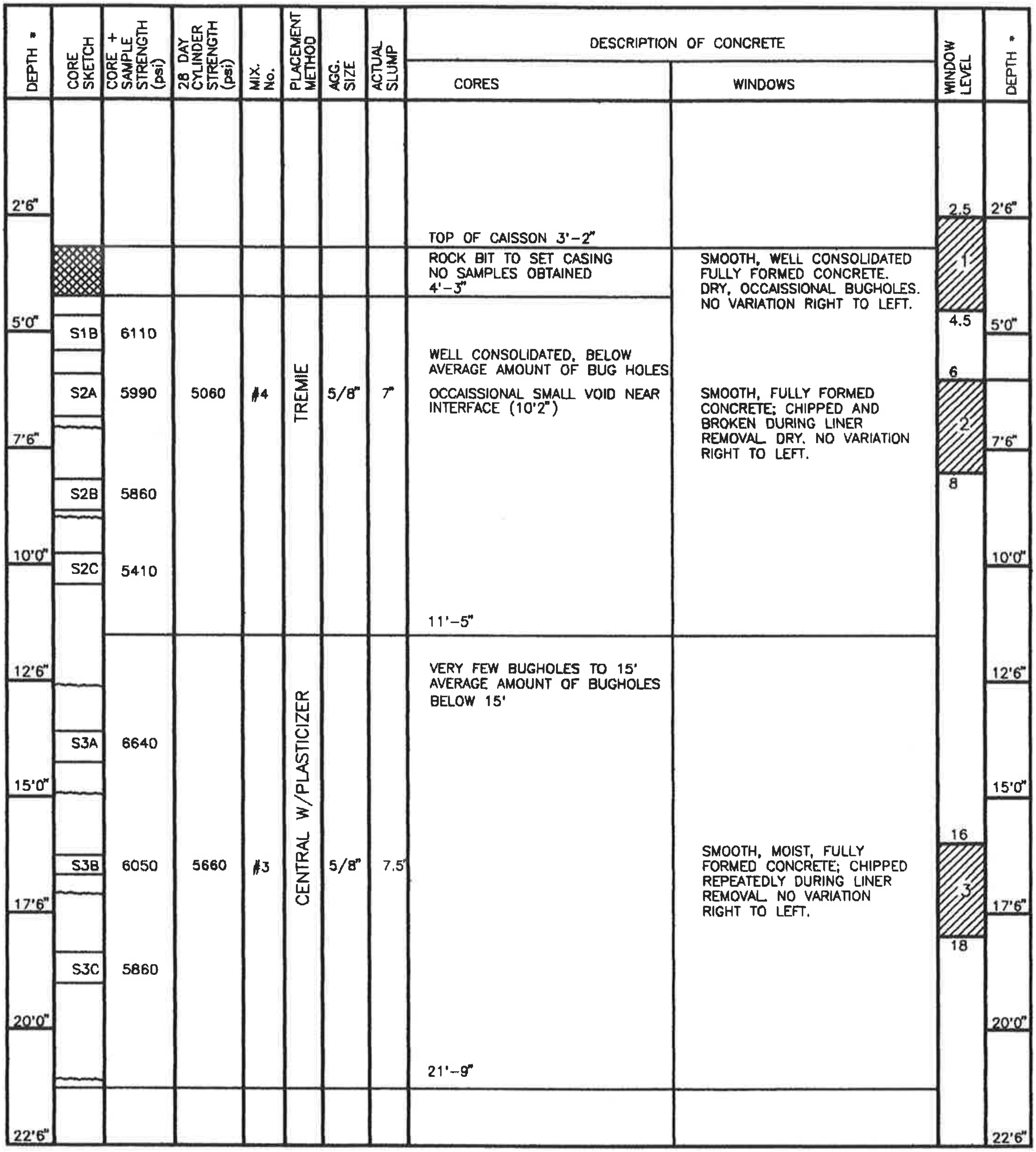
* BELOW TOP OF ACCESS CASING

\+ f'c @ 36 DAYS CORRECTED FOR DISTURBANCE

NORTH CAISSON (LIFT 5 AND 6)

SCALE: 1"=3'

FIGURE 12 (CONT.)



DEPTH *	CORE SKETCH	CORE + SAMPLE STRENGTH (psi)	28 DAY CYLINDER STRENGTH (psi)	MIX. No.	PLACEMENT METHOD	AGG. SIZE	ACTUAL SLUMP	DESCRIPTION OF CONCRETE: CORES	DESCRIPTION OF CONCRETE: WINDOWS	WINDOW LEVEL	DEPTH *
2'6"										2.5	2'6"
								TOP OF CAISSON 3'-2"			
	▨							ROCK BIT TO SET CASING NO SAMPLES OBTAINED 4'-3"	SMOOTH, WELL CONSOLIDATED FULLY FORMED CONCRETE. DRY, OCCAISSIONAL BUGHOLES. NO VARIATION RIGHT TO LEFT.	1	
5'0"	S1B	6110								4.5	5'0"
								WELL CONSOLIDATED, BELOW AVERAGE AMOUNT OF BUG HOLES		6	
	S2A	5990	5060	#4	TREMIE	5/8"	7"	OCCAISSIONAL SMALL VOID NEAR INTERFACE (10'2")	SMOOTH, FULLY FORMED CONCRETE; CHIPPED AND BROKEN DURING LINER REMOVAL. DRY. NO VARIATION RIGHT TO LEFT.	2	
7'6"											7'6"
										8	
	S2B	5860									
10'0"	S2C	5410									10'0"
								11'-5"			
12'6"								VERY FEW BUGHOLES TO 15' AVERAGE AMOUNT OF BUGHOLES BELOW 15'			12'6"
	S3A	6640									
15'0"											15'0"
										16	
	S3B	6050	5660	#3	CENTRAL W/PLASTICIZER	5/8"	7.5"		SMOOTH, MOIST, FULLY FORMED CONCRETE; CHIPPED REPEATEDLY DURING LINER REMOVAL. NO VARIATION RIGHT TO LEFT.	3	
17'6"											17'6"
										18	
	S3C	5860									
20'0"											20'0"
								21'-9"			
22'6"											22'6"

* BELOW TOP OF ACCESS CASING

+ f'c @ 35 DAYS CORRECTED FOR DISTURBANCE

SOUTH CAISSON (LIFT 1 AND 2)

SCALE: 1"=3'

FIGURE 13

DEPTH *	CORE SKETCH	CORE + SAMPLE STRENGTH (psi)	28 DAY CYLINDER STRENGTH (psi)	MIX. No.	PLACEMENT METHOD	AGG. SIZE	ACTUAL SLUMP	DESCRIPTION OF CONCRETE: CORES	DESCRIPTION OF CONCRETE: WINDOWS	WINDOW LEVEL	DEPTH *
								21'-9"			
22'6"											22'6"
	S4A	6470						FEW SMALL VOIDS AROUND TOP INTERFACE AVERAGE AMOUNT OF BUGHOLES THROUGH THE WHOLE LIFT.			
25'0"											25'0"
										26	
	S4B	6270	5660	#3	SLOPPY W/PLASTICIZER	5/8"	7.5"		ROUGH, BUT FULLY FORMED CONCRETE. OCCAISIONAL SMALL GRAVEL EMBEDDED IN SURFACE. CONCRETE VERTICALLY RIBBED AND SLIGHTLY ROUGHER ON LEFT SIDE. CONCRETE CHIPPED BY SOIL REMOVAL.	▨ 4	
27'6"											27'6"
										28	
30'0"											30'0"
	S4C	6120						FROM 27'-32'5" VERY ROUGH, RIBBED AND BROKEN.			
								32'-5"			
32'6"											32'6"
	S5A	6480						CONTINUED ROUGH RIBBED AND BROKEN UNTIL 34'11". AVERAGE AMOUNT OF BUGHOLES THROUGH THE WHOLE LIFT.			
35'0"											35'0"
										36	
									ROUGH, BUT FULLY FORMED CONCRETE. SURFACE WET AND CHIPPED . SMALL SHALE PARTICLES EMBEDDED IN SURFACE. VERTICAL RIBBING EVIDENT ON LEFT AND RIGHT SIDE. LEFT SLIGHTLY ROUGHER.	▨ 5	
37'6"											37'6"
	S5B	7050	5660	#3	CENTRAL	5/8"	3"				
										38	
40'0"											40'0"
	S5C	6920									
42'6"											

* BELOW TOP OF ACCESS CASING

+ f'c @ 35 DAYS CORRECTED FOR DISTURBANCE

SOUTH CAISSON (LIFT 3 AND 4)

SCALE: 1"=3'

FIGURE 13 (CONT.)

STS

DEPTH *	CORE SKETCH	CORE + SAMPLE STRENGTH (psi)	28 DAY CYLINDER STRENGTH (psi)	MIX. No.	PLACEMENT METHOD	AGG. SIZE	ACTUAL SLUMP	DESCRIPTION OF CONCRETE		WINDOW LEVEL	DEPTH *
								CORES	WINDOWS		
42'6"								42'-5"			42'6"
								FROM TOP INTERFACE TO 44' THERE IS AN AVERAGE AMOUNT OF BUG HOLES, AFTER THAT BELOW AVERAGE AMOUNT.			
45'0"	S6A	5860						46' SOMEWHAT ROUGH AND RIBBED.			45'0"
									CONCRETE ROUGH AND CHIPPED BY SOIL REMOVAL BUT FULLY FORMED. SLIGHT VERTICAL RIBBING, NO LATERAL VARIATION.	46 6 48	
47'6"	S6B ● ●	5330	5060	#4	CENTRAL DROP	5/8"	7"	A FEW SMALL SCATTERED VOIDS AROUND 48'8" REBAR (2.5"x3/8") AT 48'6".			47'6"
50'0"	S6C	5380						A FEW SMALL CLAY VOIDS AT 50'			50'0"
								51'-11"			
52'6"											52'6"
	S7A	7380						GOOD CONSOLIDATION VERY FEW BUGHOLES TO 56'			
55'0"									CAISSON SHAFT ENLARGED AND DEFORMED DUE TO GRAVEL POCKETS. CONCRETE VERY ROUGH AND WET. NO LATERAL VARIATION APPARENT.	55 7 57	55'0"
57'6"	S7B	5180	5060	#4	SLOPPY DROP	5/8"	4.5"	ROCK BIT 55'-6" 2" CORE OBTAINED 56'-6" TO 63'-6" BROKEN AND FRACTURED			57'6"
60'0"	S7C	4740						OCCAISSIONAL OPEN AND CLAY FILLED VOIDS 58'-0" TO 63'-6"			60'0"
62'6"	S7D	6400						BOTTOM OF CAISSON 63'-6"			62'6"

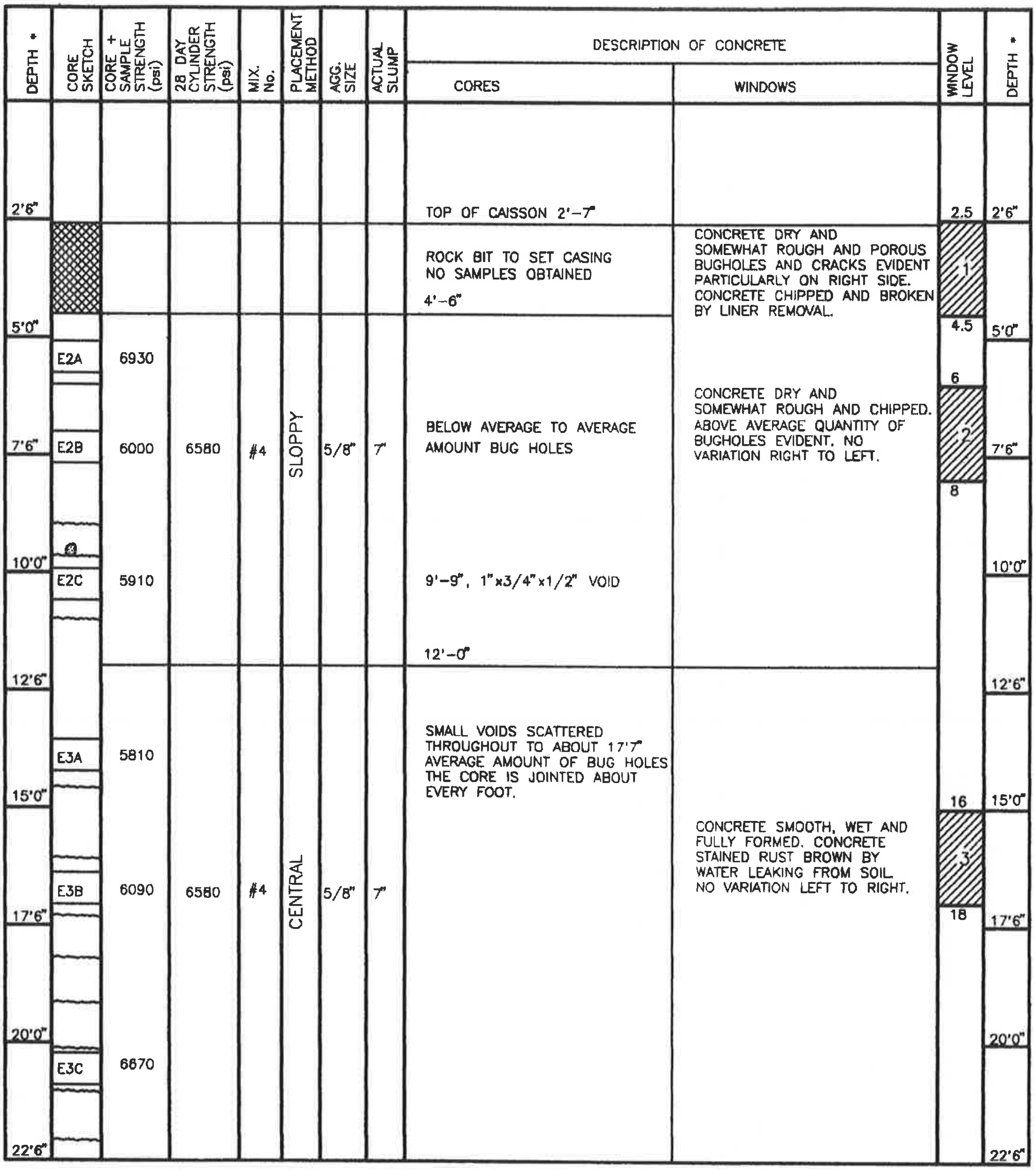
* BELOW TOP OF ACCESS CASING

\+ f'c @ 35 DAYS CORRECTED FOR DISTURBANCE

SOUTH CAISSON (LIFT 5 AND 6)

SCALE: 1"=3'

FIGURE 13 (CONT.)



DEPTH *	CORE SKETCH	CORE + SAMPLE STRENGTH (psi)	28 DAY CYLINDER STRENGTH (psi)	MIX. No.	PLACEMENT METHOD	AGG. SIZE	ACTUAL SLUMP	DESCRIPTION OF CONCRETE		WINDOW LEVEL	DEPTH *
								CORES	WINDOWS		
2'6"								TOP OF CAISSON 2'-7"		2.5	2'6"
	▨							ROCK BIT TO SET CASING NO SAMPLES OBTAINED 4'-6"	CONCRETE DRY AND SOMEWHAT ROUGH AND POROUS BUGHOLES AND CRACKS EVIDENT PARTICULARLY ON RIGHT SIDE. CONCRETE CHIPPED AND BROKEN BY LINER REMOVAL.	1	
5'0"										4.5	5'0"
	E2A	6930								6	
7'6"	E2B	6000	6580	#4	SLOPPY	5/8"	7"	BELOW AVERAGE TO AVERAGE AMOUNT BUG HOLES	CONCRETE DRY AND SOMEWHAT ROUGH AND CHIPPED. ABOVE AVERAGE QUANTITY OF BUGHOLES EVIDENT. NO VARIATION RIGHT TO LEFT.	2	7'6"
										8	
10'0"	E2C	5910						9'-9", 1"x3/4"x1/2" VOID 12'-0"			10'0"
12'6"											12'6"
	E3A	5810						SMALL VOIDS SCATTERED THROUGHOUT TO ABOUT 17'7" AVERAGE AMOUNT OF BUG HOLES THE CORE IS JOINTED ABOUT EVERY FOOT.			
15'0"										16	15'0"
									CONCRETE SMOOTH, WET AND FULLY FORMED. CONCRETE STAINED RUST BROWN BY WATER LEAKING FROM SOIL. NO VARIATION LEFT TO RIGHT.	3	
17'6"	E3B	6090	6580	#4	CENTRAL	5/8"	7"			18	17'6"
20'0"											20'0"
	E3C	6670									
22'6"											22'6"

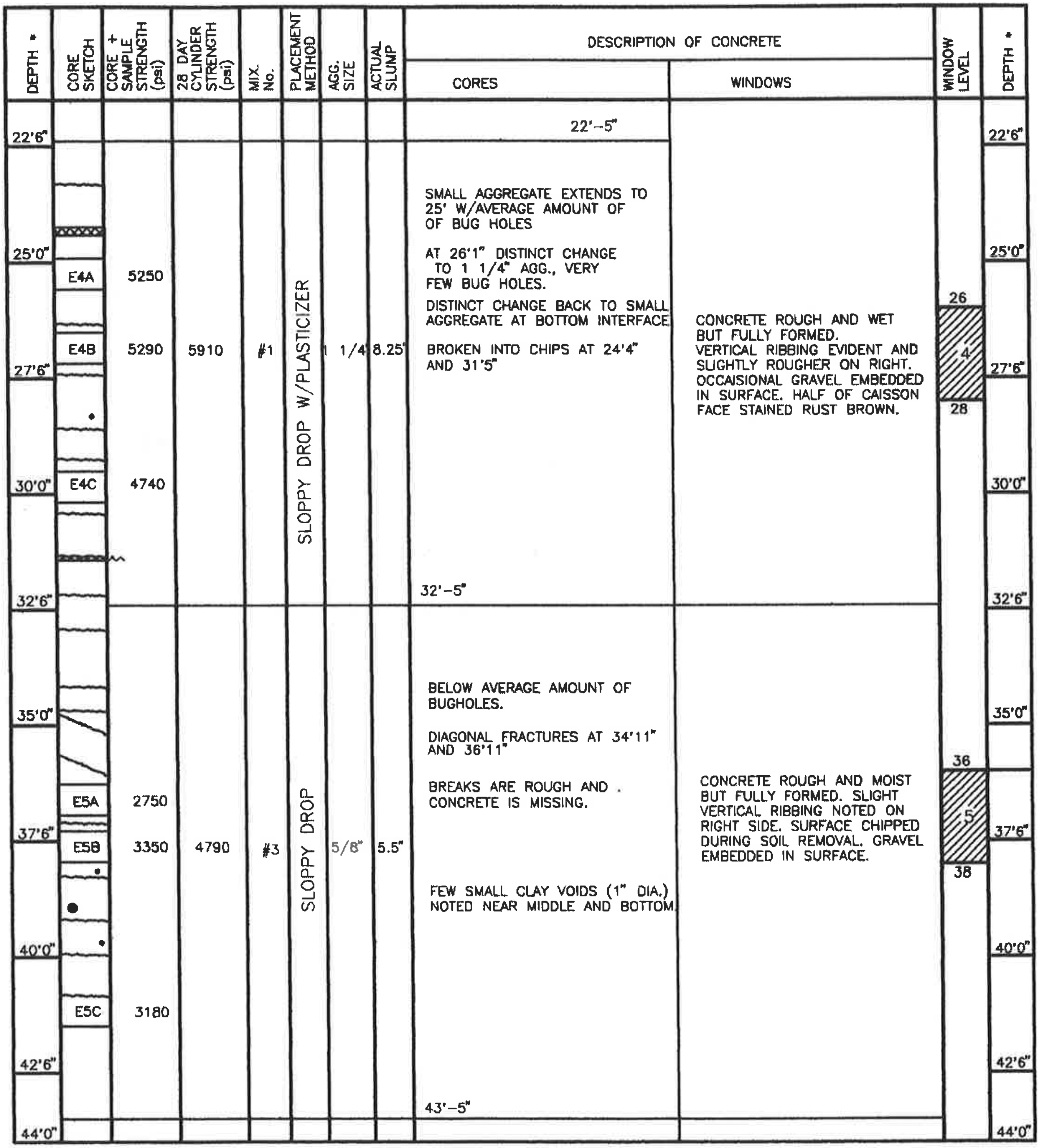
* BELOW TOP OF ACCESS CASING

\+ f'c @ 40 DAYS CORRECTED FOR DISTURBANCE

EAST CAISSON (LIFT 1 AND 2)

SCALE: 1"=3'

FIGURE 14



DEPTH *	CORE SKETCH	CORE + SAMPLE STRENGTH (psi)	28 DAY CYLINDER STRENGTH (psi)	MIX. No.	PLACEMENT METHOD	AGG. SIZE	ACTUAL SLUMP	DESCRIPTION OF CONCRETE CORES	DESCRIPTION OF CONCRETE WINDOWS	WINDOW LEVEL	DEPTH *
22'6" 25'0" 27'6" 30'0" 32'6"	E4A E4B E4C	5250 5290 4740	5910	#1	SLOPPY DROP W/PLASTICIZER	1 1/4	8.25"	22'-5" SMALL AGGREGATE EXTENDS TO 25' W/AVERAGE AMOUNT OF OF BUG HOLES AT 26'1" DISTINCT CHANGE TO 1 1/4" AGG., VERY FEW BUG HOLES. DISTINCT CHANGE BACK TO SMALL AGGREGATE AT BOTTOM INTERFACE BROKEN INTO CHIPS AT 24'4" AND 31'5" 32'-5"	CONCRETE ROUGH AND WET BUT FULLY FORMED. VERTICAL RIBBING EVIDENT AND SLIGHTLY ROUGHER ON RIGHT. OCCASIONAL GRAVEL EMBEDDED IN SURFACE. HALF OF CAISSON FACE STAINED RUST BROWN.	26 4 28	22'6" 25'0" 27'6" 30'0" 32'6"
35'0" 37'6" 40'0" 42'6" 44'0"	E5A E5B E5C	2750 3350 3180	4790	#3	SLOPPY DROP	5/8"	5.5"	BELOW AVERAGE AMOUNT OF BUGHOLES. DIAGONAL FRACTURES AT 34'11" AND 36'11" BREAKS ARE ROUGH AND CONCRETE IS MISSING. FEW SMALL CLAY VOIDS (1" DIA.) NOTED NEAR MIDDLE AND BOTTOM 43'-5"	CONCRETE ROUGH AND MOIST BUT FULLY FORMED. SLIGHT VERTICAL RIBBING NOTED ON RIGHT SIDE. SURFACE CHIPPED DURING SOIL REMOVAL. GRAVEL EMBEDDED IN SURFACE.	36 5 38	35'0" 37'6" 40'0" 42'6" 44'0"

* BELOW TOP OF ACCESS CASING

\+ f'c @ 40 DAYS CORRECTED FOR DISTURBANCE

EAST CAISSON (LIFT 3 AND 4)

SCALE: 1=3

FIGURE 14 (CONT.)

DEPTH *	CORE SKETCH	CORE + SAMPLE STRENGTH (psi)	28 DAY CYLINDER STRENGTH (psi)	MIX. No.	PLACEMENT METHOD	AGG. SIZE	ACTUAL SLUMP	DESCRIPTION OF CONCRETE		WINDOW LEVEL	DEPTH *
								CORES	WINDOWS		
44'0" 46'6" 49'0" 51'6"	E6A E6B E6C	5740 4780 5510	5830	#2	TREMIE	1 1/4"	7.5"	VERY CONSOLIDATED, FEW BUG HOLES VERTICAL COLUMN OF SEGREGATION NOTED AT 44' TO 47'. OTHER AREAS WITH VERTICAL SEGREGATION NOTED. 53'-5"	CONCRETE QUITE ROUGH, WET AND SLIGHTLY DEFORMED. CONCRETE SURFACE BROKEN DURING SOIL REMOVAL. NO VERTICAL RIBBING OR LATERIAL VARIATION NOTED.	46 6 48	44'0" 46'6" 49'0" 51'6"
54'0" 56'6" 59'0" 61'6" 64'0" 66'0"	E7A E7B E7C	4910 6690 7290	6580	#4	TREMIE	5/8"	7"	LARGE AGGREGATE FROM MIX ABOVE EXTENDS TO 55'. SMALL CLAY VOIDS NOTED AT. AT BOTTOM OF LIFT. FRACTURES GROUND AND BROKEN LOWER 10' OF CORE RIBBED. BOTTOM OF CAISSON 65'-8"	CAISSON VERY ROUGH, ENLARGED AND DEFORMED. LARGE VOID SURROUNDING CAISSON DUE TO RAVELLING OF GRANULAR LAYERS. NO LATERAL VARIATION NOTED.	55 7 57	54'0" 56'6" 59'0" 61'6" 64'0" 66'0"

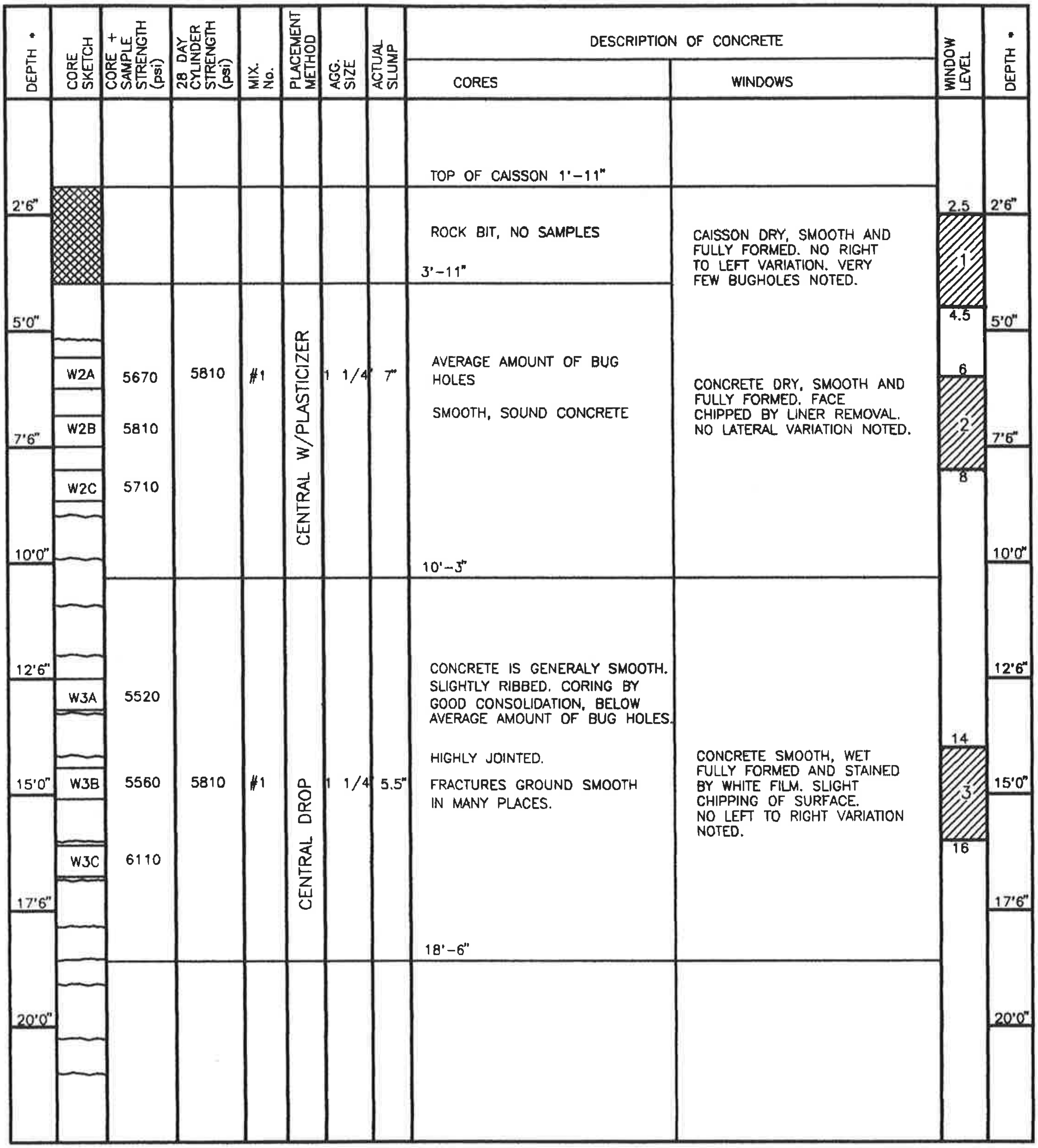
* BELOW TOP OF ACCESS CASING

\+ f'c @ 40 DAYS CORRECTED FOR DISTURBANCE

EAST CAISSON (LIFT 5 AND 6)

SCALE: 1"=3'

FIGURE 14 (CONT.)



DEPTH *	CORE SKETCH	CORE + SAMPLE STRENGTH (psi)	28 DAY CYLINDER STRENGTH (psi)	MIX. No.	PLACEMENT METHOD	AGG. SIZE	ACTUAL SLUMP	DESCRIPTION OF CONCRETE: CORES	DESCRIPTION OF CONCRETE: WINDOWS	WINDOW LEVEL	DEPTH *
								TOP OF CAISSON 1'-11"			
2'6"								ROCK BIT, NO SAMPLES 3'-11"	CAISSON DRY, SMOOTH AND FULLY FORMED. NO RIGHT TO LEFT VARIATION. VERY FEW BUGHOLES NOTED.	2.5 1 4.5	2'6"
5'0" 7'6" 10'0"	W2A W2B W2C	5670 5810 5710	5810	#1	CENTRAL W/PLASTICIZER	1 1/4	7"	AVERAGE AMOUNT OF BUG HOLES SMOOTH, SOUND CONCRETE 10'-3"	CONCRETE DRY, SMOOTH AND FULLY FORMED. FACE CHIPPED BY LINER REMOVAL. NO LATERAL VARIATION NOTED.	6 2 8	5'0" 7'6" 10'0"
12'6" 15'0" 17'6"	W3A W3B W3C	5520 5560 6110	5810	#1	CENTRAL DROP	1 1/4	5.5"	CONCRETE IS GENERALY SMOOTH. SLIGHTLY RIBBED. CORING BY GOOD CONSOLIDATION, BELOW AVERAGE AMOUNT OF BUG HOLES. HIGHLY JOINTED. FRACTURES GROUND SMOOTH IN MANY PLACES. 18'-6"	CONCRETE SMOOTH, WET FULLY FORMED AND STAINED BY WHITE FILM. SLIGHT CHIPPING OF SURFACE. NO LEFT TO RIGHT VARIATION NOTED.	14 3 16	12'6" 15'0" 17'6"
20'0"											20'0"

* BELOW TOP OF ACCESS CASING

\+ f'c @ 40 DAYS CORRECTED FOR DISTURBANCE

WEST CAISSON (LIFT 1 AND 2)

SCALE: 1"=3'

FIGURE 15

DEPTH *	CORE SKETCH	CORE + SAMPLE STRENGTH (psi)	28 DAY CYLINDER STRENGTH (psi)	MIX. No.	PLACEMENT METHOD	AGG. SIZE	ACTUAL SLUMP	DESCRIPTION OF CONCRETE: CORES	DESCRIPTION OF CONCRETE: WINDOWS	WINDOW LEVEL	DEPTH *
22'6" 25'0" 27'6"	W4A W4B W4C	6060 6020 5260	5810	#1	SLOPPY DROP	1 1/4	5.5"	CONCRETE LOOKS GOOD BUT HIGHLY FRACTURED. BELOW AVERAGE BUG HOLES. FRACTURES GROUND SMOOTH IN MANY PLACES. 28'-6"	CONCRETE SLIGHTLY ROUGH, WET AND STAINED WHITE. SOME VERTICAL RIBBING NOTED ONE LARGER RIB AT RIGHT SIDE.	24 4 26	22'6" 25'0" 27'6"
30'0" 32'6" 35'0" 37'6"	W5A W5B W5C	6680 6260 6470	6310	#3	TREMIE W/PLASTICIZER	5/8"	7.5"	LARGE AGGREGATE ENDS AT 29'-5". MAXIMUM AGGREGATE APPEARS TO BE 3/8". FROM 32'-32'4" PASTE ONLY, NO AGGREGATE VERY LOW COMPRESSIVE STRENGTH. CRUMBLES BY HAND. CORE BROKEN AND FRACTURED AT 32'7"-33'1". MANY OF OTHER FRACTURES ARE GROUND SMOOTH. 38'-4"	CONCRETE SLIGHTLY ROUGH, WET AND OCCAISIONALLY CHIPPED. HORIZONTAL JOINT EVIDENT ACROSS ENTIRE WIDTH OF WINDOW, CULMINATING IN AN EXPOSED WIRE TIE AT RIGHT. SINGLE LARGE VERTICAL RIB NOTED ON RIGHT SIDE.	34 5 36	30'0" 32'6" 35'0" 37'6"
40'0" 42'6"	W6A	5320						LARGE BREAK AT 41'11", CAUSED BY STEEL REBAR IN CONCRETE.			40'0"

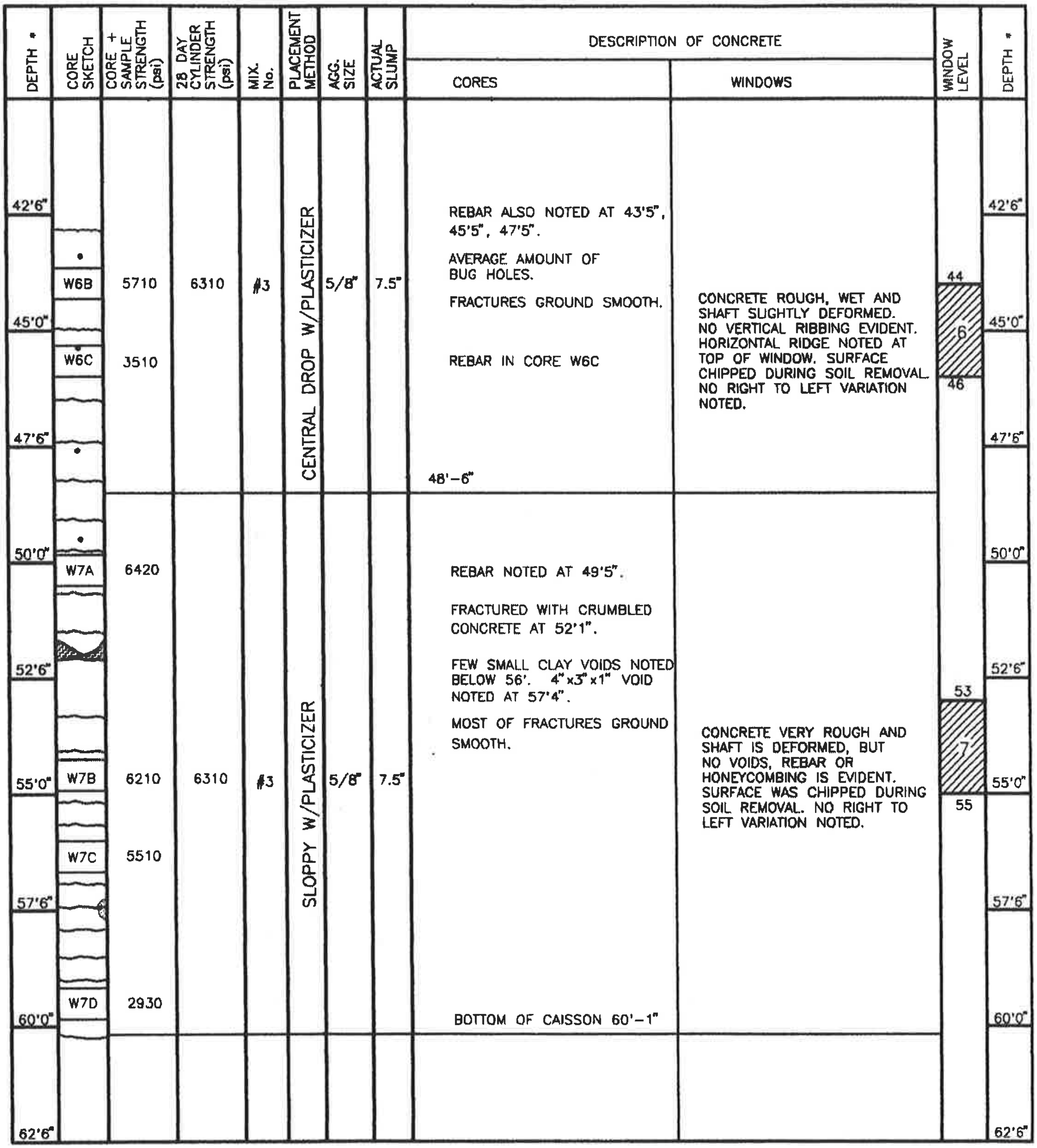
* BELOW TOP OF ACCESS CASING

\+ f'c @ 40 DAYS CORRECTED FOR DISTURBANCE

WEST CAISSON (LIFT 3 AND 4)

SCALE: 1"=3'

FIGURE 15 (CONT.)



DEPTH *	CORE SKETCH	CORE + SAMPLE STRENGTH (psi)	28 DAY CYLINDER STRENGTH (psi)	MIX. No.	PLACEMENT METHOD	AGG. SIZE	ACTUAL SLUMP	DESCRIPTION OF CONCRETE		WINDOW LEVEL	DEPTH *
								CORES	WINDOWS		
42'6"	W6B	5710	6310	#3	CENTRAL DROP W/PLASTICIZER	5/8"	7.5"	REBAR ALSO NOTED AT 43'5", 45'5", 47'5". AVERAGE AMOUNT OF BUG HOLES. FRACTURES GROUND SMOOTH.	CONCRETE ROUGH, WET AND SHAFT SLIGHTLY DEFORMED. NO VERTICAL RIBBING EVIDENT. HORIZONTAL RIDGE NOTED AT TOP OF WINDOW. SURFACE CHIPPED DURING SOIL REMOVAL. NO RIGHT TO LEFT VARIATION NOTED.	44 6	42'6"
45'0"	W6C	3510						REBAR IN CORE W6C		46	45'0"
47'6"								48'-6"			47'6"
50'0"	W7A	6420			SLOPPY W/PLASTICIZER			REBAR NOTED AT 49'5". FRACTURED WITH CRUMBLED CONCRETE AT 52'1".			50'0"
52'6"	W7B	6210	6310	#3		5/8"	7.5"	FEW SMALL CLAY VOIDS NOTED BELOW 56'. 4"x3"x1" VOID NOTED AT 57'4". MOST OF FRACTURES GROUND SMOOTH.	CONCRETE VERY ROUGH AND SHAFT IS DEFORMED, BUT NO VOIDS, REBAR OR HONEYCOMBING IS EVIDENT. SURFACE WAS CHIPPED DURING SOIL REMOVAL. NO RIGHT TO LEFT VARIATION NOTED.	53 7 55	52'6"
55'0"	W7C	5510									55'0"
57'6"	W7D	2930						BOTTOM OF CAISSON 60'-1"			57'6"
60'0"											60'0"
62'6"											62'6"

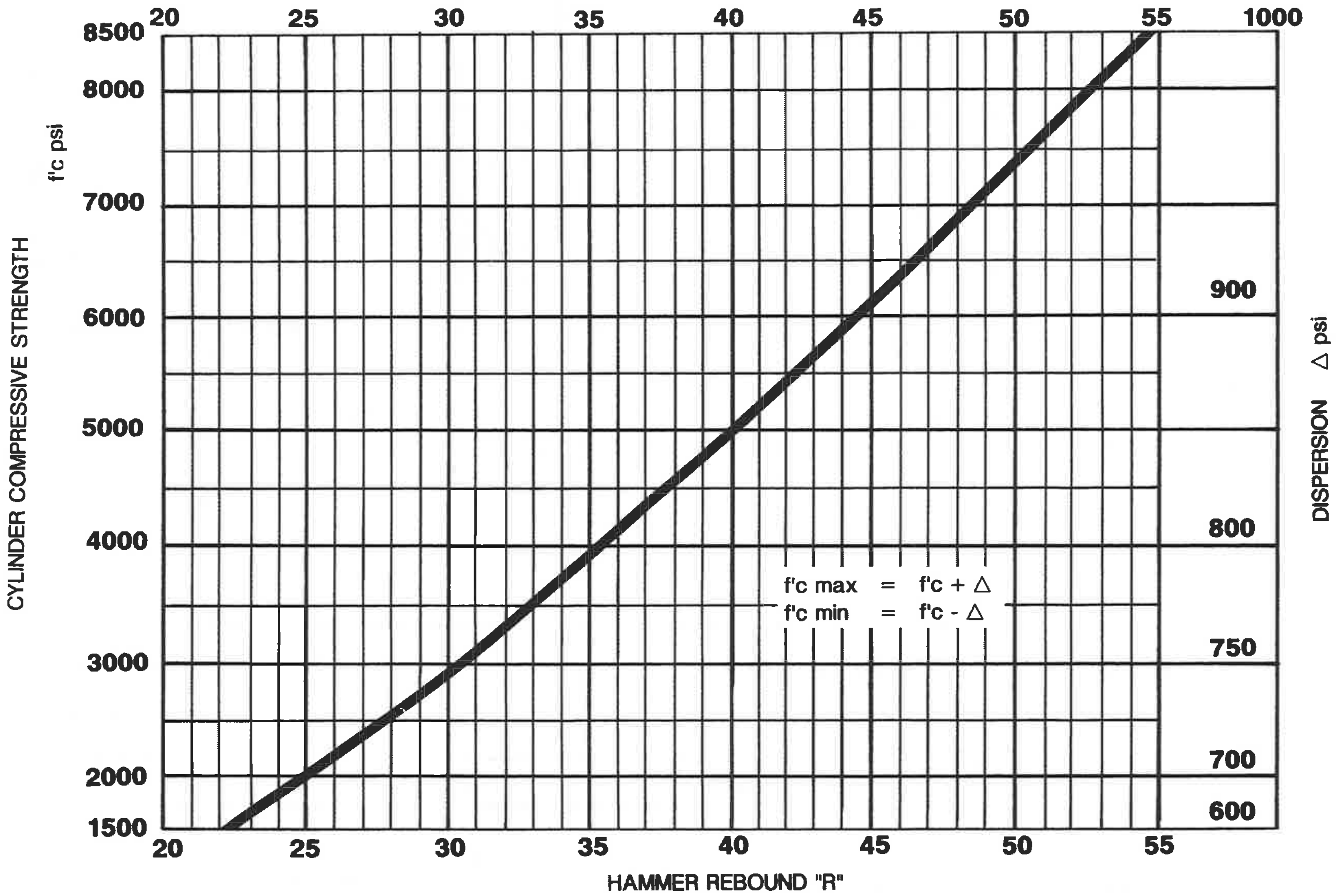
* BELOW TOP OF ACCESS CASING

\+ f'c @ 40 DAYS CORRECTED FOR DISTURBANCE

WEST CAISSON (LIFT 5 AND 6)

SCALE: 1"=3'

FIGURE 15 (CONT.)



STS Consultants Ltd.
Consulting Engineers

CORRELATION BETWEEN CYLINDER COMPRESSIVE STRENGTH AND SCHMIDT HAMMER REBOUND VALUE "R"

DRAWN BY	KKB	DATE	12-1-93
CHECKED BY		DATE	
APPROVED BY	TAK	DATE	12-1-93
CADFILE			

STS PROJECT NO. 27618

STS PROJECT FILE

SCALE NTS

SHEET NO. FIGURE 16

STS Consultants Ltd.

CLIENT
International Assn. of Foundation Drilling

LOG OF BORING NUMBER **B-101**

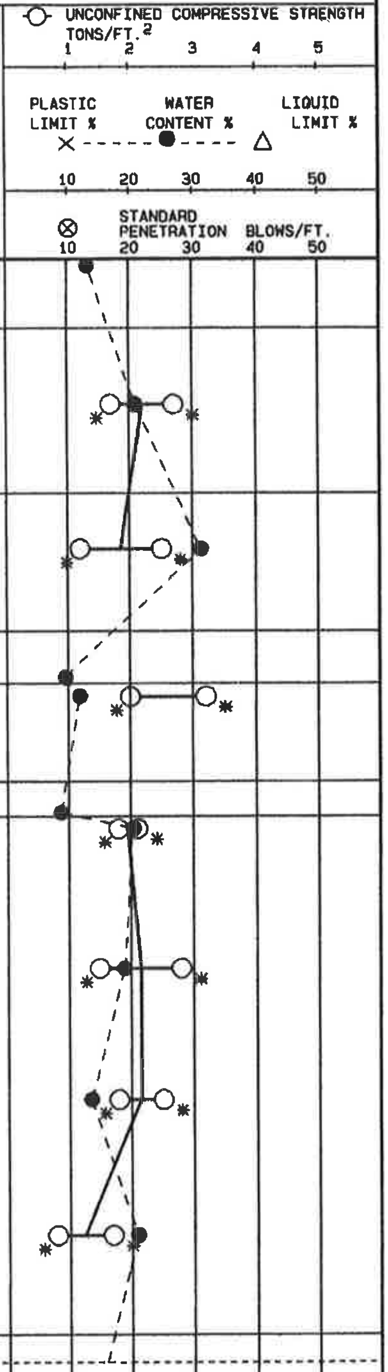
PROJECT NAME
Free-Fall Concrete Research

ARCHITECT-ENGINEER

SITE LOCATION
1869 Techny; Northbrook, Illinois

SURFACE ELEVATION **EXISTING GRADE**

DEPTH (FT)	ELEVATION (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL
		1	ST			Fill: Silty fine to coarse sand, little topsoil, trace clay, gravel and brick chips - black - moist (SM)
			PA			Fill: Silty clay, little gravel and topsoil, trace glass and brick - brownish black - stiff to very stiff (OL-CL)
5.0		2	ST			
			PA			
10.0						Silty clay, trace gravel and sand - brown and gray - stiff (CL-CH)
		3	ST			
			PA			Clayey gravel, little silt and sand - gray - saturated (GC)
15.0		4	ST			
		4A	ST			Gravelly clay, little silt and sand - gray - very stiff - moist (CL)
			RB			
						Clayey gravel, little silt and sand - gray (GC)
20.0		5	ST			
		5A	ST			Silty clay, trace gravel, sand and shale - gray - stiff to very stiff (CL)
			RB			
25.0		6	ST			
			RB			
30.0		7	ST			
			RB			
35.0		8	ST			
			RB			
40.0						Clayey silt, trace gravel - gray - very stiff to hard (ML) Note: Some isolated clay pockets.



* Calibrated Penetrometer

... continued

The stratification lines represent the approximate boundary lines between soil types: in-situ, the transition may be gradual.

STS JOB NO. 27618

SHEET NO. 1 OF 2

STS Consultants Ltd.

CLIENT
International Assn. of Foundation Drilling

LOG OF BORING NUMBER **B-101**

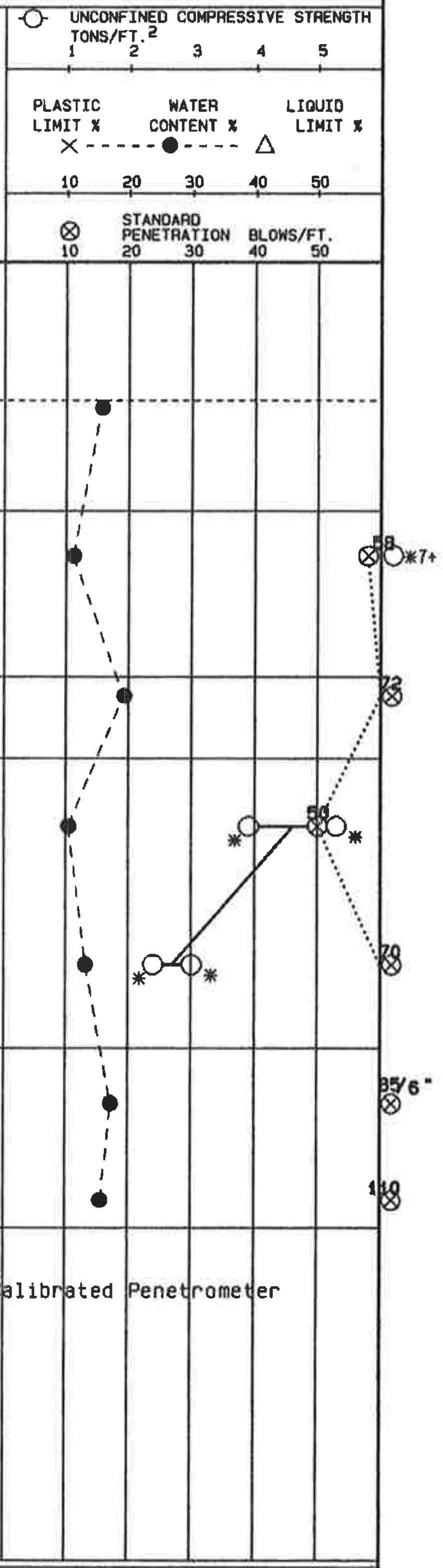
PROJECT NAME
Free-Fall Concrete Research

ARCHITECT-ENGINEER

SITE LOCATION
1869 Techny; Northbrook, Illinois

SURFACE ELEVATION **EXISTING GRADE**

DEPTH (FT)	ELEVATION (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL
						Continued from previous page
40.0		9	ST			Clayey silt, trace gravel - gray - very stiff to hard (ML)
			RB			Note: Some isolated clay pockets.
45.0		10	SS			Silty clay, trace gravel, sand and shale - gray - very hard - very dense (CL)
			RB			
50.0		11	SS			Clayey silt - gray - very dense - saturated (ML)
			RB			Silty clay, trace gravel, sand and shale - gray - very stiff to hard (CL)
55.0		12	SS			
			RB			
60.0		13	SS			
			RB			Clayey silt, trace gravel and shale - gray - extremely dense (ML)
65.0		14	SS			
			RB			
70.0		15	SS			
						End of Boring Casing used: 5 ft. of 4 in.



* Calibrated Penetrometer

The stratification lines represent the approximate boundary lines between soil types: in-situ, the transition may be gradual.

WL 14 ft	WS OR WD WD	BORING STARTED 06/01/93	STS OFFICE Northbrook-01		
WL BCR	ACR	BORING COMPLETED 06/01/93	ENTERED BY KKB	SHEET NO. 2	OF 2
WL		RIG/FOREMAN DR-9/Jack	APP'D BY TAK	STS JOB NO. 27618	

STS Consultants Ltd.

CLIENT
International Assn. of Foundation Drilling

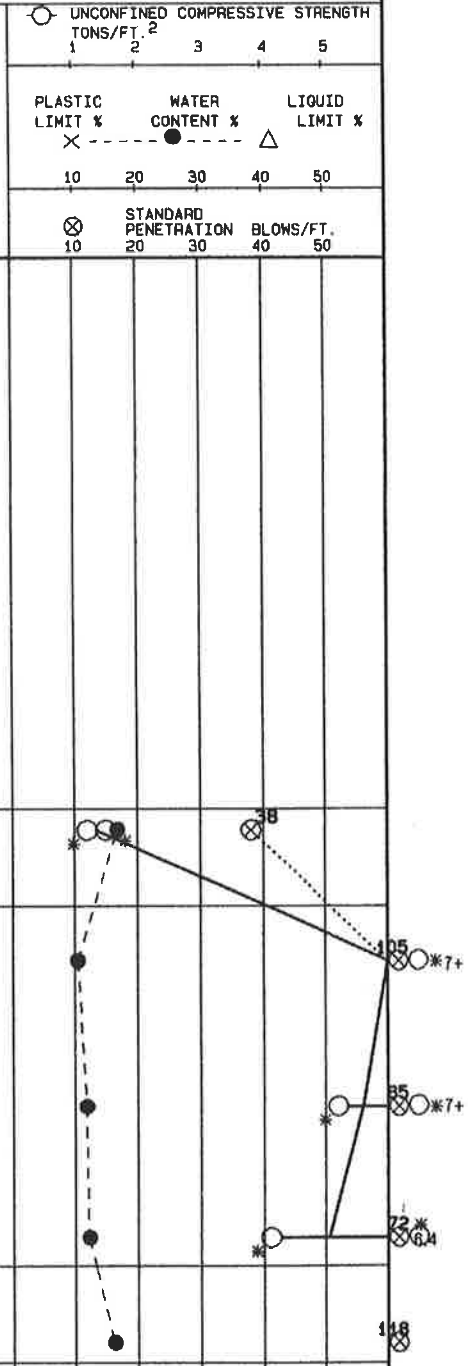
LOG OF BORING NUMBER B-102

PROJECT NAME
Free-Fall Concrete Research

ARCHITECT-ENGINEER

SITE LOCATION
1869 Techny; Northbrook, Illinois

DEPTH (FT)	ELEVATION (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL
						SURFACE ELEVATION
						Blank drilling - no samples taken
25.0						
30.0			RB			
35.0						
40.0		1	SS			Silty clay, trace sand - gray - medium to stiff (CL-ML)
			RB			
						Silty clay, trace gravel and sand - gray - hard (CL) Note: Trace of shale found in Sample 4.
45.0		2	SS			
			RB			
50.0		3	SS			
			RB			
55.0		4	SS			
			RB			Clayey silt - gray - extremely dense - wet (ML)
		5	SS			
60.0						
						End of Boring Borehole grouted upon completion.



* Calibrated Penetrometer

The stratification lines represent the approximate boundary lines between soil types: in-situ, the transition may be gradual.

WL WS OR WD	BORING STARTED 06/14/93	STS OFFICE Northbrook-01	
WL 8 ft BCR 11 ft ACR	BORING COMPLETED 06/14/93	ENTERED BY KKB	SHEET NO. 1 OF 1
WL	RIG/FOREMAN DR-9/Phil	APP'D BY TAK	STS JOB NO. 27618

MATERIALS LABORATORY
REPORT NO. 1
PROJECT:FREE FALL CONC.
STS JOB:: 27618

CONCRETE CORE COMPRESSIVE STRENGTH

DATE TESTED: 04-AUG-1993
DATE RECEIVED: 29-NOV-1993
DATE SAMPLED: 29-NOV-1993

SPECIFIED STRENGTH: 4000
MOISTURE CONDITION: SAT.

NO.	DIAM IN.	H/D RATIO	CORR. FACTOR	LOAD LBS.	PSI	*CORR. PSI	**UNIT WT.	LOCATION
N1B	3.96	1.99	1.1765	58000	4710	5540	149.1	1'6" TO 2'2"
N2A	3.96	2.00	1.1765	50750	4120	4850	152.8	3'0" TO 3'8"
N2B	3.96	1.98	1.1765	52250	4240	4990	149.9	4'6" TO 5'2"
N2C	3.96	1.99	1.1765	57000	4630	5440	152.6	7'1" TO 7'9"
N3A	3.96	1.99	1.1765	63100	5120	6030	153.8	10'6" TO 11'2"
N3B	3.96	1.98	1.1765	59400	4820	5670	153.0	14'3" TO 14'11"
N3C	3.96	1.98	1.1765	57500	4670	5490	152.0	17'0" TO 17'4"
N4A	3.96	1.97	1.1765	57500	4670	5490	153.9	21'0" TO 21'8"
N4B	3.96	1.99	1.1765	61000	4950	5830	152.5	24'0" TO 24'8"
N4C	3.96	1.99	1.1765	58550	4750	5590	152.1	28'0" TO 28'8"
N5A	3.96	2.00	1.1765	64500	5240	6150	152.2	32'6" TO 33'2"
N5B	3.96	1.99	1.1765	60000	4870	5730	152.7	35'6" TO 36'2"
N5C	3.96	1.99	1.1765	64000	5200	6110	154.9	38'9" TO 39'5"
N6A	3.96	1.99	1.1765	76000	6170	7270	156.0	41'6" TO 42'2"
N6B	3.96	2.00	1.1765	69900	5680	6680	154.5	43'5" TO 44'1"
N6C	3.96	2.00	1.1765	75700	6150	7230	153.2	46'0" TO 46'8"
N7A	3.96	1.99	1.1765	71000	5760	6780	154.4	51'0" TO 51'8"
N7B	3.96	2.00	1.1765	73500	5970	7020	154.7	53'4" TO 54'0"
N7C	3.96	2.00	1.1765	67000	5440	6400	153.1	57'0" TO 57'8"
N7D	3.96	2.00	1.1765	47000	3820	4490	149.7	60'2" TO 60'10"

NOTE:

1) CLAY IN CORE N7D

*2) COMPRESSIVE STRENGTHS WERE CORRECTED PER ACI CODE BY DIVIDING BY 0.8500 DUE TO SAMPLE DISTURBANCE.

**3) UNIT WT. CALCULATED USING WEIGHT/VOLUME RELATIONSHIP AT TIME OF TEST.

MATERIALS LABORATORY
REPORT NO. 1
PROJECT:FREE FALL CONC.
STS JOB:: 27618
11-AUG-1993

CONCRETE CORE COMPRESSIVE STRENGTH

DATE TESTED: 04-AUG-1993
DATE RECEIVED: 02-AUG-1993
DATE SAMPLED: 02-AUG-1993

SPECIFIED STRENGTH: 4000
MOISTURE CONDITION: SAT.

NO.	DIAM IN.	H/D RATIO	CORR. FACTOR	LOAD LBS.	PSI	*CORR. PSI	**UNIT WT.	LOCATION
S1B	3.96	2.00	1.1765	63900	5190	6100	145.3	1'6" TO 2'2"
S2A	3.96	2.00	1.1765	62650	5090	5980	144.8	2'9" TO 3'5"
S2B	3.96	2.00	1.1765	61300	4980	5860	144.5	5'0" TO 5'8"
S2C	3.96	2.00	1.1765	56600	4600	5410	143.6	6'6" TO 7'2"
S3A	3.96	1.99	1.1765	69500	5640	6640	148.3	10'4" TO 11'0"
S3B	3.96	1.99	1.1765	63250	5140	6040	148.5	13'0" TO 13'8"
S3C	3.96	2.00	1.1765	61350	4980	5860	147.3	15'4" TO 16'0"
S4A	3.96	1.99	1.1765	67700	5500	6470	149.0	20'4" TO 21'0"
S4B	3.96	1.98	1.1765	65600	5330	6270	149.4	23'0" TO 23'8"
S4C	3.96	2.00	1.1765	64050	5200	6120	149.5	27'0" TO 27'8"
S5A	3.96	2.00	1.1765	67900	5510	6490	146.8	30'10" TO 31'5"
S5B	3.96	1.99	1.1765	73800	5990	7050	147.0	34'2" TO 34'10"
S5C	3.96	1.99	1.1765	72400	5880	6920	146.4	36'10" TO 37'6"
S6A	3.96	1.99	1.1765	61350	4980	5860	145.7	41'7" TO 42'3"
S6B	3.96	1.99	1.1765	55850	4530	5330	145.1	44'4" TO 45'0"
S6C	3.96	1.99	1.1765	56300	4570	5380	144.9	46'8" TO 47'4"
S7A	3.96	2.00	1.1765	77200	6270	7370	149.0	50'4" TO 51'0"
S7B	2.00	1.66	1.1765	14200	4400	5320	145.8	53'2" TO 53'5"
S7C	2.00	1.76	1.1765	12900	4030	4830	147.4	54'8" TO 55'0"
S7D	2.00	2.00	1.1765	17100	5440	6400	145.5	57'3" TO 58'3"

NOTE:

1) REBAR IN CORE S7A

*2) COMPRESSIVE STRENGTHS WERE CORRECTED PER ACI CODE BY DIVIDING BY 0.8500 DUE TO SAMPLE DISTURBANCE.

**3) UNIT WT. CALCULATED USING WEIGHT/VOLUME RELATIONSHIP AT TIME OF TEST.

MATERIALS LABORATORY
REPORT NO. 1
PROJECT:FREE FALL CONC.
STS JOB:: 27618
30-NOV-1993

CONCRETE CORE COMPRESSIVE STRENGTH

DATE TESTED: 10-AUG-1993
DATE RECEIVED: 04-AUG-1993
DATE SAMPLED: 01-JUL-1993

SPECIFIED STRENGTH: 4000
MOISTURE CONDITION: SAT.

NO.	DIAM IN.	H/D RATIO	CORR. FACTOR	LOAD LBS.	PSI	*CORR. PSI	**UNIT WT.	LOCATION
E2A	3.90	2.00	1.1765	70400	5890	6930	149.5	2'6" TO 3'2"
E2B	3.90	2.00	1.1765	60900	5100	6000	145.5	4'5" TO 5'1"
E2C	3.90	2.00	1.1765	60000	5020	5910	147.1	7'4" TO 8'0"
E3A	3.90	2.00	1.1765	59050	4940	5820	148.0	11'0" TO 11'8"
E3B	3.90	2.00	1.1765	61850	5180	6090	147.1	13'10" TO 14'6"
E3C	3.90	2.00	1.1765	67950	5690	6690	147.8	17'8" TO 18'4"
E4A	3.90	2.00	1.1765	53250	4460	5240	148.2	22'4" TO 23'0"
E4B	3.90	2.00	1.1765	53800	4500	5300	153.3	23'11" TO 24'7"
E4C	3.90	2.00	1.1765	48200	4030	4750	153.7	26'11" TO 27'7"
E5A	3.90	2.00	1.1765	28000	2340	2760	143.1	33'7" TO 34'3"
E5B	3.90	2.00	1.1765	34100	2850	3360	144.0	34'7" TO 35'3"
E5C	3.90	2.00	1.1765	32200	2700	3170	142.9	38'3" TO 38'11"
E6A	3.90	2.00	1.1765	58350	4880	5750	149.7	42'5" TO 43'1"
E6B	3.90	2.00	1.1765	48450	4060	4770	151.2	44'8" TO 45'4"
E6C	3.90	2.00	1.1765	55850	4680	5500	153.3	46'11" TO 47'7"
E7A	3.90	2.00	1.1765	49850	4170	4910	147.6	53'1" TO 53'9"
E7B	3.90	2.00	1.1765	67900	5680	6690	147.5	55'0" TO 55'8"
E7C	3.90	2.00	1.1765	74050	6200	7290	149.5	60'6" TO 61'2"

NOTE:

1) MINIMUM AGGREGATE SHEAR IN CORES E5A, E5B & E5C

2) AGGREGATE APPEARS TO BE SEGREGATED IN CORE E6A.

3) ENDS WERE GROUND PLAIN ON CORE E6C DUE TO BAD SULFUR CAP.

*4) COMPRESSIVE STRENGTHS WERE CORRECTED PER ACI CODE BY DIVIDING BY 0.8500 DUE TO SAMPLE DISTURBANCE.

**5) UNIT WT. CALCULATED USING WEIGHT/VOLUME RELATIONSHIP AT TIME OF TEST.

CALCULATION SHEET   CORE PSI, UNIT WT.

JOB NO: 27618   DATE CHECKED: 04-AUG-1993
PROJECT: FREE FALL CONCRETE   CHECKED BY: FGC
DATE TESTED: 04-AUG-1993   DATE SAMPLED: 04-AUG-1993
DATE RECEIVED:04-AUG-1993   REQ,PSI 4000   MOISTURE CONDITION:SAT
REPORT NO: 1

NO	HT	CAP HT	DIAM	AREA	H/D RATIO	CORR FACTOR	LOAD LBS	UNCORR PSI	CORR PSI	NEAREST 10 PSI	WT GRAMS	UNIT WT
N1B	7.77	7.90	3.96	12.32	1.99	1.0000	58000	4709	4709	4710	3745.8	149.1
N2A	7.72	7.92	3.96	12.32	2.00	1.0000	50750	4121	4121	4120	3812.8	152.8
N2B	7.70	7.86	3.96	12.32	1.98	1.0000	52250	4242	4242	4240	3731.0	149.9
N2C	7.75	7.87	3.96	12.32	1.99	1.0000	57000	4628	4628	4630	3824.2	152.6
N3A	7.78	7.88	3.96	12.32	1.99	1.0000	63100	5123	5123	5120	3869.4	153.8
N3B	7.74	7.85	3.96	12.32	1.98	1.0000	59400	4823	4823	4820	3827.8	153.0
N3C	7.78	7.86	3.96	12.32	1.98	1.0000	57500	4669	4669	4670	3823.5	152.0
N4A	7.70	7.82	3.96	12.32	1.97	1.0000	57500	4669	4669	4670	3831.2	153.9
N4B	7.78	7.90	3.96	12.32	1.99	1.0000	61000	4953	4953	4950	3835.5	152.5
N4C	7.75	7.89	3.96	12.32	1.99	1.0000	58550	4754	4754	4750	3811.4	152.1
N5A	7.79	7.92	3.96	12.32	2.00	1.0000	64500	5237	5237	5240	3833.9	152.2
N5B	7.80	7.90	3.96	12.32	1.99	1.0000	60000	4872	4872	4870	3851.6	152.7
N5C	7.78	7.87	3.96	12.32	1.99	1.0000	64000	5196	5196	5200	3897.2	154.9
N6A	7.79	7.90	3.96	12.32	1.99	1.0000	76000	6171	6171	6170	3927.8	156.0
N6B	7.84	7.92	3.96	12.32	2.00	1.0000	69900	5675	5675	5680	3915.2	154.5
N6C	7.81	7.92	3.96	12.32	2.00	1.0000	75700	6146	6146	6150	3869.9	153.3
N7A	7.75	7.90	3.96	12.32	1.99	1.0000	71000	5765	5765	5760	3867.8	154.4
N7B	7.83	7.92	3.96	12.32	2.00	1.0000	73500	5968	5968	5970	3916.6	154.7
N7C	7.81	7.92	3.96	12.32	2.00	1.0000	67000	5440	5440	5440	3866.1	153.1
N7D	7.82	7.92	3.96	12.32	2.00	1.0000	47000	3816	3816	3820	3783.9	149.7

UNIT WT. CALCULATED USING WEIGHT/VOLUME RELATIONSHIP AT TIME OF TEST

MATERIALS LABORATORY
REPORT NO. 1
PROJECT:FREE FALL CONC.
STS JOB:: 27618
10-AUG-1993

CONCRETE CORE COMPRESSIVE STRENGTH

DATE TESTED: 10-AUG-1993
DATE RECEIVED: 04-AUG-1993
DATE SAMPLED: 07-JUL-1993

SPECIFIED STRENGTH: 4000
MOISTURE CONDITION: SAT.

NO.	DIAM IN.	H/D RATIO	CORR. FACTOR	LOAD LBS.	PSI	*CORR. PSI	**UNIT WT.	LOCATION
W2A	3.90	2.00	1.1765	57600	4820	5670	151.0	3'7" TO 4'3"
W2B	3.90	2.00	1.1765	59000	4940	5810	143.2	4'10" TO 5'6"
W2C	3.90	2.00	1.1765	57900	4850	5700	149.2	6'0" TO 6'8"
W3A	3.90	2.00	1.1765	56050	4690	5520	145.1	10'6" TO 11'2"
W3B	3.90	2.00	1.1765	56450	4730	5560	145.0	12'6" TO 13'2"
W3C	3.90	2.00	1.1765	61950	5190	6100	148.7	14'0" TO 14'9"
W4A	3.90	2.00	1.1765	61500	5150	6060	149.1	19'8" TO 20'4"
W4B	3.90	2.00	1.1765	61150	5120	6020	153.0	23'2" TO 23'10"
W4C	3.90	2.00	1.1765	53450	4470	5260	153.7	25'0" TO 25'8"
W5A	3.90	2.00	1.1765	67850	5680	6680	142.8	29'0" TO 29'8"
W5B	3.90	2.00	1.1765	63500	5320	6250	144.9	31'6" TO 32'2"
W5C	3.90	2.00	1.1765	65750	5500	6480	142.9	34'0" TO 34'8"
W6A	3.90	2.00	1.1765	54000	4520	5320	148.8	37'3" TO 37'11"
W6B	3.90	2.00	1.1765	57900	4850	5700	152.0	41'8" TO 42'4"
W6C	3.90	2.00	1.1765	35600	2980	3510	153.3	43'8" TO 44'0"
W7A	3.90	2.00	1.1765	65250	5460	6430	149.9	47'11" TO 48'7"
W7B	3.90	2.00	1.1765	63100	5280	6210	148.5	52'4" TO 53'0"
W7C	3.90	2.00	1.1765	55900	4680	5510	150.3	54'0" TO 54'8"
W7D	3.90	2.00	1.1765	29750	2490	2930	141.4	57'3" TO 57'11"

NOTE:

1) REBAR IN CORE W6B

*2) COMPRESSIVE STRENGTHS WERE CORRECTED PER ACI CODE BY DIVIDING BY 0.8500 DUE TO SAMPLE DISTURBANCE.

**3) UNIT WT. CALCULATED USING WEIGHT/VOLUME RELATIONSHIP AT TIME OF TEST

CALCULATION SHEET   CORE PSI, UNIT WT.

JOB NO: 27618   DATE CHECKED: 11-AUG-1993
PROJECT: FREE FALL CONCRETE   CHECKED BY: FGC
DATE TESTED: 04-AUG-1993   DATE SAMPLED: 02-AUG-1993
DATE RECEIVED:02-AUG-1993   REQ,PSI 4000   MOISTURE CONDITION:SAT
REPORT NO: 1

NO	HT	CAP HT	DIAM	AREA	H/D RATIO	CORR FACTOR	LOAD LBS	UNCORR PSI	CORR PSI	NEAREST 10 PSI	WT GRAMS	UNIT WT
S1B	7.80	7.92	3.96	12.32	2.00	1.0000	63900	5188	5188	5190	3664.0	145.3
S2A	7.78	7.92	3.96	12.32	2.00	1.0000	62650	5087	5087	5090	3642.2	144.8
S2B	7.76	7.92	3.96	12.32	2.00	1.0000	61300	4977	4977	4980	3625.2	144.5
S2C	7.73	7.92	3.96	12.32	2.00	1.0000	56600	4596	4596	4600	3589.4	143.6
S3A	7.76	7.90	3.96	12.32	1.99	1.0000	69500	5643	5643	5640	3721.6	148.3
S3B	7.74	7.89	3.96	12.32	1.99	1.0000	63250	5135	5135	5140	3715.8	148.5
S3C	7.74	7.92	3.96	12.32	2.00	1.0000	61350	4981	4981	4980	3685.9	147.3
S4A	7.76	7.89	3.96	12.32	1.99	1.0000	67700	5497	5497	5500	3737.2	149.0
S4B	7.69	7.85	3.96	12.32	1.98	1.0000	65600	5326	5326	5330	3715.3	149.4
S4C	7.83	7.92	3.96	12.32	2.00	1.0000	64050	5200	5200	5200	3785.7	149.5
S5A	7.77	7.92	3.96	12.32	2.00	1.0000	67900	5513	5513	5510	3687.6	146.8
S5B	7.69	7.88	3.96	12.32	1.99	1.0000	73800	5992	5992	5990	3655.2	147.0
S5C	7.74	7.87	3.96	12.32	1.99	1.0000	72400	5878	5878	5880	3664.2	146.4
S6A	7.72	7.87	3.96	12.32	1.99	1.0000	61350	4981	4981	4980	3635.6	145.7
S6B	7.76	7.90	3.96	12.32	1.99	1.0000	55850	4535	4535	4530	3641.2	145.1
S6C	7.78	7.90	3.96	12.32	1.99	1.0000	56300	4571	4571	4570	3643.6	144.9
S7A	7.83	7.92	3.96	12.32	2.00	1.0000	77200	6268	6268	6270	3772.0	149.0
S7B	3.17	3.32	2.00	3.14	1.66	0.9728	14200	4520	4397	4400	381.1	145.8
S7C	3.35	3.52	2.00	3.14	1.76	0.9808	12900	4106	4027	4030	407.2	147.4
S7D	3.90	4.00	2.00	3.14	2.00	1.0000	17100	5443	5443	5440	467.8	145.5

UNIT WT. CALCULATED USING WEIGHT/VOLUME RELATIONSHIP AT TIME OF TEST

CALCULATION SHEET   CORE PSI, UNIT WT.

JOB NO: 27618   DATE CHECKED: 10-AUG-1993
PROJECT: FREE FALL CONCRETE   CHECKED BY: FGC
DATE TESTED: 10-AUG-1993   DATE SAMPLED: 01-JUL-1993
DATE RECEIVED:04-AUG-1993   REQ,PSI 4000   MOISTURE CONDITION:SAT
REPORT NO: 1

NO	HT	CAP HT	DIAM	AREA	H/D RATIO	CORR FACTOR	LOAD LBS	UNCORR PSI	CORR PSI	NEAREST 10 PSI	WT GRAMS	UNIT WT
E2A	7.86	7.92	3.90	11.95	2.03	1.0000	70400	5893	5893	5890	3684.8	149.5
E2B	7.73	7.92	3.90	11.95	2.03	1.0000	60900	5098	5098	5100	3526.0	145.5
E2C	7.79	7.92	3.90	11.95	2.03	1.0000	60000	5023	5023	5020	3594.1	147.1
E3A	7.67	7.92	3.90	11.95	2.03	1.0000	59050	4943	4943	4940	3558.6	148.0
E3B	7.71	7.90	3.90	11.95	2.03	1.0000	61850	5177	5177	5180	3556.3	147.1
E3C	7.85	7.89	3.90	11.95	2.02	1.0000	67950	5688	5688	5690	3637.9	147.8
E4A	7.81	7.92	3.90	11.95	2.03	1.0000	53250	4458	4458	4460	3629.0	148.2
E4B	7.57	7.57	3.90	11.95	1.94	1.0000	53800	4504	4504	4500	3640.0	153.3
E4C	7.77	7.85	3.90	11.95	2.01	1.0000	48200	4035	4035	4030	3743.9	153.7
E5A	7.80	7.92	3.90	11.95	2.03	1.0000	28000	2344	2344	2340	3501.0	143.1
E5B	7.85	7.92	3.90	11.95	2.03	1.0000	34100	2855	2855	2850	3544.7	144.0
E5C	7.69	7.88	3.90	11.95	2.02	1.0000	32200	2695	2695	2700	3446.9	142.9
E6A	7.74	7.87	3.90	11.95	2.02	1.0000	58350	4885	4885	4880	3634.1	149.7
E6B	7.82	7.87	3.90	11.95	2.02	1.0000	48450	4056	4056	4060	3707.9	151.2
E6C	7.81	7.90	3.90	11.95	2.03	1.0000	55850	4675	4675	4680	3754.5	153.3
E7A	7.82	7.90	3.90	11.95	2.03	1.0000	49850	4173	4173	4170	3618.7	147.6
E7B	7.77	7.92	3.90	11.95	2.03	1.0000	67900	5684	5684	5680	3594.4	147.5
E7C	7.77	7.92	3.90	11.95	2.03	1.0000	74050	6199	6199	6200	3642.4	149.5

UNIT WT. CALCULATED USING WEIGHT/VOLUME RELATIONSHIP AT TIME OF TEST

CALCULATION SHEET CORE PSI, UNIT WT.

JOB NO: 27618 DATE CHECKED: 10-AUG-1993
PROJECT: FREE FALL CONCRETE CHECKED BY: FGC
DATE TESTED: 10-AUG-1993 DATE SAMPLED: 07-JUL-1993
DATE RECEIVED:04-JUL-1993 REQ,PSI 4000 MOISTURE CONDITION:SAT
REPORT NO: 1

NO	HT	CAP HT	DIAM	AREA	H/D RATIO	CORR FACTOR	LOAD LBS	UNCORR PSI	CORR PSI	NEAREST 10 PSI	WT GRAMS	UNIT WT
W2A	7.78	7.90	3.90	11.95	2.03	1.0000	57600	4822	4822	4820	3684.8	151.0
W2B	7.85	7.92	3.90	11.95	2.03	1.0000	59000	4939	4939	4940	3526.0	143.2
W2C	7.68	7.92	3.90	11.95	2.03	1.0000	57900	4847	4847	4850	3594.1	149.2
W3A	7.82	7.92	3.90	11.95	2.03	1.0000	56050	4692	4692	4690	3558.6	145.1
W3B	7.82	7.90	3.90	11.95	2.03	1.0000	56450	4725	4725	4730	3556.3	145.0
W3C	7.80	7.89	3.90	11.95	2.02	1.0000	61950	5186	5186	5190	3637.9	148.7
W4A	7.76	7.92	3.90	11.95	2.03	1.0000	61500	5148	5148	5150	3629.0	149.1
W4B	7.82	7.89	3.90	11.95	2.02	1.0000	61150	5119	5119	5120	3752.6	153.0
W4C	7.77	7.85	3.90	11.95	2.01	1.0000	53450	4474	4474	4470	3743.9	153.7
W5A	7.82	7.92	3.90	11.95	2.03	1.0000	67850	5680	5680	5680	3501.0	142.8
W5B	7.80	7.92	3.90	11.95	2.03	1.0000	63500	5316	5316	5320	3544.7	144.9
W5C	7.69	7.88	3.90	11.95	2.02	1.0000	65750	5504	5504	5500	3446.9	142.9
W6A	7.79	7.87	3.90	11.95	2.02	1.0000	54000	4520	4520	4520	3634.1	148.8
W6B	7.78	7.87	3.90	11.95	2.02	1.0000	57900	4847	4847	4850	3707.9	152.0
W6C	7.81	7.90	3.90	11.95	2.03	1.0000	35600	2980	2980	2980	3754.5	153.3
W7A	7.70	7.90	3.90	11.95	2.03	1.0000	65250	5462	5462	5460	3618.7	149.9
W7B	7.72	7.92	3.90	11.95	2.03	1.0000	63100	5282	5282	5280	3594.4	148.5
W7C	7.73	7.92	3.90	11.95	2.03	1.0000	55900	4679	4679	4680	3642.4	150.3
W7D	7.85	7.92	3.90	11.95	2.03	1.0000	29750	2490	2490	2490	3479.9	141.4

UNIT WT. CALCULATED USING WEIGHT/VOLUME RELATIONSHIP AT TIME OF TEST

STS Construction Technology Group
Concrete Compressive Strength Report

PROJECT NAME: Free-Fall Concrete
PROJECT LOCATION: 1869 Techny Road
Northbrook, IL
STS PROJECT NUMBER: 27618
STS PROJECT ENGINEER: Tony A. Kiefer

SET NUMBER: 1.0
CONCRETE DESIGN STRENGTH: 4000 PSI
DATE SAMPLED AND CAST: 06/29/93

GENERAL PROJECT INFORMATION

OWNER: STS Consultants
CLIENT: ASDC
ARCHITECT:
GENERAL CONTRACTOR: Milgard
STRUCTURAL ENGINEER:
CONCRETE CONTRACTOR: Prairie Materials

CONCRETE PLACEMENT LOCATION: NORTH CAISSON 3RD LIFT (TECHNY)

MIX DESIGN INFORMATION
NAME OF SUPPLIER: PRAIRIE MATERIAL
MIX DESIGNATION: S1231
MIX DESIGN STRENGTH: 4000 PSI @28 DAYS

MATERIALS USED		**PER CUBIC YARD**	
CEMENT (TYPE):	______	447	LBS.
FLY ASH:		100	LBS.
FINE AGGREGATE:		1520	LBS.
COARSE AGGREGATE1:		1740	LBS.
COARSE AGGREGATE2:			LBS.
MIXING WATER:		31	GALS.

ADMIXTURES
AIR ENTRAINING:
WATER REDUCING:
ACCEL/RETARD: 14 oz
OTHER:

LOAD INFORMATION
TICKET: 349162
TRUCK: 1156
SLUMP: 4.50 IN.
AIR CONTENT: NONE TAKEN
CONCRETE TEMP:
WATER ADDED: 0 GALS.
NOTES:

FIELD TEST DATA
YARD: 21 **TIME SAMPLED:** 2:50 pm
AIR TEMP: **MADE BY:** 047
DATE RECEIVED: 06/30/93

CYLINDER NUMBER	TEST DATE	TEST AGE	TYPE CURING	CYLINDER DIA.-IN.	AREA SQ.IN.	MAXIMUM LOAD-LBS.	STRENGTH PSI	FRAC. TYPE	STRENGTH REVIEW
06654	07/06/93	7	Lab	6.00	28.27	148700	5260	A	
06655	07/27/93	28	Lab	6.00	28.27	191050	6760	A	
06656	07/27/93	28	Lab	6.00	28.27	180050	6370	A	
06657		R	Lab	6.00	28.27				Reserve

X_i @28 days = 6570 PSI

A) CONE B) CONE AND SPLIT C) CONE AND SHEAR D) SHEAR E) COLUMNAR

GENERAL NOTES
Possible unacceptable test result if **STRENGTH REVIEW** = "-".
Sampling: In accordance with ASTM C-172, except that sample may have been taken from the beginning of the load after minimum discharge of approximately one cubic yard.
Cylinder casting and laboratory curing: In accordance with ASTM C-31.

CYLINDERS TESTED BY: 089

DEFECTS NOTED UPON ARRIVAL:
Compressive strength test: In accordance with ASTM C-39.

STS Construction Technology Group
Concrete Compressive Strength Report

PROJECT NAME: Free-Fall Concrete
PROJECT LOCATION: 1869 Techny Road
Northbrook, IL
STS PROJECT NUMBER: 27618
STS PROJECT ENGINEER: Tony A. Kiefer

SET NUMBER: 3.0
CONCRETE DESIGN STRENGTH: 4000 PSI
DATE SAMPLED AND CAST: 06/30/93

GENERAL PROJECT INFORMATION

OWNER: STS Consultants
CLIENT: ASDC
ARCHITECT:
GENERAL CONTRACTOR: Milgard
STRUCTURAL ENGINEER:
CONCRETE CONTRACTOR: Prairie Materials

CONCRETE PLACEMENT LOCATION: SOUTH CAISSON (SUPERPLASTICISER)

MIX DESIGN INFORMATION (NOT PROVIDED)
NAME OF SUPPLIER:
MIX DESIGNATION: 2994
MIX DESIGN STRENGTH:

MATERIALS USED **PER CUBIC YARD**
CEMENT (TYPE): ______ ______ LBS.
FLY ASH: ______ LBS.
FINE AGGREGATE: ______ LBS.
COARSE AGGREGATE1: ______ LBS.
COARSE AGGREGATE2: ______ LBS.
MIXING WATER: ______ GALS.

ADMIXTURES
AIR ENTRAINING:
WATER REDUCING:
ACCEL/RETARD:
OTHER:

LOAD INFORMATION
TICKET:
TRUCK: 901
SLUMP: 7.50 IN.
AIR CONTENT: NONE TAKEN
CONCRETE TEMP:
WATER ADDED: 0 GALS.

NOTES:

FIELD TEST DATA
YARD: ___ **TIME SAMPLED:** 11:30 am
AIR TEMP: 68 F **MADE BY:** 047
DATE RECEIVED: 07/01/93

CYLINDER NUMBER	TEST DATE	TEST AGE	TYPE CURING	CYLINDER DIA.-IN.	AREA SQ.IN.	MAXIMUM LOAD-LBS.	STRENGTH PSI	FRAC. TYPE	STRENGTH REVIEW
06674	07/07/93	7	Lab	6.00	28.27	111450	3940		L
06675	07/28/93	28	Lab	6.00	28.27	164550	5820	A	
06676	07/28/93	28	Lab	6.00	28.27	155500	5500	A	
06677		R	Lab	6.00	28.27				Reserve

X_i **@28 days =** 5660 PSI

A) CONE **B) CONE AND SPLIT** **C) CONE AND SHEAR** **D) SHEAR** **E) COLUMNAR**

GENERAL NOTES

Possible unacceptable test result if **STRENGTH REVIEW** = "-".
Sampling: In accordance with ASTM C-172, except that sample may have been taken from the beginning of the load after minimum discharge of approximately one cubic yard.
Cylinder casting and laboratory curing: In accordance with ASTM C-31.

CYLINDERS TESTED BY: 089

DEFECTS NOTED UPON ARRIVAL:
Compressive strength test: In accordance with ASTM C-39.

STS Construction Technology Group
Concrete Compressive Strength Report

PROJECT NAME: Free-Fall Concrete
PROJECT LOCATION: 1869 Techny Road
Northbrook, IL
STS PROJECT NUMBER: 27618
STS PROJECT ENGINEER: Tony A. Kiefer

SET NUMBER: 2.0
CONCRETE DESIGN STRENGTH: 4000 PSI
DATE SAMPLED AND CAST: 06/29/93

GENERAL PROJECT INFORMATION

OWNER: STS Consultants
CLIENT: ASDC
ARCHITECT:
GENERAL CONTRACTOR: Milgard
STRUCTURAL ENGINEER:
CONCRETE CONTRACTOR: Prairie Materials

CONCRETE PLACEMENT LOCATION: ELEV -20 NORTH CAISSON (TECHNY)

MIX DESIGN INFORMATION

NAME OF SUPPLIER: PRAIRIE MATERIAL
MIX DESIGNATION: S1232
MIX DESIGN STRENGTH: 4000 PSI @28 DAYS

MATERIALS USED		**PER CUBIC YARD**	
CEMENT (TYPE):	______	480	LBS.
FLY ASH:		100	LBS.
FINE AGGREGATE:		1460	LBS.
COARSE AGGREGATE1:		1740	LBS.
COARSE AGGREGATE2:			LBS.
MIXING WATER:		34	GALS.

ADMIXTURES
AIR ENTRAINING:
WATER REDUCING:
ACCEL/RETARD: 15 oz
OTHER:

LOAD INFORMATION

TICKET: 349160
TRUCK: 1176
SLUMP: 7.00 IN.
AIR CONTENT: NONE TAKEN
CONCRETE TEMP:
WATER ADDED: 5 GALS.

NOTES:

FIELD TEST DATA

YARD: 21 **TIME SAMPLED:** 3:30 pm
AIR TEMP: 80 F **MADE BY:** 147
DATE RECEIVED: 06/30/93

CYLINDER NUMBER	TEST DATE	TEST AGE	TYPE CURING	CYLINDER DIA.-IN.	AREA SQ.IN.	MAXIMUM LOAD-LBS.	STRENGTH PSI	FRAC. TYPE	STRENGTH REVIEW
06658	07/06/93	7	Lab	6.00	28.27	128800	4560	A	
06659	07/27/93	28	Lab	6.00	28.27	166200	5880	A	
06660	07/27/93	28	Lab	6.00	28.27	176850	6260	A	
06661		R	Lab	6.00	28.27				Reserve

X_i **@28 days =** **6070 PSI**

A) CONE **B) CONE AND SPLIT** **C) CONE AND SHEAR** **D) SHEAR** **E) COLUMNAR**

GENERAL NOTES

Possible unacceptable test result if **STRENGTH REVIEW** = "-".
Sampling: In accordance with ASTM C-172, except that sample may have been taken from the beginning of the load after minimum discharge of approximately one cubic yard.
Cylinder casting and laboratory curing: In accordance with ASTM C-31.

CYLINDERS TESTED BY: 089

DEFECTS NOTED UPON ARRIVAL:
Compressive strength test: In accordance with ASTM C-39.

STS Construction Technology Group
Concrete Compressive Strength Report

PROJECT NAME: Free-Fall Concrete
PROJECT LOCATION: 1869 Techny Road
Northbrook, IL
STS PROJECT NUMBER: 27618
STS PROJECT ENGINEER: Tony A. Kiefer

SET NUMBER: 5.0
CONCRETE DESIGN STRENGTH: 4000 PSI
DATE SAMPLED AND CAST: 07/01/93

GENERAL PROJECT INFORMATION

OWNER: STS Consultants
CLIENT: ASDC
ARCHITECT:
GENERAL CONTRACTOR: Milgard
STRUCTURAL ENGINEER:
CONCRETE CONTRACTOR: Prairie Materials

CONCRETE PLACEMENT LOCATION: EAST CAISSON (40-50)

MIX DESIGN INFORMATION (NOT PROVIDED)
NAME OF SUPPLIER:
MIX DESIGNATION: 2
MIX DESIGN STRENGTH:

MATERIALS USED		**PER CUBIC YARD**
CEMENT (TYPE):		LBS.
FLY ASH:		LBS.
FINE AGGREGATE:		LBS.
COARSE AGGREGATE1:		LBS.
COARSE AGGREGATE2:		LBS.
MIXING WATER:		GALS.

ADMIXTURES
AIR ENTRAINING:
WATER REDUCING:
ACCEL/RETARD:
OTHER:

LOAD INFORMATION
TICKET: 349245
TRUCK: 1178
SLUMP: 7.50 IN.
AIR CONTENT: NONE TAKEN
CONCRETE TEMP:
WATER ADDED: 2 GALS.

NOTES:

FIELD TEST DATA
YARD:
TIME SAMPLED: 11:00 am
AIR TEMP: 70 F
MADE BY:
DATE RECEIVED: 07/02/93

CYLINDER NUMBER	TEST DATE	TEST AGE	TYPE CURING	CYLINDER DIA.-IN.	AREA SQ.IN.	MAXIMUM LOAD-LBS.	STRENGTH PSI	FRAC. TYPE	STRENGTH REVIEW
06682	07/08/93	7	Lab	6.00	28.27	131000	4630		L
06683	07/29/93	28	Lab	6.00	28.27	169650	6000	A	
06684	07/29/93	28	Lab	6.00	28.27	159850	5650	A	
06685		R	Lab	6.00	28.27				Reserve

X_i **@28 days =** **5830 PSI**

A) CONE B) CONE AND SPLIT C) CONE AND SHEAR D) SHEAR E) COLUMNAR

GENERAL NOTES

Possible unacceptable test result if **STRENGTH REVIEW** = "-".
Sampling: In accordance with ASTM C-172, except that sample may have been taken from the beginning of the load after minimum discharge of approximately one cubic yard.
Cylinder casting and laboratory curing: In accordance with ASTM C-31.

CYLINDERS TESTED BY: 089

DEFECTS NOTED UPON ARRIVAL:
Compressive strength test: In accordance with ASTM C-39.

STS Construction Technology Group
Concrete Compressive Strength Report

PROJECT NAME: Free-Fall Concrete
PROJECT LOCATION: 1869 Techny Road
Northbrook, IL
STS PROJECT NUMBER: 27618
STS PROJECT ENGINEER: Tony A. Kiefer

SET NUMBER: 4.0
CONCRETE DESIGN STRENGTH: 4000 PSI
DATE SAMPLED AND CAST: 06/30/93

GENERAL PROJECT INFORMATION

OWNER: STS Consultants
CLIENT: ASDC
ARCHITECT:
GENERAL CONTRACTOR: Milgard
STRUCTURAL ENGINEER:
CONCRETE CONTRACTOR: Prairie Materials

CONCRETE PLACEMENT LOCATION: SOUTH CAISSON (NO SUPERPLASTICIZER)

MIX DESIGN INFORMATION (NOT PROVIDED)
NAME OF SUPPLIER:
MIX DESIGNATION: 2995
MIX DESIGN STRENGTH:

MATERIALS USED		**PER CUBIC YARD**
CEMENT (TYPE):		LBS.
FLY ASH:		LBS.
FINE AGGREGATE:		LBS.
COARSE AGGREGATE1:		LBS.
COARSE AGGREGATE2:		LBS.
MIXING WATER:		GALS.

ADMIXTURES
AIR ENTRAINING:
WATER REDUCING:
ACCEL/RETARD:
OTHER:

LOAD INFORMATION
TICKET:
TRUCK: 610
SLUMP: 7.00 IN.
AIR CONTENT: NONE TAKEN
CONCRETE TEMP:
WATER ADDED: 0 GALS.
NOTES:

FIELD TEST DATA
YARD:
TIME SAMPLED: 11:45 pm
AIR TEMP: 68 F
MADE BY: 047
DATE RECEIVED: 07/01/93

CYLINDER NUMBER	TEST DATE	TEST AGE	TYPE CURING	CYLINDER DIA.-IN.	AREA SQ.IN.	MAXIMUM LOAD-LBS.	STRENGTH PSI	FRAC. TYPE	STRENGTH REVIEW
06678	07/07/93	7	Lab	6.00	28.27	92650	3280		L
06679	07/28/93	28	Lab	6.00	28.27	145450	5150	A	
06680	07/28/93	28	Lab	6.00	28.27	140300	4960	A	
06681		R	Lab	6.00	28.27				Reserve

X_i **@28 days =** 5060 PSI

A) CONE **B) CONE AND SPLIT** **C) CONE AND SHEAR** **D) SHEAR** **E) COLUMNAR**

GENERAL NOTES
Possible unacceptable test result if **STRENGTH REVIEW** = "-".
Sampling: In accordance with ASTM C-172, except that sample may have been taken from the beginning of the load after minimum discharge of approximately one cubic yard.
Cylinder casting and laboratory curing: In accordance with ASTM C-31.

CYLINDERS TESTED BY: 089

DEFECTS NOTED UPON ARRIVAL:
Compressive strength test: In accordance with ASTM C-39.

STS Construction Technology Group

Concrete Compressive Strength Report

PROJECT NAME: Free-Fall Concrete
PROJECT LOCATION: 1869 Techny Road
Northbrook, IL
STS PROJECT NUMBER: 27618
STS PROJECT ENGINEER: Tony A. Kiefer

SET NUMBER: 7.0
CONCRETE DESIGN STRENGTH: 4000 PSI
DATE SAMPLED AND CAST: 07/01/93

GENERAL PROJECT INFORMATION

OWNER: STS Consultants
CLIENT: ASDC
ARCHITECT:
GENERAL CONTRACTOR: Milgard
STRUCTURAL ENGINEER:
CONCRETE CONTRACTOR: Prairie Materials

CONCRETE PLACEMENT LOCATION: EAST CAISSON (30'-40')

MIX DESIGN INFORMATION (NOT PROVIDED)
NAME OF SUPPLIER:
MIX DESIGNATION: 3
MIX DESIGN STRENGTH:

MATERIALS USED		**PER CUBIC YARD**
CEMENT (TYPE):		LBS.
FLY ASH:		LBS.
FINE AGGREGATE:		LBS.
COARSE AGGREGATE1:		LBS.
COARSE AGGREGATE2:		LBS.
MIXING WATER:		GALS.

ADMIXTURES
AIR ENTRAINING:
WATER REDUCING:
ACCEL/RETARD:
OTHER:

LOAD INFORMATION
TICKET: 18516
TRUCK: 547
SLUMP: 5.50 IN.
AIR CONTENT: NONE TAKEN
CONCRETE TEMP:
WATER ADDED: 14 GALS.

NOTES:

FIELD TEST DATA
YARD:
TIME SAMPLED: 11:00 am
AIR TEMP: 70 F
MADE BY:
DATE RECEIVED: 07/02/93

CYLINDER NUMBER	TEST DATE	TEST AGE	TYPE CURING	CYLINDER DIA.-IN.	AREA SQ.IN.	MAXIMUM LOAD-LBS.	STRENGTH PSI	FRAC. TYPE	STRENGTH REVIEW
06690	07/08/93	7	Lab	6.00	28.27	93050	3290		L
06691	07/29/93	28	Lab	6.00	28.27	138550	4900	A	
06692	07/29/93	28	Lab	6.00	28.27	132000	4670	A	
06693		R	Lab	6.00	28.27				Reserve

X_i **@28 days = 4790 PSI**

A) CONE   B) CONE AND SPLIT   C) CONE AND SHEAR   D) SHEAR   E) COLUMNAR

GENERAL NOTES

Possible unacceptable test result if **STRENGTH REVIEW** = "-".
Sampling: In accordance with ASTM C-172, except that sample may have been taken from the beginning of the load after minimum discharge of approximately one cubic yard.
Cylinder casting and laboratory curing: In accordance with ASTM C-31.

CYLINDERS TESTED BY: 089

DEFECTS NOTED UPON ARRIVAL:
Compressive strength test: In accordance with ASTM C-39.

STS Construction Technology Group
Concrete Compressive Strength Report

PROJECT NAME: Free-Fall Concrete
PROJECT LOCATION: 1869 Techny Road
Northbrook, IL
STS PROJECT NUMBER: 27618
STS PROJECT ENGINEER: Tony A. Kiefer

SET NUMBER: 6.0
CONCRETE DESIGN STRENGTH: 4000 PSI
DATE SAMPLED AND CAST: 07/01/93

GENERAL PROJECT INFORMATION

OWNER: STS Consultants
CLIENT: ASDC
ARCHITECT:
GENERAL CONTRACTOR: Milgard
STRUCTURAL ENGINEER:
CONCRETE CONTRACTOR: Prairie Materials

CONCRETE PLACEMENT LOCATION: EAST CAISSON (50-60)

MIX DESIGN INFORMATION (NOT PROVIDED)
NAME OF SUPPLIER:
MIX DESIGNATION: 4
MIX DESIGN STRENGTH:

MATERIALS USED		**PER CUBIC YARD**
CEMENT (TYPE):		LBS.
FLY ASH:		LBS.
FINE AGGREGATE:		LBS.
COARSE AGGREGATE1:		LBS.
COARSE AGGREGATE2:		LBS.
MIXING WATER:		GALS.

ADMIXTURES
AIR ENTRAINING:
WATER REDUCING:
ACCEL/RETARD:
OTHER:

LOAD INFORMATION
TICKET: 18517
TRUCK: 9101
SLUMP: 7.00 IN.
AIR CONTENT: NONE TAKEN
CONCRETE TEMP:
WATER ADDED: 15 GALS.
NOTES:

FIELD TEST DATA
YARD: **TIME SAMPLED:** 11:00 am
AIR TEMP: 70 F **MADE BY:**
DATE RECEIVED: 07/02/93

CYLINDER NUMBER	TEST DATE	TEST AGE	TYPE CURING	CYLINDER DIA.-IN.	AREA SQ.IN.	MAXIMUM LOAD-LBS.	STRENGTH PSI	FRAC. TYPE	STRENGTH REVIEW
06686	07/08/93	7	Lab	6.00	28.27	117450	4150		L
06687	07/29/93	28	Lab	6.00	28.27	184250	6520	A	
06688	07/29/93	28	Lab	6.00	28.27	187550	6630	A	
06689		R	Lab	6.00	28.27				Reserve

X_i @28 days = 6580 PSI

A) CONE B) CONE AND SPLIT C) CONE AND SHEAR D) SHEAR E) COLUMNAR

GENERAL NOTES
Possible unacceptable test result if **STRENGTH REVIEW** = "-".
Sampling: In accordance with ASTM C-172, except that sample may have been taken from the beginning of the load after minimum discharge of approximately one cubic yard.
Cylinder casting and laboratory curing: In accordance with ASTM C-31.

CYLINDERS TESTED BY: 089

DEFECTS NOTED UPON ARRIVAL:
Compressive strength test: In accordance with ASTM C-39.

STS Construction Technology Group
Concrete Compressive Strength Report

PROJECT NAME: Free-Fall Concrete
PROJECT LOCATION: 1869 Techny Road
Northbrook, IL
STS PROJECT NUMBER: 27618
STS PROJECT ENGINEER: Tony A. Kiefer

SET NUMBER: 9.0
CONCRETE DESIGN STRENGTH: 4000 PSI
DATE SAMPLED AND CAST: 07/01/93

GENERAL PROJECT INFORMATION

OWNER: STS Consultants
CLIENT: ASDC
ARCHITECT:
GENERAL CONTRACTOR: Milgard
STRUCTURAL ENGINEER:
CONCRETE CONTRACTOR: Prairie Materials

CONCRETE PLACEMENT LOCATION: WEST CAISSON (30'-60' SUPERPLASTICIZER)

MIX DESIGN INFORMATION (NOT PROVIDED)
NAME OF SUPPLIER:
MIX DESIGNATION: 3
MIX DESIGN STRENGTH:

MATERIALS USED		**PER CUBIC YARD**
CEMENT (TYPE):		LBS.
FLY ASH:		LBS.
FINE AGGREGATE:		LBS.
COARSE AGGREGATE1:		LBS.
COARSE AGGREGATE2:		LBS.
MIXING WATER:		GALS.

ADMIXTURES
AIR ENTRAINING:
WATER REDUCING:
ACCEL/RETARD:
OTHER:

LOAD INFORMATION
TICKET:
TRUCK: 912
SLUMP: 7.50 IN.
AIR CONTENT: NONE TAKEN
CONCRETE TEMP:
WATER ADDED: 0 GALS.

NOTES:

FIELD TEST DATA
YARD:
TIME SAMPLED: 3:30 pm
AIR TEMP: 72 F
MADE BY:
DATE RECEIVED: 07/02/93

CYLINDER NUMBER	TEST DATE	TEST AGE	TYPE CURING	CYLINDER DIA.-IN.	AREA SQ.IN.	MAXIMUM LOAD-LBS.	STRENGTH PSI	FRAC. TYPE	STRENGTH REVIEW
06698	07/08/93	7	Lab	6.00	28.27	110550	3910		L
06699	07/29/93	28	Lab	6.00	28.27	178550	6320	A	
06700	07/29/93	28	Lab	6.00	28.27	178100	6300	A	
06701		R	Lab	6.00	28.27				Reserve

X_i @28 days = 6310 PSI

A) CONE B) CONE AND SPLIT C) CONE AND SHEAR D) SHEAR E) COLUMNAR

GENERAL NOTES
Possible unacceptable test result if **STRENGTH REVIEW** = "-".
Sampling: In accordance with ASTM C-172, except that sample may have been taken from the beginning of the load after minimum discharge of approximately one cubic yard.
Cylinder casting and laboratory curing: In accordance with ASTM C-31.

CYLINDERS TESTED BY: 089

DEFECTS NOTED UPON ARRIVAL:
Compressive strength test: In accordance with ASTM C-39.

STS Construction Technology Group

Concrete Compressive Strength Report

PROJECT NAME: Free-Fall Concrete
PROJECT LOCATION: 1869 Techny Road
Northbrook, IL
STS PROJECT NUMBER: 27618
STS PROJECT ENGINEER: Tony A. Kiefer

SET NUMBER: 8.0
CONCRETE DESIGN STRENGTH: 4000 PSI
DATE SAMPLED AND CAST: 07/01/93

GENERAL PROJECT INFORMATION

OWNER: STS Consultants
CLIENT: ASDC
ARCHITECT:
GENERAL CONTRACTOR: Milgard
STRUCTURAL ENGINEER:
CONCRETE CONTRACTOR: Prairie Materials

CONCRETE PLACEMENT LOCATION: EAST CAISSON (20′-30′ SUPERPLASTICIZER)

MIX DESIGN INFORMATION (NOT PROVIDED)
NAME OF SUPPLIER:
MIX DESIGNATION: 1
MIX DESIGN STRENGTH:

MATERIALS USED		**PER CUBIC YARD**	
CEMENT (TYPE):			LBS.
FLY ASH:			LBS.
FINE AGGREGATE:			LBS.
COARSE AGGREGATE1:			LBS.
COARSE AGGREGATE2:			LBS.
MIXING WATER:			GALS.

ADMIXTURES
AIR ENTRAINING:
WATER REDUCING:
ACCEL/RETARD:
OTHER:

LOAD INFORMATION
TICKET:
TRUCK: 1156
SLUMP: 8.25 IN.
AIR CONTENT: NONE TAKEN
CONCRETE TEMP:
WATER ADDED: 8 GALS.

NOTES:

FIELD TEST DATA
YARD:
TIME SAMPLED: 11:30 am
AIR TEMP: 70 F
MADE BY:
DATE RECEIVED: 07/02/93

CYLINDER NUMBER	**TEST DATE**	**TEST AGE**	**TYPE CURING**	**CYLINDER DIA.-IN.**	**AREA SQ.IN.**	**MAXIMUM LOAD-LBS.**	**STRENGTH PSI**	**FRAC. TYPE**	**STRENGTH REVIEW**
06694	07/08/93	7	Lab	6.00	28.27	119750	4240		L
06695	07/29/93	28	Lab	6.00	28.27	170050	6020	A	
06696	07/29/93	28	Lab	6.00	28.27	163800	5790	A	
06697		R	Lab	6.00	28.27				Reserve

X_i **@28 days =** **5910 PSI**

A) CONE **B) CONE AND SPLIT** **C) CONE AND SHEAR** **D) SHEAR** **E) COLUMNAR**

GENERAL NOTES
Possible unacceptable test result if **STRENGTH REVIEW** = "-".
Sampling: In accordance with ASTM C-172, except that sample may have been taken from the beginning of the load after minimum discharge of approximately one cubic yard.
Cylinder casting and laboratory curing: In accordance with ASTM C-31.

CYLINDERS TESTED BY: 089

DEFECTS NOTED UPON ARRIVAL:
Compressive strength test: In accordance with ASTM C-39.

STS Construction Technology Group

Concrete Compressive Strength Report

PROJECT NAME: Free-Fall Concrete
PROJECT LOCATION: 1869 Techny Road
Northbrook, IL
STS PROJECT NUMBER: 27618
STS PROJECT ENGINEER: Tony A. Kiefer

SET NUMBER: 10.0
CONCRETE DESIGN STRENGTH: 4000 PSI
DATE SAMPLED AND CAST: 07/01/93

GENERAL PROJECT INFORMATION

OWNER: STS Consultants
CLIENT: ASDC
ARCHITECT:
GENERAL CONTRACTOR: Milgard
STRUCTURAL ENGINEER:
CONCRETE CONTRACTOR: Prairie Materials

CONCRETE PLACEMENT LOCATION: WEST CAISSON (0-30')

MIX DESIGN INFORMATION (NOT PROVIDED)
NAME OF SUPPLIER: ______
MIX DESIGNATION: 1
MIX DESIGN STRENGTH: ______
MATERIALS USED **PER CUBIC YARD**
CEMENT (TYPE): ______ ______ LBS.
FLY ASH: ______ LBS.
FINE AGGREGATE: ______ LBS.
COARSE AGGREGATE1: ______ LBS.
COARSE AGGREGATE2: ______ LBS.
MIXING WATER: ______ GALS.

ADMIXTURES
AIR ENTRAINING: ______
WATER REDUCING: ______
ACCEL/RETARD: ______
OTHER: ______

LOAD INFORMATION
TICKET: ______
TRUCK: 1102
SLUMP: 5.50 IN.
AIR CONTENT: NONE TAKEN
CONCRETE TEMP: ______
WATER ADDED: 0 GALS.
NOTES: ______

FIELD TEST DATA
YARD: ___ **TIME SAMPLED:** 3:45 pm
AIR TEMP: 75 F **MADE BY:** ___
DATE RECEIVED: 07/02/93

CYLINDER NUMBER	TEST DATE	TEST AGE	TYPE CURING	CYLINDER DIA.-IN.	AREA SQ.IN.	MAXIMUM LOAD-LBS.	STRENGTH PSI	FRAC. TYPE	STRENGTH REVIEW
06702	07/08/93	7	Lab	6.00	28.27	121450	4300		L
06703	07/29/93	28	Lab	6.00	28.27	162200	5740	A	
06704	07/29/93	28	Lab	6.00	28.27	166200	5880	A	
06705		R	Lab	6.00	28.27				Reserve

X_i @28 days = 5810 PSI

A) CONE B) CONE AND SPLIT C) CONE AND SHEAR D) SHEAR E) COLUMNAR

GENERAL NOTES
Possible unacceptable test result if **STRENGTH REVIEW** = "-".
Sampling: In accordance with ASTM C-172, except that sample may have been taken from the beginning of the load after minimum discharge of approximately one cubic yard.
Cylinder casting and laboratory curing: In accordance with ASTM C-31.
CYLINDERS TESTED BY: 089

DEFECTS NOTED UPON ARRIVAL: ______
Compressive strength test: In accordance with ASTM C-39.

Material Service Corporation
222 North LaSalle Street
Chicago, Illinois 60601
312/372-3600

Mix Design

Return to
Material Service Corporation

☐ Approved

☐ Approved as noted

☐ Resubmit as noted

☐ Reviewed

☐ Reviewed as noted

By ________ Date ________

Date June 28, 1993

Contractor Case, Millgard, Goettle Joint Venture

Project ADSC Research Program

Location Northbrook, Illinois

Material Service Corporation Mix Number			2994	2995		
Specified strength	PSI @	28 days	4000	4000		
Specified slump range	Inches		4-5	7-8		
Specified air content	Percent		----	----		
Placement method						
Usage		*Caisson concrete - 5/8" aggregate normal consistency **Caisson concrete - 5/8" aggregate high slump	*	**		
		Material specification and description	**One cubic yard weights (SSD)**			
Cement	Lbs	ASTM C-150 TYPE I	470	500		
Fly ash	Lbs	ASTM C-618	100	100		
Fine aggregate	Lbs	ASTM C-33	1420	1400		
Coarse aggregate	Lbs	ASTM C-33 #7 STONE	1750	1700		
Coarse aggregate	Lbs					
Water	Lbs	ASTM C-94 POTABLE	300	330		
Water reducing admixture		ASTM C-494 TYPE D RETARDER	14.1	15.5		
Air entraining agent						
WATER CEMENTITIOUS		RATIO AS PER ACI 211.1	.53	.53		

Remarks

Please Note: This submittal certifies that the materials to be used conform to the indicated specifications.

Please notify this office as to the acceptance or rejection of these mix designs. Lack of response prior to first pour shall constitute acceptance.

Evaluation of this concrete must be conducted in accordance with current ASTM and ACI standards.

Please furnish us compressive strength test results for evaluation per ACI 318.

Respectfully submitted,

Arthur A. King

Arthur A. King
Manager, Technical Service

AAK/sm
cc: Joe Harmening
Joni Jenkins

STS Consultants
Tony Kiefer - FAX

University of Houston
Department of Civil and Environmental Engineering

Reply to:
Michael W. O'Neill, PhD, PE
John and Rebecca Moores Professor of Civil Engineering
Department of Civil and Environmental Engineering
University of Houston
Houston, TX 77204-4791

Phone: (713) 743-4252 *Fax*: (713) 743-4260 *e-mail*: "Oneill@uh.edu"

February 4, 1998

Mr. S. Scot Litke
Executive Director
ADSC: The International Association of Foundation Drilling
P. O. Box 280379
Dallas, Texas 75228

Re: Final report for Phase I research project on drilled shafts with minor defects

Dear Scot,

Enclosed are nine copies of the final report for Phase I of the above project. I intended for two of the copies to remain with the ADSC and for seven to be forwarded on to Al DiMillio. I would expect him, in turn, to send a copy to each state participant. If there is a shortage, please let me know, and I will send additional copies to you or Al, as directed by you. Please note that our funds for this phase are completely depleted and that we have not made provisions to send more than one copy to each individual state participant. We can conveniently use these reports as a point of departure for our meeting with all of the participants in the early part of Phase II.

We have enjoyed working with the ADSC, as usual, on this project, and we look forward to starting Phase II immediately. Please especially thank A. H. Beck Company for their considerable "sweat equity" help in executing the field tests.

Sincerely,

Michael W. O'Neill, PhD, PE
Principal Investigator

cc: Report cover material only, UH OSP (Budget No. 1-5-5749)

ADSC Code TL112

The International Association of Foundation Drilling

P.O. Box 280379
Dallas, Texas 75228
Phone: 214/343-2091 • FAX: 214/343-2384