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EFFECT OF PUMPING ON CONCRETE, PHASE II

WP Item No. 0510681

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Submitted to the
Florida Department of Transportation
and
Federal Highway Administration

By
Nur Yazdani, Ph.D., P.E.

August, 1998

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16. Abstract

This report summarizes the second part of an original FDOT sponsored project titled "Effect of Pumping on Concrete." The final report for the original project was completed in 1996. Both studies investigated the changes which occur in concrete due to the effect of pumping. The studied are important because the pumping of fresh concrete is gaining popularity due to economics and ease of construction. The detrimental and beneficial effects of pumping, if any, should be known so that they may be accounted for in design. Concrete samples were collected and analyzed from 11 FDOT construction sites before and after pumping, during the original project. In the second phase, an additional 62 samples were collected and analyzed. This report presents the combined results for 73 samples from both studies. Collection and testing of concrete were performed in accordance with the ASTM and AASHTO test methods. By testing samples before and after pumping, the changes in the properties of concrete due to pumping were determined. The tests used in this study were Air Content (ASTM C173), Slump (ASTM C143), Unit Weight (ASTM C138), Compressive Strength (ASTM C39), Rapid Chloride Permeability (AASHTO T277), and Water Permeability (FDOT). The test results were statistically analyzed to determine whether the changes caused by pumping were statistically significant. The air content and the slump of concrete decreased by of about one percent and 13 mm (0.5 in) on the average, respectively, due to pumping. The unit weight and compressive strength of concrete were found to increase by about 24 kg/m^3 (1.5 pcf) and 1.83 Mpa (266 psi), respectively, due to pumping. Pumping decreased the water and chloride ion permeabilities in the majority of tested samples. Results show that pumping does not have detrimental effects on concrete properties. In many cases, it results in stronger, denser, and more durable concrete. It is suggested that pumping be continued as a means on concrete placement on FDOT projects with confidence.

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ABSTRACT

This report summarizes the second part of an original FDOT sponsored project titled "Effect of Pumping on Concrete." The final report for the original project was completed in 1996. Both studies investigated the changes which occur in concrete due to the effect of pumping. The studied are important because the pumping of fresh concrete is gaining popularity due to economics and ease of construction. The detrimental and beneficial effects of pumping, if any, should be known so that they may be accounted for in design. Concrete samples were collected and analyzed from 11 FDOT construction sites before and after pumping, during the original project. In the second phase, an additional 62 samples were collected and analyzed. This report presents the combined results for 73 samples from both studies. Collection and testing of concrete were performed in accordance with the ASTM and AASHTO test methods. By testing samples before and after pumping, the changes in the properties of concrete due to pumping were determined. The tests used in this study were Air Content (ASTM C173), Slump (ASTM C143), Unit Weight (ASTM C138), Compressive Strength (ASTM C39), Rapid Chloride Permeability (AASHTO T277), and Water Permeability (FDOT). The test results were statistically analyzed to determine whether the changes caused by pumping were statistically significant. The air content and the slump of concrete decreased by of about one percent and 13 mm (0.5 in) on the average, respectively, due to pumping. The unit weight and compressive strength of concrete were found to increase by about 24 kg/m^3 (1.5 pcf) and 1.83 Mpa (266 psi), respectively, due to pumping. Pumping decreased the water and chloride ion permeabilities in the majority of tested samples. Results show that pumping does not have detrimental effects on concrete

properties. In many cases, it results in stronger, denser, and more durable concrete. It is suggested that pumping be continued as a means on concrete placement on FDOT projects with confidence

CHAPTER 1

INTRODUCTION

Pumping as a means of concrete placement in large projects has gained substantial popularity due to economics and ease of construction. Pumped concrete has been widely used in Florida Department of Transportation (FDOT) projects, such as bridges. The short-term effects of pumping on concrete such as slump loss and air loss are well known, and studies on these effects have been undertaken. The long-term effect of pumping on the durability of concrete is much less understood. Contractors supplying concrete on FDOT projects are responsible only for the short-term properties; therefore, there is a need to study the effect of pumping on the long-term durability problems observed in FDOT concrete. It has been shown in many research studies that concrete durability in aggressive environments is dependent upon, among other parameters, the volume and quality of entrained air and the liquid and chloride ion permeability. Although the total volume change of entrained air due to pumping is established in industry, the extent to which pumping affects the air void system in Florida concrete has not been investigated to date. In the aggressive environment, which exists in the Florida Coastal areas, the rate of ion transfer between the environment and the reinforcing steel is a major concern. This can lead to corrosion, causing decreased durability and service life of concrete structures. As it is the intent of the FDOT to build structures with extended service life, any operation, such as pumping, which may greatly impact concrete durability, should be investigated.

Section 346 of the FDOT Standard Specifications for Bridge and Road Construction requires the contractors to submit the proposed concrete mix designs to the FDOT Materials Engineer for approval. FDOT specifications contain guidelines for coarse aggregate, fine aggregate, water and various admixtures in concrete mixes. However, these guidelines are not designed to reduce the adverse effects (if any) of pumping on the long-term durability of concrete. The presence of some admixtures, such as fly ash, makes concrete mixes more pumpable, although the admixtures are generally added for other primary purposes. The present intent of admixtures, such as plasticizers, is to provide workability to concrete mixes with low water to cement ratios. Typically, contractors will furnish concrete with extra air in order to compensate for air loss during pumping, but increasing air content above the maximum permitted by specifications may be risky. Because of variations in concrete properties, air loss due to pumping may not be uniform. Excessive air content may cause decreased compressive strength at some locations.

Because of the nature of tasks involved, the study was accomplished using admixture industry cooperation under field conditions. Pumping of concrete is an expensive process, and it is only feasible when high volumes of concrete are pumped. Therefore, a completely laboratory oriented study would not be practical.

It is well known that the permeability of concrete can be used as a yardstick to measure its durability, as durable concrete is generally less permeable. Two types of permeability tests are utilized for concrete mixes: water permeability and chloride ion permeability. Both can be used to gauge the durability of concrete, and both types of pumped concrete permeability were measured in this study.

The effect of pumping on concrete mixes can only be determined through comparison of test data from prepared concrete samples collected before and after pumping. This approach was utilized for all parameters considered in this study. The following specific objectives were addressed in the study. Literature on short-term effects of pumping on concrete was gathered and comprehensively organized. The effect of pumping on short term properties of several Florida concrete mixes was determined. Finally, the effect of pumping on long term durability of Florida concrete mixes was determined through measuring the permeability changes.

The study reported herein is the second part of an earlier FDOT research project titled "Effect of Pumping on Properties of Concrete", WPI No. 0510681 (Yazdani 1996). The final report for this project was submitted to FDOT in October, 1995. A total of only 11 samples were collected and analyzed during the original study. Because of the small sample size, reliable conclusions could not be drawn in the original project. Therefore, the second phase of the study was initiated by the FDOT. During this phase, a total of 62 samples were collected and analyzed, which was facilitated through the collection of multiple samples from each FDOT project site. This report contains the combined result of 73 samples from the Phase I and II studies.

CHAPTER 2

LITERATURE REVIEW

A literature review was undertaken to gather information from published articles dealing with pumping effects, pumping procedures, concrete air content and concrete concerns related to the scope of this project. The literature review covered information that was found in research reports, refereed journals and magazines. The reviewed articles were authored by professionals in the fields of concrete and pumping.

There are two main elements involved in concrete pumping: the concrete and the pump. The history of concrete is well known and thoroughly documented; however, the pump has not received quite as much attention. A brief history of the concrete pump is provided in the report *Pumping of Concrete* (Liu, 1993). Concrete was first pumped in the year 1913. The concrete pump was patented in the U.S. shortly thereafter. After World War II, pumping received worldwide acceptance as a means of placing concrete. Although more concrete is pumped in the U.S.A. than in any other country, it produces very few concrete pumps. Most of the pumps used in the U.S. are manufactured in Germany. The main reason for the popularity of concrete pumping is the reduced time required for pouring and placing. The concrete pump is also frequently more convenient than other conventional methods of placement such as bucketing and conveying. A pumpable concrete mix should be able to maintain consistency throughout the pumping process, and thereby avoid any bleeding. A poor concrete mix design may cause segregation and reduction in strength and durability. The most common practice used to make concrete pumpable is to use admixtures. The admixtures increase the workability and flow of the concrete, therefore making the pumping process easier.

The Washington Aggregates and Concrete Association performed a study titled *Effects of Pumping Air Entrained Concrete* (Washington Agg., 1991). The test involved pumping a concrete mix through a variety of boom angles. The air content of the fresh concrete was measured both before and after pumping, then compared. The summary results indicate that when there was a negative pressure in the pump line, or when the concrete was allowed to fall freely, a reduction in air content was detected in the pumped concrete. If the pump line was kept full, there was little change or even an increase in air content in the pumped concrete.

An article found in Concrete International, *Loss of Air Content in Pumped Concrete* (Yingling, 1992), details the loss of air in pumped concrete, and also lists the reasons why the losses may be expected. Three reasons are mentioned that may cause the concrete to lose air during the pumping process: first, the entrained air bubbles become extremely small due to the pump pressure and subsequently do not reform when the pumping process is finished. Second, when concrete is pumped and dropped vertically, a vacuum can be created which may remove air from pumped concrete. Finally, when concrete is pumped and dropped simultaneously, the impact that occurs may break air bubbles and cause air content losses in pumped concrete. In this study, tests were performed to investigate the loss of air in concrete during the pumping process. Concrete was pumped through a variety of boom angles and the air content was measured both before and after pumping. It was demonstrated that significant amounts of air can be lost during pumping, but losses are much less if the boom angle is very low. Also, it was observed that rapidly moving concrete lost air from dropping impact, but this air content loss could be reduced by using four ninety-degree elbows. It was also observed that pumped concrete could be remixed to restore the original pre-pumped air content.

In concrete, air voids can help improve resistance to freezing and thawing, workability, and reduce bleeding and segregation. In *Why is There Air in Concrete?* (Hover, 1993), why air content is important in concrete is discussed. Concrete contains both entrained and entrapped air. Entrained air consists of small bubbles associated with fines, and entrapped air consists of large bubbles often associated with coarse voids. Entrapped air is usually detrimental to concrete because of high porosity and poor consolidation, resulting in lower concrete strength. Entrained air, however, is beneficial for concrete because of increased workability with a smaller slump. Air-entraining admixtures chemically stabilize and trap the air bubbles produced during mixing. The air content in fresh concrete is usually measured in accordance with ASTM C173 or ASTM C231. The air content measured from ASTM C173 involves a volumetric air meter, while ASTM C231 involves a pressure meter. Both tests are more reliable when the air is entrapped rather than entrained. This is because the entrained air bubbles require more force to disperse than the entrapped air bubbles. A distinction between entrained and entrapped air in concrete is not recognized by current specifications, because they only deal with the total air content.

Full hydration of 45.5 kg (100 lbs) of cement requires 19.1 kg (42 lbs) of water. This provides a water/cement ratio of 0.42. According to *Water-Cement Ratio, Water Reducers, and Finishabilty* (Malisch, 1992), any water/cement ratio beyond 0.42 creates air voids because of the chemical bonding process. The excess water that does not bond eventually evaporates and leaves air pockets. These voids increase permeability and reduce strength. Lower water/cement ratios result in stronger concrete until a ratio of 0.36 is reached. However, lower water/cement ratio makes handling and placing more difficult. The use of superplasticizers allows the concrete to be more workable at a lower water/cement ratio. This creates a high strength workable concrete that is also pumpable.

Some Recent Problems With Air-Entrained Concrete (Hover, 1989) states that fresh concrete with entrained air tends to provide an air content reading that is lower than the actual amount of air present in the fresh concrete. It has been reported that contractors have unintentionally increased air content to meet specifications. Subsequently, microscopic analysis showed air contents that were well above allowable specifications. This problem is apparent when a significant portion of air bubbles are smaller than 0.05 mm (0.002 in) in diameter. This can lead to a large reduction in compressive strength and greater risk of side effects from the freezing and thawing cycle. In four studied cases, the air content from the fresh concrete was found to be lower than microscopic air content of the hardened concrete.

The report, *The Influence of Handling on Air-Entrained Concrete* (Hover, 1993), states that it is not unusual for concrete to lose between 1 and 1.5% of air content due to any conventional means of placement. This means that air loss in concrete may occur through other means of placing concrete besides pumping. It is assumed that the air losses in pumping are caused by free fall and impact. However, it is also stated that air content may occasionally increase in pumped concrete. This is due to the pressurization and the rapid depressurization in the pump line, and the effect is fairly easy to control by keeping the pumping pressure as low as possible.

Poor pumping procedures may be another cause of air loss in pumped concrete. *A Guide for Pumping Lightweight Concrete* (Expanded Shale, Clay, and Slate Inst., 1992) describes the responsibilities of everyone involved in the pumping process. The design engineer should ensure that the concrete mix is pumpable and has been properly tested. The general contractor should use experienced pumping personnel and provide a helper for the test inspector. The pumping contractor should use the proper size pump and a good pump operator. The concrete producer should provide good quality concrete that meets the design specifications. The testing laboratory should provide experienced field inspectors and equip them with proper equipment to accurately test the concrete.

Tips for Ordering Concrete Pumping Services (Malisch, 1992) and *Concrete Producers Who Also Pump Concrete* (Malisch, 1991) address ways to make concrete pumping more efficient. Good quality control of the concrete and of the pump is of primary importance in ensuring smooth concrete pumping. The pumping contractor handles the quality control of the pump and the field inspector handles the concrete quality control. *Batch Plant Inspection and Field Testing of Ready-Mixed Concrete* (ACI, 1988) details the testing procedure necessary to ensure quality concrete. One important step in ensuring good concrete is using a qualified inspector who is familiar with the ASTM testing procedures. The inspector should also provide daily inspection reports so that any concrete deficiencies can be identified and corrected.

The above referenced articles address the issue of concrete pumping and related topics, thereby directly addressing the basic premise of the present study. Virtually all of the surveyed literature articles deal with two issues related to concrete pumping: the loss of air content due to pumping and efficient pumping operation. No previous or present studies were encountered (except the Phase I FDOT project) which address the important question of whether pumping affects the long term durability of concrete. The literature review demonstrated conclusively the justification of performing the research work narrated in this report.

CHAPTER 3

MIX DESIGNS

A mix that is suitable for pumping should have proper gradation. It should also resist bleeding and have a nominal aggregate diameter of 37 mm (1.5 in) or less. The gradation helps in the pumping process by keeping the concrete from segregating. The small diameter aggregate keeps the pump line from becoming clogged. These same properties also help in determining how much air content will be changed during the pumping process. Concrete mixes with a high air content are more likely to lose air content during the pumping process than concrete mixes with a lower air content.

A total of 21 different mix designs were used in this research project. These mix designs were collected from the FDOT data banks and field personnel. Samples were collected from projects located in each of the FDOT's seven districts.

The copy of each FDOT approved mix design is presented in Appendix A. Concrete properties are determined at the site and in the laboratory prior to the submission and approval of the proposed mix design by the FDOT District Materials Offices. The producer's data is presented in Appendix A. The laboratory data of mix designs can be used as a reference database to compare with the results of the field-testing.

CHAPTER 4

SAMPLE COLLECTION

Concrete samples for this research project were collected from FDOT construction sites. The team of researchers visited sites in Tampa, Miami, Ft. Myers, Orlando, Pensacola, New Port Richey, and other locations in Florida. Samples were collected under a variety of climatic conditions. The process of sample collection involved extensive travel and work on the part of the research team. In the pre-travel stage the research personnel located FDOT project sites where concrete was to be placed with the use of pumps. Sampling and testing of concrete before and after the pumping procedure was the most important part of this study. Various on-site and laboratory tests on the collected concrete samples led to conclusions drawn about the effect of pumping on the properties and durability of concrete. Concrete samples were collected under a variety of climatic conditions.

Concrete samples were collected and a series of tests were performed at each site. Samples were collected using the Florida test method (FM1-T141/93). Each test was performed on the same batch of concrete before and after pumping occurred. Samples were taken by the same research personnel, using identical procedures. The field tests included Air Content, Slump, and Unit Weight. Two 100 by 200 mm (4 by 8 in) cylinders and three 150 by 300 mm (6 by 12 in) cylinders were made before and after pumping. The smaller cylinders were used for subsequent Chloride Ion Permeability and Water Permeability tests. The larger cylinders were used for Compressive Strength tests. Projects were located through FDOT personnel, consulting firms, and pumping companies. Permission to visit the site was normally obtained from the project manager of the contracting company.

Upon arrival at the project site, the research team contacted the FDOT project manager. The equipment necessary for collection of concrete samples was then set up in a convenient location. Samples were normally collected from trucks near the center of the pour to preclude samples with mixing errors. The samples were taken from the middle portion of each truck. The FDOT project engineer or his/her representative was present at the project site during the field sampling and testing.

Concrete samples were collected in two wheelbarrows, one from the truck chute and one from the end of the pump line. Concrete from each wheelbarrow was tested for air content, slump and unit weight. Also, five cylinders from each wheelbarrow were cast for later testing in the laboratory. Collecting the samples in this manner allowed the concrete to be identical except for the pumping process. This allowed the results to be compared for determination of how the pumping process affected the properties of the concrete. The samples were cured in the curing boxes that were available in the field. The final step consisted of transporting the samples to the FAMU-FSU College of Engineering. The general information about all sites visited during this research project is presented in Table 4.1. The table provides information on the test date, location, type of structure, ambient temperature, pump configuration, and general information about pumping elevation. The diameter of the hose at each location was 127 mm (5 in), and each location used a hose made of reinforced rubber.

CHAPTER 5

TESTING PROCEDURE

5.1 Introduction

Most of the tests performed in this study were in accordance with the methods specified by the American Society for Testing and Materials (ASTM) and the American Association of State and Highway Transportation Officials (AASHTO). One test (namely, the Water Permeability test) was performed using an FDOT test method. The tests consisted of field and laboratory methods. Field tests performed on fresh concrete were: Air Content by the Volumetric Method (ASTM C173), Slump (ASTM C143) and Unit Weight (ASTM C138). These tests were performed on concrete samples, which were taken before and after pumping. Each test was performed by the same research group throughout the length of the project. This process is likely to decrease multiple operator differences in results.

The cylinders for laboratory tests were stored and cured in the laboratory for 28 days prior to testing. The Compressive Strength (ASTM C39), Rapid Chloride Permeability (AASHTO T-277), and Water Permeability (FDOT Method) tests were performed in the laboratory. The Compressive Strength test was performed at the FAMU-FSU College of Engineering, using three 150 by 300 mm (6 by 12 in) cylinders made before pumping and three 150 by 300 mm (6 by 12 in) cylinders made after pumping. The Rapid Chloride Permeability and Water Permeability tests were performed at the FDOT Materials Laboratory located in Gainesville, using two 100 by 200 mm (4 by 8 in) cylinders made before pumping and two 100 by 200 mm (4 by 8 in) cylinders made after pumping.

5.2 Air Content Test (ASTM C173)

The air content of fresh concrete was determined using the volumetric method. The bottom section (bowl) of the air meter was filled with three equal layers of concrete, each layer was rodded 25 times and the sides were tapped 12 times. Once the bowl was completely filled, the excess concrete was struck off until the surface was flush with the lip of the bowl. The flange was then wiped clean. The top was clamped onto the bowl and water was added through a funnel. When water was near the top, the funnel was removed and additional water was added with syringes until the meniscus was level with the zero mark. The cap was then screwed on tightly and the entire apparatus was agitated and rolled vigorously until all of the concrete had settled free from the base. The apparatus was then allowed to stand until all the air was released and the water column became constant. The cap was then removed and isopropyl alcohol was added in 0.1% increments, using the syringe. After all bubbles were dispelled, a direct reading was taken from the neck. This reading was added to the amount of alcohol used to determine the final air content of the fresh concrete.

5.3 Slump Test (ASTM C143)

The slump cone was moistened and placed on a flat non-absorbent surface. It was then filled with concrete in three layers that were equal in volume. Each volume was rodded 25 times throughout its depth. The top layer remained above the top of the mold throughout the rodding. Excess concrete was struck off after rodding was completed. The mold was then removed by lifting directly upwards in a steady motion, with no lateral or torsional movement. This process was completed in no more than seven seconds. The mold was then inverted and the vertical distance between the top of the mold and displaced center of the concrete specimen was measured.

5.4 Unit Weight Test (ASTM C138)

The unit weight test was initiated by filling the 0.014 m^3 (0.5 ft^3) bucket with three equal layers of concrete. Each layer was rodded 25 times and tapped on the side 12 times. Rodding penetrated the previous layer by approximately 25 mm (1 in) in layers two and three. Strike off plate was used to insure that concrete was level with the lip of the mold. All excess concrete was then cleaned from the exterior of the mold. The mold and concrete were subsequently weighed. From this weight, the weight of the mold was subtracted to produce the unit weight for 0.014 m^3 (0.5 ft^3). This result was then multiplied by two to produce the unit weight per cubic meter (cubic foot).

5.5 Compressive Strength Test (ASTM C39)

The three concrete cylinders were tested as soon as possible after removal from the curing tank. Once the cylinders were removed from wet storage, sulfur mortar caps were placed on the ends to produce a plane surface for compression testing. Capping was performed according to ASTM C617 procedures. After the cylinders were capped, they were kept moist until compression testing was performed. Testing was carried out after 28 days within the 20 hour variance allowed. After the specimen faces were cleaned, they were placed in a Forney testing machine with the specimen axis directly under the center of the compressive platter. A steady rate of loading was used until the specimen failed. The compressive strength was found by dividing the maximum crushing force by the area of the specimen. The average of the strengths from the cylinders was recorded as the compressive strength.

5.6 Rapid Chloride Permeability Test (ASTM C1202)

This test was performed at the FDOT State Materials Office Durability Laboratory in Gainesville. Samples were wrapped in moist burlap and shipped to Gainesville for testing. This test monitors the amount of electrical current that passes through a 50 mm (2 in) thick slice of 100 mm (4 in) diameter concrete over a time span of six hours. One end of the concrete was immersed in a sodium chloride solution, while the other end was immersed in a sodium hydroxide solution. A potential difference of 60V DC was created across the ends of the concrete specimen and the amount of charge, in coulombs, that passed through the specimen was measured and recorded. This charge is related to the resistance of the specimen to chloride ion penetration.

5.7 Water Permeability Test (FDOT)

This test was also performed at the FDOT State Materials Office Durability Laboratory in Gainesville. Specimens were wrapped in moist burlap and shipped for testing. For this test, a 50 mm (2 in) thick slice of 100 mm (4 in) diameter concrete was placed in a permeameter and then connected to a manometer filled with water and a pressure of 0.69 MPa (100 psi). The water level in the manometer was then read daily to determine when the steady state flow was achieved. After this stage, the test was continued for approximately ten more days. The average rate of flow measured in the last seven to ten days was then used as the water permeability for the specimen.

CHAPTER 6

TEST RESULTS AND DISCUSSION

6.1 Introduction

The results obtained from field and laboratory testing were statistically analyzed to determine if a significant change occurred in the properties of the concrete due to pumping. Some of the test results showed apparent trends, later supported by statistical analysis. In this study, sets of data from before and after pumping were to be compared. The database of the test samples was large enough for the production of sound statistical results. In these situations, the best available statistical analysis tool is the paired t-test, assuming equal variances. This method allows all of the before pumping results to be compared to all of the after pumping results for a single concrete test. The paired t-test would show if a statistical change occurred in the properties of the concrete by comparing the means of the test results before pumping and the test results after pumping. A level of significance (α) of 0.05 was used in the analysis. This value ensures results that are reliable 95% of the time. The Data Analysis option contained within the Tools menu of the Excel Spreadsheet Version 7.0 of Microsoft Corporation software was used to perform the statistical analysis. Statistical test results are presented in Appendix B.

The results for each performed concrete test are listed in Tables 6.1 to 6.6. Listed results include values obtained before and after pumping. These tables also present the actual change as well as the percentage change in the results due to pumping. The results for each test are also presented graphically in Figs. 6.1 to 6.6. These graphs present each test value before and after pumping, the changes as well as the percent change in the test parameter.

6.2 Air Content Results

The results of the Air Content test are presented in Table 6.1, and Figs. 6.1 and 6.2. Review of these results indicate that the air content decreased due to pumping in 65 out of the 73 samples tested. A null hypothesis was assumed, meaning that pumping has no effect on the concrete air content. A single tailed t-test with equal variances was performed to determine if air content decrease was statistically significant. This test was used because the original study (Yazdani, 1996) showed a general decreasing trend in air content due to pumping. The t-test results indicated that the air content data have a t-value of 5.654 which falls well within the rejection region of the null hypothesis with a t-critical one-tail value of 1.655. These results indicated that there is a statistically significant change in air content due to pumping. It was observed that the air content decreased by 0.9% on the average due to pumping. This change in air content is statistically significant.

6.3 Slump Results

The results of the Slump test are presented in Table 6.2, and Figs. 6.3 and 6.4. The concrete slump increased in only nine of the 73 tested samples due to pumping. Similar to the Air Content analysis, a one-tailed t-test was performed to measure the statistical significance of the changes. Results indicated that the slump change values possess a t-statistic of 2.393, which falls within the rejection region (t >1.655) of the null hypothesis. These results clearly show that pumping has an effect on concrete slump. From an engineering standpoint, the slump is found to have an average decrease of 13 mm (0.5 in). One must keep in mind the sensitivity of this test to time, since slump tests must be performed within two and a half minutes of the time of sampling, and the fact that slump is measured to the closest 6 mm (0.25 in).

6.4 Unit Weight Results

The Unit Weight test results are presented in Table 6.3, and Figs. 6.5 and 6.6. Unit weight was found to increase in all but three of the 73 sample pairs due to pumping. Because unit weight was found to increase in general, a single tailed t-test was performed to find out if pumping significantly affects the unit weight. The t-test results showed that the unit weight change data due to pumping has a t-value of 2.7477. Again, this value falls within the rejection region of the null hypothesis, which states that pumping has no effect on the unit weight of concrete. It may be concluded from the t-test results that the unit weight change due to pumping is statistically significant. The unit weight increase due to pumping was about 24 kg/m^3 (5 pcf) on the average. This produces concrete that may be denser than desired, so this change should be taken into account if unit weight is an important part of the specifications.

6.5 Compressive Strength Results

The Compressive Strength test results are presented in Table 6.4, and Figs. 6.7 and 6.8. The compressive strength increased in all but two of the tests after pumping. A single tailed t-test was performed to determine if the compressive strength increase due to pumping was statistically significant. The t-test results showed that the compressive strength changes have a t-value of -2.0762, which is less than the -1.6555 critical t-value. This means that the null hypothesis must be rejected, and the alternate hypothesis, that pumping will increase the compressive strength of the concrete, must be accepted. The compressive strength increase was about 1.83 MPa (266 psi) on the average. This increase may not be all that important in the field because concrete mix designs tend to result in compressive strengths that vary from batch to batch.

6.6 Chloride Permeability Results

The Chloride Permeability test results are presented in Table 6.5, and Figs. 6.9 and 6.10. For this test, 32 samples showed an increase in chloride ion penetration, whereas the remaining 41 samples showed decreased chloride ion penetration after pumping. It is evident that this test is inconclusive as to whether pumping has an effect on chloride ion penetration in concrete. Because of this, a two-tailed t-test was performed to determine if a statistically significant change in chloride penetration occurred in the samples due to pumping. The t-test results showed that the chloride ion penetration data has a t-value of 0.2947, which is well within the region of acceptance ($-1.6555 < t > 1.6555$). Therefore, the null hypothesis that pumping has no effect on chloride ion penetration must be accepted. It should be noted, however, that the chloride ion penetration decreased in the majority of the samples.

6.7 Water Permeability Results

The Water Permeability results are presented in Table 6.6, and Figs. 6.11 and 6.12. The water permeability test results showed a decrease in permeability in 50 of the 73 samples due to pumping. The water permeability changes were evaluated using a two-tailed t-test to determine if they were statistically significant. The t-test results showed that the water permeability changes have a t-value of 0.9573, which falls within the region of acceptance. Therefore, similar to the chloride ion penetration results, the null hypothesis, that pumping has no effect on the water permeability of concrete, should be accepted. The water permeability decreased in nearly 70% of the tested samples.

6.8 Discussion

The test results show that pumping does have an effect on the properties of concrete, the effect being mostly positive. The most important property in this regard appears to be the air content. Table 6.7 presents sample data after pumping. The air content needs to be controlled since other properties of the concrete such as compressive strength, and unit weight are directly related to the amount of air in the concrete. Table 6.7 shows that the air content for most samples decreased due to pumping, resulting in corresponding decreases in slump, and increases in unit weight and compressive strength. This is because concrete becomes denser with the loss of air content.

The unit weight of concrete was lower after pumping only for test samples 5, 20, 65, and 69. The slump was also higher for sample 5 after pumping. For sample 20, the air content and the two permeabilities were also higher. The air content, chloride ion permeability, and slump were higher for sample 65, whereas the air content and slump were higher for sample 69. Therefore, it is observed that the unit weight results for samples 5, 20, 65, and 69 were generally consistent with other test results.

The compressive strength of concrete was found to be higher after pumping, with the exception of samples 69 and 71. The air content and slump were higher, whereas the unit weight was lower for sample 69 after pumping. For sample 71, both slump and chloride ion permeability were higher after pumping. It may be inferred that the compressive strength results are consistent in general with other test results.

There are variations in the permeability test data, especially in the chloride ion test, which are not consistent with the other test results. The inconsistencies may be due to the precision of the tests, duration of the tests, and/or age of the test samples. However, the majority of the test results for the two permeability tests indicate that permeability is expected to decrease at the end of the pump-line in most cases. It is known that concrete mixes with calcium nitrite admixtures as corrosion inhibitor will not provide reliable results for the Chloride Ion Permeability test. Only one sample mix design from this study was found to contain calcium nitrite. Therefore, the presence of calcium nitrite can be ignored in the interpretation of the chloride ion permeability results. It may be inferred from this study that pumping increases long term durability of concrete by reducing permeability in most cases. This is important because high permeability makes it easier for water and salt to penetrate concrete structures. Both of these environmental factors can adversely affect the steel reinforcement contained in the concrete by causing corrosion, leading to service life reduction.

Several factors that could vary in the field may have affected the test results obtained in this study. These factors include boom angle and length, hose diameter, temperature, pressure in the pump line and the configuration used during pumping. These factors were controlled by the project contractor; therefore, it would be impossible to keep them constant from project to project. During this study, boom angle, boom length, and hose diameter were similar for every site, with a boom length averaging about 39.6 m (130 ft) and a hose diameter of 127 mm (5 in). The pressure exerted in the line by the pump was also similar at each site. The hose pressure in the line at the sites varied between 4.8 to 6.9 MPa (700 to 1000 psi) during the pumping of an entire batch of concrete. No significant effect on these parameters was found on the field and laboratory results obtained in this project.

The configuration of the pump in relation to the hose outlet was also unlikely to affect the test results for this study. This is because concrete was usually pumped to elevations that did not differ significantly from the elevation of the concrete truck for sampling purposes. The pump operator would bring the hose down to the ground level, where inspectors and the research team from this project collected samples for testing.

CHAPTER 7

CONCLUSIONS

The following conclusions can be made based on the findings of this study:

1. The process of concrete pumping for highway bridge projects is likely to improve various short term and long term properties of concrete in general, resulting in increased strength and service life. Results from this study show that even from a conservative viewpoint, pumping is not necessarily detrimental to concrete quality or performance.
2. The air content is expected to significantly drop due to the pumping of bridge concrete. The air content of concrete may be expected to decrease by one percent on average and as high as 3% due to pumping.
3. Bridge concrete may lose slump of about 13mm (0.5 in) on the average due to pumping, which is statistically significant. The slump decrease may be as high as 69 mm (2.7 in) due to pumping.
4. The unit weight of bridge concrete is expected to significantly rise due to pumping. This increase could be 24 kg/m^3 (1.5 pcf) on the average and may be as high as 89 kg/m^3 (5.6 pcf).
5. Bridge concrete may gain a 28-day compressive strength of about 1.83 MPa (266 psi) on the average due to pumping, which is statistically significant. The strength increase may be as high as 7.1 MPa (1030 psi) in some situations.
6. In general, the chloride ion permeability and the water permeability may be expected to decrease due to pumping. The permeability test results from this study showed wide

fluctuations from sample to sample, which may be attributed to precision of measurements, time of testing, and age of samples at testing. But, the permeabilities decreased significantly for the majority of samples.

7. The air content, slump, and compressive test results were consistent for almost all samples. In general, air content loss due to pumping led to slump loss, unit weight increase, and compressive strength increase.

8. The expected increase in strength due to pumping of bridge concrete is less than 10% in general, and may be neglected in design for practical purposes.

CHAPTER 8

RECOMMENDATIONS

Several recommendations may be made based on the test results and conclusions from this study:

1. Air content of bridge concrete is affected by pumping, and this should be taken into account when concrete is being pumped. Therefore, concrete should be delivered to the site with an air content near the higher end of the mix design range. Subsequently, the average one percent drop of air content will still be acceptable on FDOT projects.
2. As long as the air content decrease due to pumping is compensated by pre-mixing, pumping of bridge concrete may be widely used with confidence on FDOT projects as needed. This process is likely to produce stronger, denser, and less permeable concrete.
3. The concrete pumps generally operate in a range of pressures from 4.8 to 6.9 MPa (700 to 1000 psi). These pressures should remain as low as possible to keep from impacting the concrete as much as possible. Using a lower pressure in the pump line minimizes the effects of compression and segregation of the concrete.
4. Weather conditions may affect the air content, therefore, the concrete and the pump should be protected from adverse weather. If pumping has to occur during rain, a method should be implemented to keep excess water from building up in the pump hopper. This water can increase the concrete air content because the excess water, which does not hydrate, eventually evaporates and causes air voids. These air voids can in turn cause the concrete to have a higher water and chloride permeability. Both of these factors are detrimental to long term durability of concrete.

5. Before concrete is placed using a pump, the line needs to be properly primed. If the line is not completely primed, the concrete that is discharged will be substandard. The initial slurry that is pumped through the line has to be completely discharged away from the pour, and the concrete that follows may be accepted for placement. Sufficient priming is quite important, which only a good operator with enough experience can guarantee.

Table 4.1

A General Guide Of the Project

Sample Number	Test Date	Location	Structure	Ambient Temperature (^oF)	Boom Angle (degrees)	Boom Length (ft)	Mix Design	Comments
1	12/1/95	Tampa, Gandy	Foundation	81	85	105	1	Level
2	12/1/95	Tampa, Gandy	Foundation	81	85	105	1	Level
3	12/22/95	Flagler Beach	Columns	73	90	150	2	Level
4	12/22/95	Flagler Beach	Columns	73	90	150	2	Level
5	1/12/96	Flagler Beach	Columns	77	90	150	2	Level
6	1/12/96	Flagler Beach	Columns	77	90	150	2	Level
7	1/26/96	Tampa, Gandy	Foundation	78	80	120	1	Higher, 10 ft
8	2/16/96	Blind Pass	Pile Caps	65	70	133	3	Higher, 10 ft
9	3/14/96	Blind Pass	Pile Caps	79	90	100	3	Higher, 10 ft
10	3/14/96	Blind Pass	Pile Caps	79	90	100	3	Higher, 10 ft
11	3/21/96	Flagler Beach	Slabs	80	90	137	4	Higher, 10 ft
12	3/21/96	Flagler Beach	Slabs	80	90	137	4	Higher, 10 ft
13	3/21/96	Flagler Beach	Slabs	80	90	137	4	Higher, 10 ft
14	3/29/96	Blind Pass	Slabs	81	85	125	3	Level
15	3/29/96	Blind Pass	Slabs	81	85	125	3	Level
16	5/3/96	Blind Pass	Slabs	87	85	12	3	Level
17	5/3/96	Blind Pass	Slabs	87	85	12	3	Level
18	6/6/96	New Port Richey	Slabs	77	90	175	5	Level
19	6/6/96	New Port Richey	Slabs	77	90	175	5	Level
20	7/31/96	Pensacola	Shaft Caps	95	80	130	5	Lower, 10 ft
21	9/7/96	Pensacola	Slabs	85	85	125	6	Lower 20 ft
22	9/7/96	Pensacola	Slabs	85	85	125	6	Lower, 20 ft
23	10/17/96	Blountstown	Shafts	67	90	180	7	Lower, 30 ft
24	10/17/96	Blountstown	Shafts	67	90	180	7	Lower, 30 ft

Table 4.1 (cont.)
A General Guide Of the Project

Sample Number	Test Date	Location	Structure	Ambient Temperature (^oF)	Boom Angle (degrees)	Boom Length (ft)	Mix Design	Comments
25	11/8/96	Tampa,Hillsborough	Foundation	77	85	135	8	Level
26	11/8/96	Tampa,Hillsborough	Foundation	77	80	135	8	Level
27	11/22/96	Blind Pass	Slabs	62	80	150	3	Level
28	11/22/96	Blind Pass	Slabs	62	90	150	3	Level
29	1/28/97	Blountstown	Walls	45	90	170	9	Level
30	1/28/97	Blountstown	Walls	45	90	170	9	Level
31	1/31/97	Flagler Beach	Slabs	62	90	150	4	Level
32	1/31/97	Flagler Beach	Slabs	62	90	150	4	Level
33	2/4/97	Blountstown	Shafts	73	87	165	7	Level
34	2/4/97	Blountstown	Shafts	73	87	165	7	Level
35	2/6/97	Blountstown	Shafts	73	87	165	7	Level
36	02/06/97	Blountstown	Shafts	73	87	165	7	Level
37	03/05/97	Walt Disney World	Slabs	63	90	126	8	Level
38	03/05/97	Walt Disney World	Slabs	63	90	126	8	Level
39	04/19/97	Walt Disney World	Slabs	82	90	154	8	Level
40	04/19/97	Walt Disney World	Slabs	82	90	154	8	Level
41	05/22/97	Pensacola	Slabs	67	86	138	6	Level
42	05/22/97	Pensacola	Slabs	67	86	138	6	Level
43	05/30/97	Blountstown	Slabs	72	90	160	10	Level
44	05/30/97	Blountstown	Slabs	72	90	160	10	Level
45	06/26/97	Pensacola	Slabs	91	80	145	6	Level
46	06/26/97	Pensacola	Slabs	91	80	145	6	Level
47	07/14/97	Pensacola	Slabs	96	85	128	6	Level
48	07/14/97	Pensacola	Slabs	96	85	128	6	Level

Table 4.1 (cont.)
A General Guide Of the Project

Sample Number	Test Date	Location	Structure	Ambient Temperature (^oF)	Boom Angle (degrees)	Boom Length (ft)	Mix Design	Comments
49	09/29/97	Walt Disney World	Slabs	75	90	133	8	Higher, 5 ft
50	09/29/97	Walt Disney World	Slabs	75	90	133	8	Higher, 5 ft
51	09/29/97	Walt Disney World	Slabs	75	90	133	8	Higher, 5 ft
52	10/08/97	Blountstown	Slabs	83	90	148	10	Level
53	10/08/97	Blountstown	Slabs	83	90	148	10	Level
54	10/08/97	Blountstown	Slabs	83	90	148	10	Level
55	10/17/97	Blountstown	Slabs	79	90	145	10	Level
56	10/17/97	Blountstown	Slabs	79	90	145	10	Level
57	10/30/97	Orlando, I4 & Rep.	Slabs	63	85	130	11	Level
58	10/30/97	Orlando, I4 & Rep.	Slabs	63	85	130	11	Level
59	11/18/97	Blountstown	Slabs	82	87	135	10	Level
60	11/18/97	Blountstown	Slabs	82	87	135	10	Level
61	12/17/97	Orlando, I4 & Rep.	Slabs	71	90	40	11	Level
62	12/17/97	Orlando, I4 & Rep.	Slabs	71	90	140	11	Level
63	No data	Jacksonville	No data	85	85	90	12	Level
64	No data	Miami	No data	75	90	200	13	Lower, 25 ft
65	No data	Tampa	No data	82	85	120	14	Level
66	No data	Jacksonville	No data	80	60	130	15	Level
67	No data	Jacksonville	No data	72	80	130	16	Higher, 25 ft
68	No data	St. Augustine	No data	78	90	130	16	Higher, 12 ft
69	No data	Orlando	No data	58	80	142	17	Higher, 25 ft
70	No data	Orlando	No data	55	90	100	18	Higher, 10 ft
71	No data	Ft. Lauderdale	No data	65	85	130	19	Level
72	No data	Miami	No data	70	85	130	20	Level
73	No data	St. Augustine	No data	44	60	130	21	Higher, 10 ft

Table 6.1

Results of the Air Content Test

Sample Number	Air Content Before Pumping (%)	Air Content After Pumping (%)	Change	Percent Change	Mix Design No.
1	4.5	3.7	-0.8	-18	1
2	3.2	3.0	-0.2	-6	1
3	4.4	3.2	-1.2	-27	2
4	5.0	3.0	-2.0	-40	2
5	5.1	3.5	-1.6	-31	2
6	5.3	4.4	-0.9	-17	2
7	5.3	2.7	-2.6	-49	1
8	3.0	2.5	-0.5	-17	3
9	7.5	5.5	-2.0	-27	3
10	6.0	4.5	-1.5	-25	3
11	7.0	4.3	-2.7	-39	4
12	6.0	4.2	-1.8	-30	4
13	5.5	4.5	-1.0	-18	4
14	4.3	3.8	-0.5	-12	3
15	2.8	1.8	-1.0	-36	3
16	4.5	2.5	-2.0	-44	3
17	4.5	3.0	-1.5	-33	3
18	6.0	2.9	-3.1	-52	5
19	6.0	3.5	-2.5	-42	5
20	3.5	5.5	2.0	57	5
21	7.0	4.7	-2.3	-33	6
22	6.0	4.5	-1.5	-25	6
23	4.0	3.5	-0.5	-13	7
24	5.0	4.0	-1.0	-20	7
25	4.0	3.0	-1.0	-25	8
26	4.3	3.5	-0.8	-19	8
27	6.0	4.5	-1.5	-25	3
28	6.2	4.5	-1.7	-27	3
29	4.3	4.0	-0.3	-7	9
30	4.0	3.5	-0.5	-13	9
31	5.0	4.5	-0.5	-10	4
32	5.0	4.6	-0.4	-8	4
33	4.5	4.0	-0.5	-11	7
34	4.7	4.2	-0.5	-11	7
35	5.1	4.2	-0.9	-18	7
36	5.2	4.2	-1	-19	7

Table 6.1 (cont.)

Results of the Air Content Test

Sample Number	Air Content Before Pumping (%)	Air Content After Pumping (%)	Change	Percent Change	Mix Design No.
37	5.0	4.0	-1.0	-20	8
38	4.9	4.1	-0.8	-16	8
39	4.8	4.0	-0.8	-17	8
40	4.5	3.9	-0.6	-13	8
41	4.2	3.8	-0.4	-10	6
42	4.7	3.2	-1.5	-32	6
43	4.1	2.8	-1.3	-32	10
44	4.2	3.5	-0.7	-17	10
45	5.2	3.1	-2.1	-40	6
46	4.7	2.9	-1.8	-38	6
47	4.7	5.0	0.3	-6	6
48	4.5	5.0	0.5	-13	6
49	4.2	3.1	-1.1	-26	8
50	4.1	3.1	-1.0	-24	8
51	4.5	3.3	-1.2	-27	8
52	3.7	3.9	0.2	5	10
53	3.7	3.3	-0.4	-11	10
54	3.8	3.5	-0.3	-8	10
55	3.0	2.5	-0.5	-17	10
56	3.1	2.7	-0.4	-13	10
57	3.5	2.7	-0.8	-23	11
58	3.8	3.0	-0.8	-21	11
59	3.5	3.0	-0.5	-14	10
60	2.8	3.0	0.2	7	10
61	4.1	3.6	-0.5	-12	11
62	4.2	3.8	-0.4	-10	11
63	5.6	4.4	-1.2	-21	12
64	3.1	2.3	-0.8	-26	13
65	2.3	2.5	0.2	9	14
66	3.9	3.1	-0.8	-21	15
67	3.3	5.0	1.7	52	16
68	2.4	1.5	-0.9	-38	16
69	3.7	4.5	0.8	22	17
70	4.1	3.7	-0.4	-10	18
71	3.7	2.5	-1.2	-32	19
72	3.8	2.7	-1.1	-29	20
73	4.3	2.8	-1.5	-35	21

Table 6.2
Results of the Slump Test

Sample	Slump Before pumping		Slump After pumping		Change		Percent	Mix
Number	(mm)	(inches)	(mm)	(inches)	(mm)	(inches)	Change	Design No.
1	191	7.50	197	7.75	6	0.25	3	1
2	203	8.00	191	7.50	-13	-0.50	-6	1
3	102	4.00	102	4.00	0	0.00	0	2
4	127	5.00	108	4.25	-19	-0.75	-15	2
5	89	3.50	95	3.75	6	0.25	7	2
6	140	5.50	140	5.50	0	0.00	0	2
7	135	5.30	69	2.70	-66	-2.60	-49	1
8	89	3.50	76	3.00	-13	-0.50	-14	3
9	121	4.75	114	4.50	-6	-0.25	-5	3
10	127	5.00	121	4.75	-6	-0.25	-5	3
11	178	7.00	109	4.30	-69	-2.70	-39	4
12	83	3.25	76	3.00	-6	-0.25	-8	4
13	76	3.00	70	2.75	-6	-0.25	-8	4
14	178	7.00	114	4.50	-64	-2.50	-36	3
15	171	6.75	114	4.50	-57	-2.25	-33	3
16	89	3.50	95	3.75	6	0.25	7	3
17	89	3.50	83	3.25	-6	-0.25	-7	3
18	89	3.50	95	3.75	6	0.25	7	5
19	89	3.50	89	3.50	0	0.00	0	5
20	114	4.50	102	4.00	-13	-0.50	-11	5
21	133	5.25	95	3.75	-38	-1.50	-29	6
22	140	5.50	102	4.00	-38	-1.50	-27	6
23	127	5.00	114	4.50	-13	-0.50	-10	7
24	140	5.50	114	4.50	-25	-1.00	-18	7
25	102	4.00	89	3.50	-13	-0.50	-13	8

Table 6.2 (cont.)
Results of the Slump Test

Sample	Slump Before pumping		Slump After pumping		Change		Percent	Mix
Number	(mm)	(inches)	(mm)	(inches)	(mm)	(inches)	Change	Design No.
26	108	4.25	83	3.25	-25	-1.00	-24	8
27	127	5.00	114	4.50	-13	-0.50	-10	3
28	121	4.75	108	4.25	-13	-0.50	-11	3
29	102	4.00	89	3.50	-13	-0.50	-13	9
30	89	3.50	89	3.50	0	0.00	0	9
31	114	4.50	102	4.00	-13	-0.50	-11	4
32	89	3.50	76	3.00	-13	-0.50	-14	4
33	210	8.25	203	8.00	-6	-0.25	-3	7
34	191	7.50	178	7.00	-13	-0.50	-7	7
35	197	7.75	178	7.00	-19	-0.75	-10	7
36	191	7.50	178	7.00	-13	-0.50	-7	7
37	89	3.50	76	3.00	-13	-0.50	-14	8
38	102	4.00	89	3.50	-13	-0.50	-13	8
39	95	3.75	83	3.25	-13	-0.50	-13	8
40	102	4.00	95	3.75	-6	-0.25	-6	8
41	89	3.50	83	3.25	-6	-0.25	-7	6
42	89	3.50	76	3.00	-13	-0.50	-14	6
43	102	4.00	89	3.50	-13	-0.50	-13	10
44	83	3.25	76	3.00	-6	-0.25	-8	10
45	76	3.00	70	2.75	-6	-0.25	-8	6
46	83	3.25	70	2.75	-13	-0.50	-15	6
47	114	4.50	102	4.00	-13	-0.50	-11	6
48	112	4.40	102	4.00	-10	-0.40	-9	6
49	95	3.75	64	2.50	-32	-1.25	-33	8
50	89	3.50	64	2.50	-25	-1.00	-29	8

Table 6.2 (cont.)
Results of the Slump Test

Sample	Slump Before pumping		Slump After pumping		Change		Percent	Mix
Number	(mm)	(inches)	(mm)	(inches)	(mm)	(inches)	Change	Design No.
51	102	4.00	76	3.00	-25	-1.00	-25	8
52	114	4.50	108	4.25	-6	-0.25	-6	10
53	102	4.00	95	3.75	-6	-0.25	-6	10
54	114	4.50	108	4.25	-6	-0.25	-6	10
55	102	4.00	89	3.50	-13	-0.50	-13	10
56	95	3.75	83	3.25	-13	-0.50	-13	10
57	108	4.25	102	4.00	-6	-0.25	-6	11
58	102	4.00	89	3.50	-13	-0.50	-13	11
59	102	4.00	89	3.50	-13	-0.50	-13	10
60	95	3.75	89	3.50	-6	-0.25	-7	10
61	70	2.75	57	2.25	-13	-0.50	-18	11
62	76	3.00	57	2.25	-19	-0.75	-25	11
63	70	2.75	70	2.75	0	0.00	0	12
64	76	3.00	83	3.25	6	0.25	8	13
65	76	3.00	89	3.50	13	0.50	17	14
66	114	4.50	64	2.50	-51	-2.00	-44	15
67	152	6.00	114	4.50	-38	-1.50	-25	16
68	102	4.00	89	3.50	-13	-0.50	-13	16
69	108	4.25	152	6.00	44	1.75	41	17
70	89	3.50	95	3.75	6	0.25	7	18
71	64	2.50	102	4.00	38	1.50	60	19
72	178	7.00	152	6.00	-25	-1.00	-14	20
73	133	5.25	76	3.00	-57	-2.25	-43	21

Table 6.3
Results of the Unit Weight Test

Sample Number	Unit Weight Before Pumping (Kg/m^3)	Unit Weight Before Pumping (lb/ft^3)	Unit Weight After Pumping (Kg/m^3)	Unit Weight After Pumping (lb/ft^3)	Change (Kg/m^3)	Change (lb/ft^3)	Percent Change	Mix Design
1	2234	139.5	2234	139.5	0	0.0	0.0	1
2	2233	139.4	2236	139.6	3	0.2	0.1	1
3	2217	138.4	2249	140.4	32	2.0	1.4	2
4	2178	136.0	2194	137.0	16	1.0	0.7	2
5	2165	135.2	2162	135.0	-3	-0.2	-0.1	2
6	2130	133.0	2138	133.5	8	0.5	0.4	2
7	2263	141.3	2317	144.7	54	3.4	2.4	1
8	2186	136.5	2202	137.5	16	1.0	0.7	3
9	2146	134.0	2210	138.0	64	4.0	3.0	3
10	2162	135.0	2226	139.0	64	4.0	3.0	3
11	2202	137.5	2263	141.3	61	3.8	2.8	4
12	2186	136.5	2247	140.3	61	3.8	2.8	4
13	2194	137.0	2245	140.2	51	3.2	2.3	4
14	2233	139.4	2244	140.1	11	0.7	0.5	3
15	2258	141.0	2279	142.3	21	1.3	0.9	3
16	2194	137.0	2258	141.0	64	4.0	2.9	3
17	2226	139.0	2258	141.0	32	2.0	1.4	3
18	2210	138.0	2226	139.0	16	1.0	0.7	5
19	2194	137.0	2210	138.0	16	1.0	0.7	5
20	2338	146.0	2306	144.0	-32	-2.0	-1.4	5
21	2306	144.0	2338	146.0	32	2.0	1.4	6
22	2303	143.8	2346	146.5	43	2.7	1.9	6
23	2210	138.0	2242	140.0	32	2.0	1.4	7
24	2226	139.0	2258	141.0	32	2.0	1.4	7
25	2226	139.0	2242	140.0	16	1.0	0.7	8

Table 6.3 (cont.)
Results of the Unit Weight Test

Sample Number	Unit Weight Before Pumping (Kg/m^3)	Unit Weight Before Pumping (lb/ft^3)	Unit Weight After Pumping (Kg/m^3)	Unit Weight After Pumping (lb/ft^3)	Change (Kg/m^3)	Change (lb/ft^3)	Percent Change	Mix Design
26	2210	138.0	2242	140.0	32	2.0	1.4	8
27	2178	136.0	2210	138.0	32	2.0	1.5	3
28	2226	139.0	2258	141.0	32	2.0	1.4	3
29	2306	144.0	2322	145.0	16	1.0	0.7	9
30	2322	145.0	2338	146.0	16	1.0	0.7	9
31	2194	137.0	2210	138.0	16	1.0	0.7	4
32	2210	138.0	2210	138.0	0	0.0	0.0	4
33	2274	142.0	2274	142.0	0	0.0	0.0	7
34	2274	142.0	2290	143.0	16	1.0	0.7	7
35	2282	142.5	2290	143.0	8	0.5	0.4	7
36	2274	142.0	2306	144.0	32	2.0	1.4	7
37	2194	137.0	2210	138.0	16	1.0	0.7	8
38	2202	137.5	2218	138.5	16	1.0	0.7	8
39	2194	137.0	2210	138.0	16	1.0	0.7	8
40	2210	138.0	2234	139.5	24	1.5	1.1	8
41	2329	145.4	2338	146.0	10	0.6	0.4	6
42	2321	144.9	2343	146.3	22	1.4	1.0	6
43	2306	144.0	2333	145.7	27	1.7	1.2	10
44	2305	143.9	2319	144.8	14	0.9	0.6	10
45	2308	144.1	2343	146.3	35	2.2	1.5	6
46	2321	144.9	2338	146.0	18	1.1	0.8	6
47	2303	143.8	2333	145.7	30	1.9	1.3	6
48	2300	143.6	2337	145.9	37	2.3	1.6	6
49	2210	138.0	2234	139.5	24	1.5	1.1	8
50	2207	137.8	2226	139.0	19	1.2	0.9	8

Table 6.3 (cont.)
Results of the Unit Weight Test

Sample Number	Unit Weight Before Pumping (Kg/m^3)	Unit Weight Before Pumping (lb/ft^3)	Unit Weight After Pumping (Kg/m^3)	Unit Weight After Pumping (lb/ft^3)	Change (Kg/m^3)	Change (lb/ft^3)	Percent Change	Mix Design
51	2202	137.5	2226	139.0	24	1.5	1.1	8
52	2309	144.2	2316	144.6	6	0.4	0.3	10
53	2314	144.5	2322	145.0	8	0.5	0.3	10
54	2306	144.0	2321	144.9	14	0.9	0.6	10
55	2319	144.8	2330	145.5	11	0.7	0.5	10
56	2316	144.6	2335	145.8	19	1.2	0.8	10
57	2204	137.6	2218	138.5	14	0.9	0.7	11
58	2196	137.1	2213	138.2	18	1.1	0.8	11
59	2311	144.3	2322	145.0	11	0.7	0.5	10
60	2321	144.9	2324	145.1	3	0.2	0.1	10
61	2201	137.4	2210	138.0	10	0.6	0.4	11
62	2204	137.6	2213	138.2	10	0.6	0.4	11
63	2236	139.6	2263	141.3	27	1.7	1.2	12
64	2210	138.0	2245	140.2	35	2.2	1.6	13
65	2277	142.2	2242	140.0	-35	-2.2	-1.5	14
66	2194	137.0	2225	138.9	30	1.9	1.4	15
67	2226	139.0	2306	144.0	80	5.0	3.6	16
68	2233	139.4	2292	143.1	59	3.7	2.7	16
69	2204	137.6	2172	135.6	-32	-2.0	-1.5	17
70	2194	137.0	2229	139.2	35	2.2	1.6	18
71	2245	140.2	2258	141.0	13	0.8	0.6	19
72	2245	140.2	2325	145.2	80	5.0	3.6	20
73	2159	134.8	2249	140.4	90	5.6	4.2	21

Table 6.4
Results of the Compressive Strength Test

Sample Number	Strength Before pumping		Strength After pumping		Change		Percent Change	Mix Design No.
	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)		
1	40.7	5908	41.6	6027	0.8	119	2.0	1
2	41.1	5968	42.6	6178	1.4	210	3.5	1
3	43.6	6327	46.9	6808	3.3	481	7.6	2
4	42.8	6208	47.6	6908	4.8	700	11.3	2
5	48.2	6984	50.8	7369	2.7	385	5.5	2
6	45.4	6582	49.6	7199	4.3	617	9.4	2
7	38.4	5569	41.2	5979	2.8	410	7.4	1
8	46.4	6723	46.7	6778	0.4	55	0.8	3
9	23.5	3409	28.4	4115	4.9	706	20.7	3
10	29.2	4236	31.2	4519	2.0	283	6.7	3
11	40.4	5858	45.5	6596	5.1	738	12.6	4
12	40.4	5858	45.6	6612	5.2	754	12.9	4
13	40.3	5840	45.3	6575	5.1	735	12.6	4
14	46.3	6712	47.1	6832	0.8	120	1.8	3
15	45.9	6653	46.1	6690	0.3	37	0.6	3
16	44.1	6400	44.6	6464	0.4	64	1.0	3
17	44.5	6450	45.3	6564	0.8	114	1.8	3
18	29.1	4220	30.4	4410	1.3	190	4.5	5
19	28.6	4150	29.6	4300	1.0	150	3.6	5
20	36.8	5340	39.1	5673	2.3	333	6.2	5
21	38.3	5560	39.9	5790	1.6	230	4.1	6
22	37.7	5472	39.6	5743	1.9	271	5.0	6
23	37.9	5500	39.3	5700	1.4	200	3.6	7
24	38.3	5550	39.0	5650	0.7	100	1.8	7
25	38.9	5645	39.3	5700	0.4	55	1.0	8

Table 6.4 (cont.)
Results of the Compressive Strength Test

Sample Number	Strength Before pumping (MPa)	(psi)	Strength After pumping (MPa)	(psi)	Change (MPa)	(psi)	Percent Change	Mix Design
26	38.0	5505	39.0	5650	1.0	145	2.6	8
27	40.0	5800	41.5	6020	1.5	220	3.8	3
28	39.6	5745	41.3	5986	1.7	241	4.2	3
29	49.8	7230	50.5	7330	0.7	100	1.4	9
30	50.3	7300	51.0	7400	0.7	100	1.4	9
31	51.9	7534	52.4	7600	0.5	66	0.9	4
32	52.4	7600	53.4	7740	1.0	140	1.8	4
33	37.5	5440	38.6	5600	1.1	160	2.9	7
34	36.9	5345	38.2	5543	1.4	198	3.7	7
35	36.7	5320	37.2	5400	0.6	80	1.5	7
36	36.5	5287	38.1	5519	1.6	232	4.4	7
37	36.5	5287	37.4	5430	1.0	143	2.7	8
38	36.0	5219	37.1	5388	1.2	169	3.2	8
39	36.9	5356	38.6	5595	1.6	239	4.5	8
40	36.4	5276	37.0	5364	0.6	88	1.7	8
41	36.6	5302	39.1	5678	2.6	376	7.1	6
42	36.4	5280	40.8	5922	4.4	642	12.2	6
43	35.4	5134	39.3	5701	3.9	567	11.0	10
44	36.0	5227	38.4	5566	2.3	339	6.5	10
45	39.0	5662	40.1	5821	1.1	159	2.8	6
46	38.2	5543	39.8	5769	1.6	226	4.1	6
47	38.2	5540	40.2	5834	2.0	294	5.3	6
48	38.3	5560	40.0	5800	1.7	240	4.3	6
49	35.9	5200	36.7	5320	0.8	120	2.3	8
50	36.6	5312	37.1	5380	0.5	68	1.3	8

Table 6.4 (cont.)
Results of the Compressive Strength Test

Sample Number	Strength Before pumping		Strength After pumping		Change		Percent Change	Mix Design
	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)		
51	36.4	5280	37.2	5390	0.8	110	2.1	8
52	36.4	5278	37.2	5392	0.8	114	2.2	10
53	37.4	5420	38.5	5585	1.1	165	3.0	10
54	34.4	4996	37.5	5441	3.1	445	8.9	10
55	36.1	5241	39.2	5690	3.1	449	8.6	10
56	34.9	5062	36.9	5348	2.0	286	5.6	10
57	38.1	5520	38.8	5634	0.8	114	2.1	11
58	37.4	5426	40.0	5804	2.6	378	7.0	11
59	39.9	5786	40.1	5814	0.2	28	0.5	10
60	39.2	5692	40.6	5883	1.3	191	3.4	10
61	38.7	5612	42.0	6091	3.3	479	8.5	11
62	38.3	5560	41.3	5987	2.9	427	7.7	11
63	39.6	5747	41.0	5950	1.4	203	3.5	12
64	36.1	5240	36.7	5316	0.5	76	1.5	13
65	39.3	5700	39.9	5781	0.6	81	1.4	14
66	45.1	6544	47.3	6863	2.2	319	4.9	15
67	46.4	6724	49.8	7216	3.4	492	7.3	16
68	45.1	6548	50.9	7377	5.7	829	12.7	16
69	40.4	5863	39.6	5743	-0.8	-120	-2.0	17
70	32.7	4738	33.3	4830	0.6	92	1.9	18
71	42.5	6163	38.7	5609	-3.8	-554	-9.0	19
72	46.7	6768	49.4	7171	2.8	403	6.0	20
73	45.3	6572	52.4	7602	7.1	1030	15.7	21

Table 6.5
Results of the Chloride Ion Permeability Test

Sample Number	Permeability		Change	Percent Change	Mix Design No.
	Before Pumping (C_b)	After Pumping (C_b)			
1	3940	4047	107	2.7	1
2	3980	3962	-18	-0.5	1
3	5506	5506	0	0.0	2
4	6327	6389	62	1.0	2
5	7409	7009	-400	-5.4	2
6	8699	8339	-360	-4.1	2
7	8165	8795	630	7.7	1
8	12511	11077	-1434	-11.5	3
9	13165	9914	-3251	-24.7	3
10	16132	10798	-5334	-33.1	3
11	4557	4034	-523	-11.5	4
12	4377	4655	278	6.4	4
13	4760	4486	-274	-5.8	4
14	11032	10799	-233	-2.1	3
15	10327	10297	-30	-0.3	3
16	4680	4600	-80	-1.7	3
17	4480	4445	-35	-0.8	3
18	4402	4534	132	3.0	5
19	4367	4523	156	3.6	5
20	2924	2981	57	1.9	5
21	2598	3249	651	25.1	6
22	2344	2553	209	8.9	6
23	6452	5323	-1129	-17.5	7
24	6387	5811	-576	-9.0	7
25	7971	7918	-53	-0.7	8
26	7311	7171	-140	-1.9	8
27	17514	17056	-458	-2.6	3
28	18016	17283	-733	-4.1	3
29	3482	3616	134	3.8	9
30	3691	3512	-179	-4.8	9
31	5142	5514	372	7.2	4
32	5407	5858	451	8.3	4
33	6380	7051	671	10.5	7
34	6607	6389	-218	-3.3	7
35	6240	6095	-145	-2.3	7
36	6001	6028	27	0.4	7

Table 6.5 (cont.)
Results of the Chloride Ion Permeability Test

Sample Number	Permeability		Change	Percent Change	Mix Design No.
	Before Pumping (C_b)	After Pumping (C_b)			
37	5998	6218	220	3.7	8
38	6188	6250	62	1.0	8
39	4100	4208	108	2.6	8
40	4100	4438	338	8.2	8
41	2657	2754	97	3.7	6
42	2725	2634	-91	-3.3	6
43	3218	2771	-447	-13.9	10
44	3247	2921	-326	-10.0	10
45	1812	1981	169	9.3	6
46	1630	1598	-32	-2.0	6
47	2800	2722	-78	-2.8	6
48	2692	2514	-178	-6.6	6
49	3108	3443	335	10.8	8
50	3247	3293	46	1.4	8
51	3116	3340	224	7.2	8
52	5088	4475	-613	-12.0	10
53	5053	4987	-66	-1.3	10
54	4797	4782	-15	-0.3	10
55	6181	6276	95	1.5	10
56	5507	5133	-374	-6.8	10
57	3785	4154	369	9.7	11
58	3528	3768	240	6.8	11
59	5986	5136	-850	-14.2	10
60	5854	4831	-1023	-17.5	10
61	6236	7360	1124	18.0	11
62	6450	6468	18	0.3	11
63	5973	5852	-121	-2.0	12
64	9641	10057	416	4.3	13
65	5163	5375	212	4.1	14
66	1632	1524	-108	-6.6	15
67	1873	1804	-69	-3.7	16
68	2294	2087	-207	-9.0	16
69	8695	8491	-204	-2.3	17
70	5326	6241	915	17.2	18
71	3184	3683	499	15.7	19
72	4176	4147	-29	-0.7	20
73	1382	1331	-51	-3.7	21

Table 6.6
Results of the Water Permeability Test

Sample Number	Permeability Before Pumping (mm/hr x 10^{-10})	Permeability Before Pumping (in/hr x 10^{-11})	Permeability After Pumping (mm/hr x 10^{-10})	Permeability After Pumping (in/hr x 10^{-11})	Change (mm/hr x 10^{-10})	Change (in/hr x 10^{-11})	Percent Change	Mix Design No.
1	3.29	1.30	3.25	1.28	-0.04	-0.02	-1	1
2	16.81	6.62	12.06	4.75	-4.75	-1.87	-28	1
3	21.57	8.49	4.48	1.77	-17.09	-6.73	-79	2
4	3.61	1.42	3.45	1.36	-0.16	-0.06	-4	2
5	1.97	0.78	1.55	0.61	-0.42	-0.17	-21	2
6	12.99	5.12	15.05	5.93	2.06	0.81	16	2
7	6.17	2.43	3.68	1.45	-2.50	-0.98	-40	1
8	2.72	1.07	2.26	0.89	-0.46	-0.18	-17	3
9	18.02	7.10	5.97	2.35	-12.06	-4.75	-67	3
10	7.87	3.10	7.59	2.99	-0.28	-0.11	-4	3
11	3.86	1.52	3.30	1.30	-0.56	-0.22	-15	4
12	13.54	5.33	12.87	5.07	-0.67	-0.27	-5	4
13	3.16	1.24	2.89	1.14	-0.27	-0.11	-9	4
14	6.06	2.39	6.41	2.52	0.35	0.14	6	3
15	5.10	2.01	4.96	1.95	-0.14	-0.05	-3	3
16	5.64	2.22	4.75	1.87	-0.89	-0.35	-16	3
17	5.03	1.98	4.32	1.70	-0.71	-0.28	-14	3
18	3.86	1.52	3.30	1.30	-0.56	-0.22	-15	5
19	13.54	5.33	12.87	5.07	-0.67	-0.27	-5	5
20	1.49	0.59	1.75	0.69	0.26	0.10	18	5
21	1.72	0.68	1.64	0.65	-0.09	-0.03	-5	6
22	4.35	1.71	3.49	1.38	-0.86	-0.34	-20	6
23	3.38	1.33	3.43	1.35	0.05	0.02	1	7
24	2.96	1.17	2.79	1.10	-0.17	-0.06	-6	7
25	4.87	1.92	4.87	1.92	0.00	0.00	0	8

Table 6.6 (cont.)
Results of the Water Permeability Test

Sample	Permeability Before Pumping		Permeability After Pumping		Change		Percent	Mix
Number	(mm/hr x 10^{-10})	(in/hr x 10^{-11})	(mm/hr x 10^{-10})	(in/hr x 10^{-11})	(mm/hr x 10^{-10})	(in/hr x 10^{-11})	Change	Design No.
26	16.16	6.36	3.33	1.31	-12.83	-5.05	-79.4	8
27	3.20	1.26	5.43	2.14	2.23	0.88	69.7	3
28	4.98	1.96	4.57	1.80	-0.41	-0.16	-8.2	3
29	5.99	2.36	3.90	1.54	-2.09	-0.82	-34.9	9
30	7.03	2.77	6.75	2.66	-0.27	-0.11	-3.9	9
31	3.67	1.44	2.81	1.11	-0.86	-0.34	-23.4	4
32	3.62	1.43	3.33	1.31	-0.29	-0.11	-8.0	4
33	3.13	1.23	2.78	1.10	-0.35	-0.14	-11.1	7
34	3.33	1.31	2.60	1.02	-0.73	-0.29	-22.0	7
35	3.97	1.56	3.72	1.46	-0.25	-0.10	-6.3	7
36	3.67	1.45	2.66	1.05	-1.02	-0.40	-27.7	7
37	3.67	1.44	10.06	3.96	6.40	2.52	175	8
38	3.62	1.43	8.55	3.37	4.93	1.94	136	8
39	7.80	3.07	9.72	3.83	1.92	0.76	25	8
40	5.17	2.03	15.33	6.03	10.16	4.00	197	8
41	1.94	0.76	2.05	0.81	0.12	0.05	6	6
42	2.07	0.82	6.27	2.47	4.20	1.65	202	6
43	4.77	1.88	4.77	1.88	0.00	0.00	0	10
44	11.58	4.56	22.69	8.93	11.11	4.38	96	10
45	2.81	1.11	3.08	1.21	0.27	0.11	10	6
46	3.01	1.19	4.27	1.68	1.25	0.49	42	6
47	1.59	0.63	1.73	0.68	0.14	0.05	9	6
48	1.51	0.59	2.00	0.79	0.49	0.19	33	6
49	3.42	1.35	1.42	0.56	-2.01	-0.79	-59	8
50	5.44	2.14	1.62	0.64	-3.82	-1.50	-70	8

Table 6.6 (cont.)
Results of the Water Permeability Test

Sample Number	Permeability Before Pumping		Permeability After Pumping		Change		Percent Change	Mix Design No.
	(mm/hr x 10^{-10})	(in/hr x 10^{-11})	(mm/hr x 10^{-10})	(in/hr x 10^{-11})	(mm/hr x 10^{-10})	(in/hr x 10^{-11})		
51	2.31	0.91	1.81	0.71	-0.50	-0.20	-22	8
52	2.39	0.94	2.35	0.93	-0.04	-0.02	-2	10
53	2.01	0.79	2.13	0.84	0.12	0.05	6	10
54	3.78	1.49	1.90	0.75	-1.88	-0.74	-50	10
55	1.52	0.60	1.19	0.47	-0.33	-0.13	-22	10
56	1.74	0.69	6.31	2.49	4.57	1.80	262	10
57	3.16	1.24	3.16	1.24	0.00	0.00	0	11
58	5.30	2.09	7.71	3.04	2.42	0.95	46	11
59	1.66	0.65	2.03	0.80	0.37	0.14	22	10
60	1.59	0.62	1.76	0.69	0.17	0.07	11	10
61	1.63	0.64	1.11	0.44	-0.52	-0.20	-32	11
62	4.61	1.81	1.56	0.62	-3.04	-1.20	-66	11
63	4.75	1.87	4.95	1.95	0.20	0.08	4	12
64	4.60	1.81	3.99	1.57	-0.61	-0.24	-13	13
65	7.19	2.83	3.56	1.40	-3.63	-1.43	-51	14
66	1.01	0.40	0.76	0.30	-0.25	-0.10	-25	15
67	5.08	2.00	1.43	0.56	-3.65	-1.44	-72	16
68	5.59	2.20	0.39	0.15	-5.20	-2.05	-93	16
69	17.09	6.73	12.85	5.06	-4.24	-1.67	-25	17
70	22.96	9.04	8.81	3.47	-14.15	-5.57	-62	18
71	16.70	6.57	6.50	2.56	-10.19	-4.01	-61	19
72	4.70	1.85	8.84	3.48	4.14	1.63	88	20
73	3.76	1.48	4.04	1.59	0.28	0.11	7	21

Table 6.7
Comparison of Various Test Samples After Pumping

Sample Number	Air Content	Slump	Unit Weight	Compressive Strength	Chloride Ion Permeability	Water Permeability
1	L[1]	H[2]	NC[3]	H	H	L
2	L	H	H	H	L	L
3	L	NC	H	H	NC	L
4	L	L	H	H	H	L
5	L	H	L	H	L	L
6	L	NC	H	H	L	H
7	L	L	H	H	H	L
8	L	L	H	H	L	L
9	L	L	H	H	L	L
10	L	L	H	H	L	L
11	L	L	H	H	L	L
12	L	L	H	H	H	L
13	L	L	H	H	L	L
14	L	L	H	H	L	H
15	L	L	H	H	L	L
16	L	H	H	H	L	L
17	L	L	H	H	L	L
18	L	H	H	H	H	L
19	L	NC	H	H	H	L
20	H	L	L	H	H	H
21	L	L	H	H	H	L
22	L	L	H	H	H	L
23	L	L	H	H	L	H
24	L	L	H	H	L	L
25	L	L	H	H	L	NC
26	L	L	H	H	L	L
27	L	L	H	H	L	H
28	L	L	H	H	L	L
29	L	L	H	H	H	L
30	L	NC	H	H	L	L
31	L	L	H	H	H	L

[1] L: Decreased after pumping
[2] H: Increased after pumping
[3] NC: No change after pumping

Table 6.7 (Cont.)
Comparison of Various Test Samples After Pumping

Sample Number	Air Content	Slump	Unit Weight	Compressive Strength	Chloride Ion Permeability	Water Permeability
32	L	L	NC	H	H	L
33	L	L	NC	H	H	L
34	L	L	H	H	L	L
35	L	L	H	H	L	L
36	L	L	H	H	H	L
37	L	L	H	H	H	H
38	L	L	H	H	H	H
39	L	L	H	H	H	H
40	L	L	H	H	H	H
41	L	L	H	H	H	H
42	L	L	H	H	L	H
43	L	L	H	H	L	H
44	L	L	H	H	L	H
45	L	L	H	H	H	H
46	L	L	H	H	L	H
47	H	L	H	H	L	H
48	H	L	H	H	L	H
49	L	L	H	H	H	L
50	L	L	H	H	H	L
51	L	L	H	H	H	L
52	H	L	H	H	L	L
53	L	L	H	H	L	H
54	L	L	H	H	L	L
55	L	L	H	H	H	L
56	L	L	H	H	L	H
57	L	L	H	H	H	NC
58	L	L	H	H	H	H
59	L	L	H	H	L	H
60	L	L	H	H	L	H
61	L	L	H	H	H	L
62	L	L	H	H	H	L
63	L	NC	H	H	L	H
64	L	H	H	H	H	L
65	H	H	L	H	H	L

Table 6.7 (Cont.)
Comparison of Various Test Samples After Pumping

Sample Number	Air Content	Slump	Unit Weight	Compressive Strength	Chloride Ion Permeability	Water Permeability
66	L	L	H	H	L	L
67	H	L	H	H	L	L
68	L	L	H	H	L	L
69	H	H	L	L	L	L
70	L	H	H	H	H	L
71	L	H	H	L	H	L
72	L	L	H	H	L	H
73	L	L	H	H	L	H

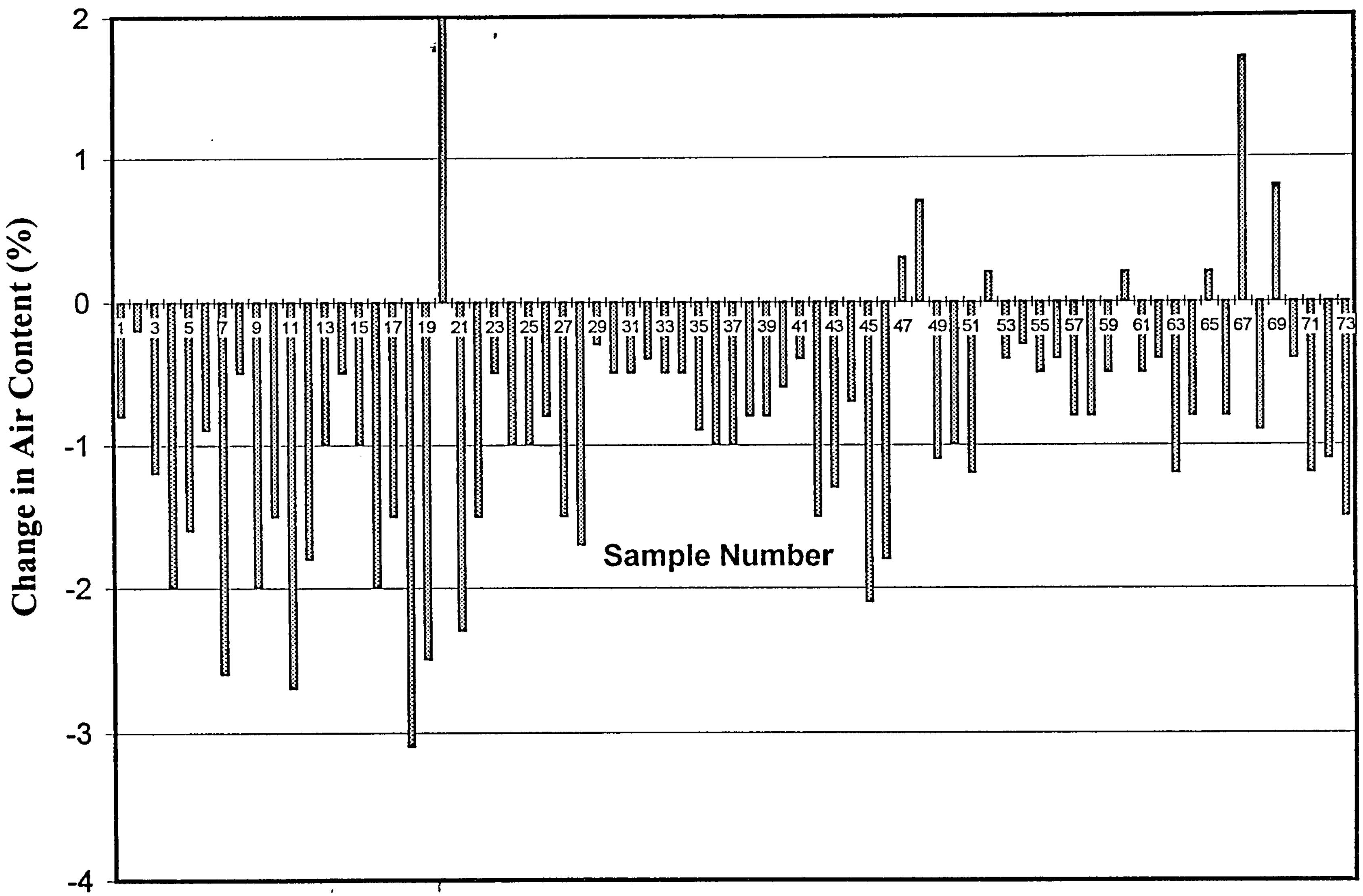

Figure 6.1: Change in Air Content Due to Pumping

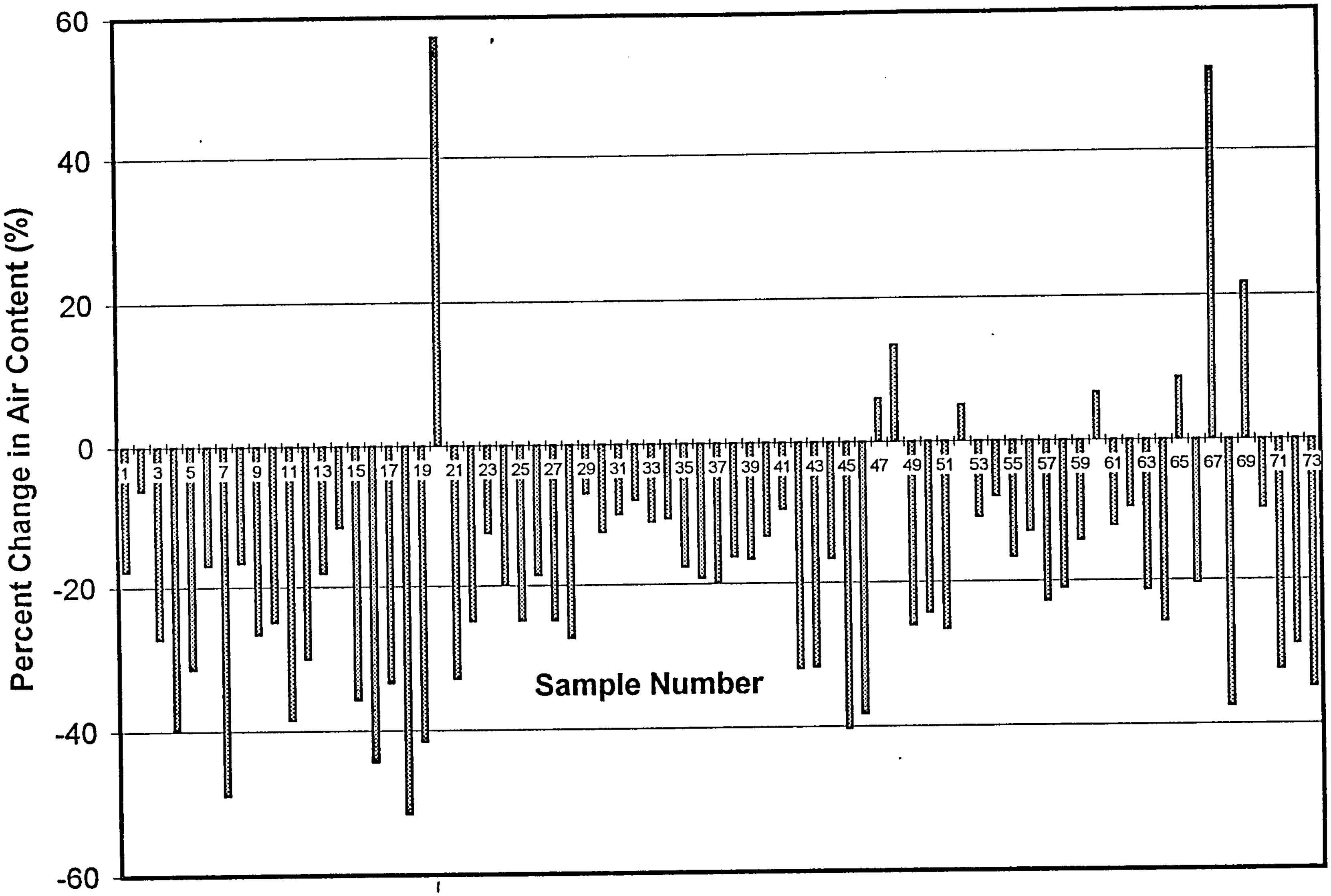

Figure 6.2: Percent Change in Air Content Due to Pumping

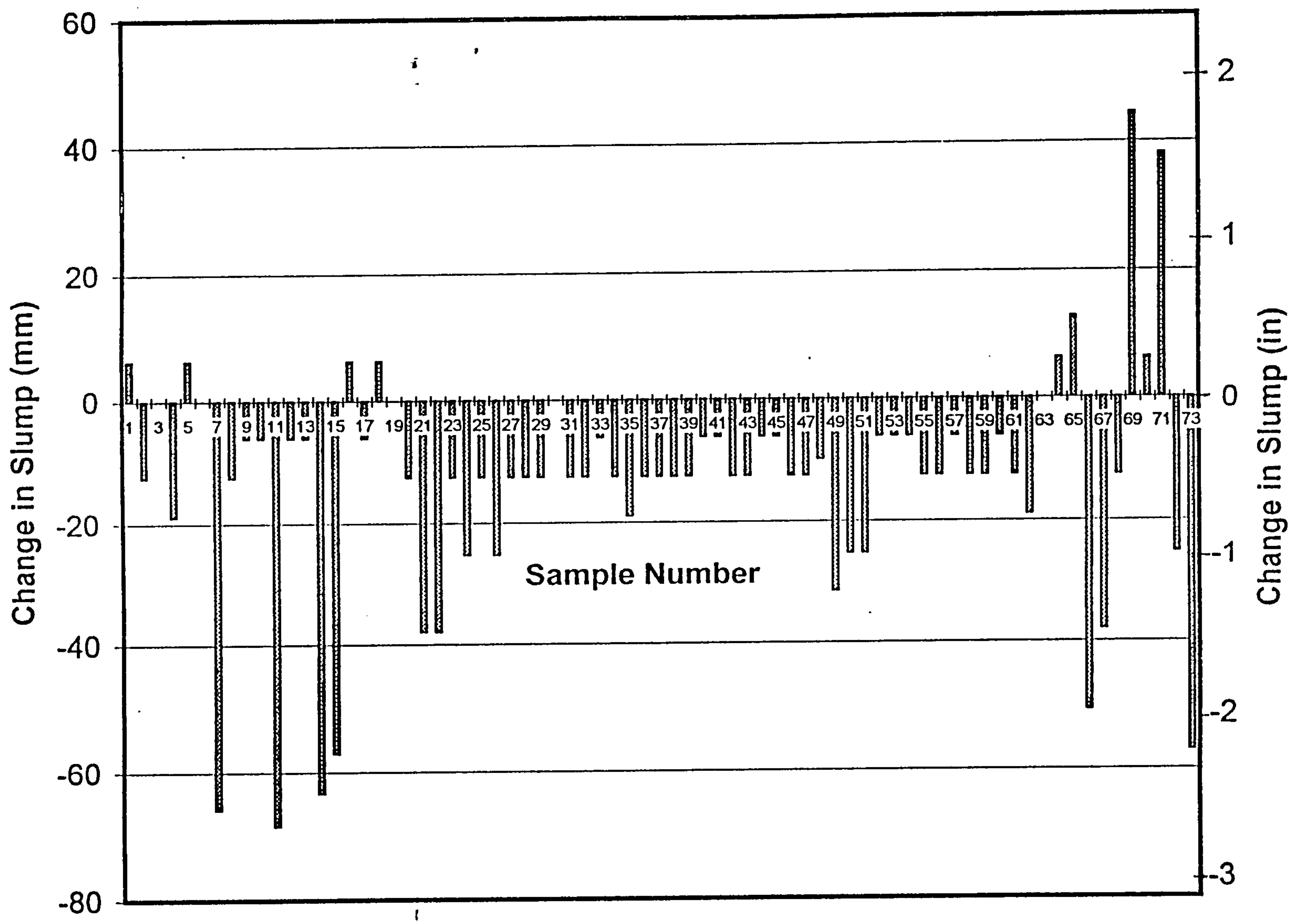

Figure 6.3: Change in Slump Due to Pumping

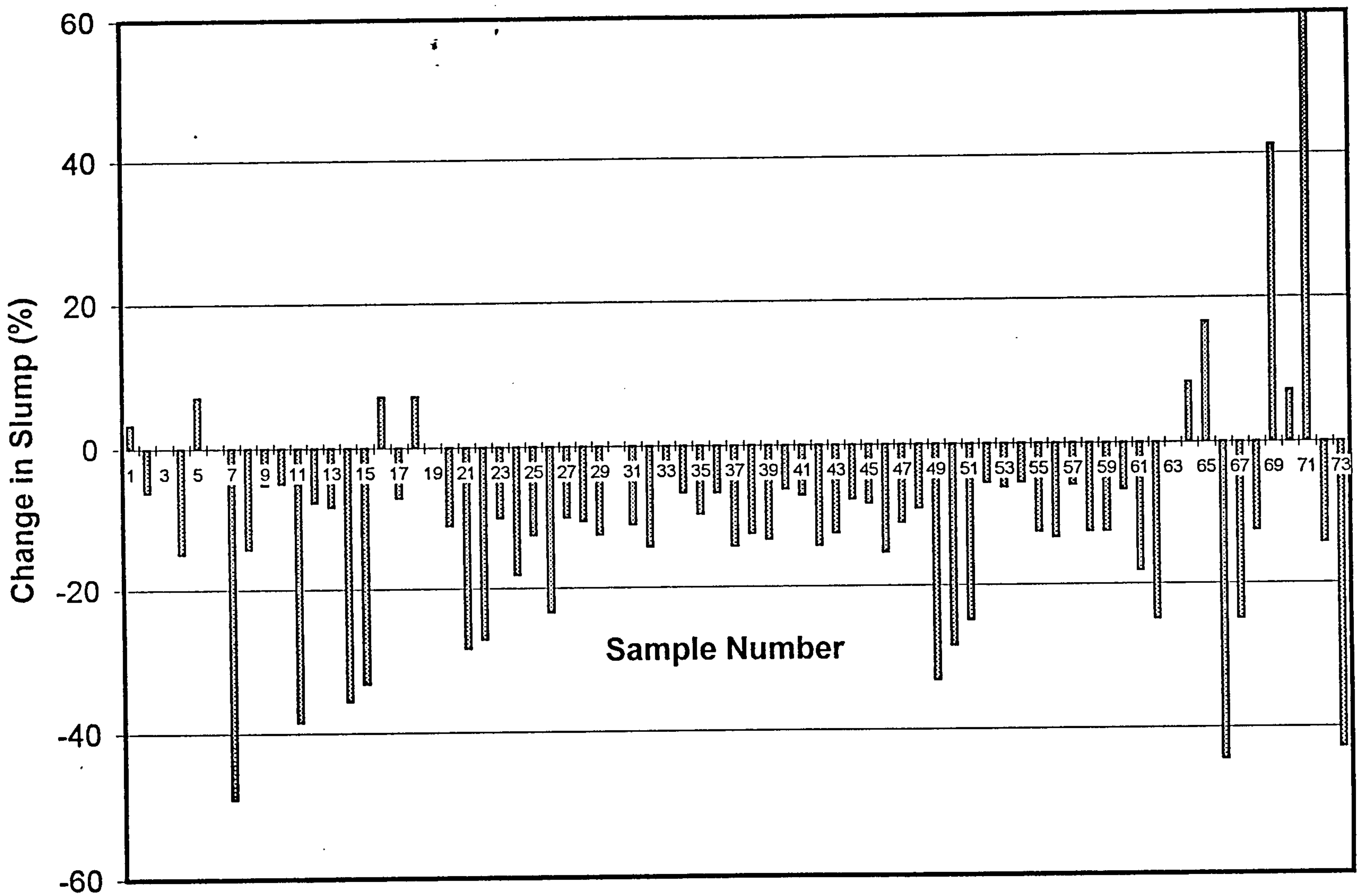

Figure 6.4: Percent Change in Slump Due to Pumping

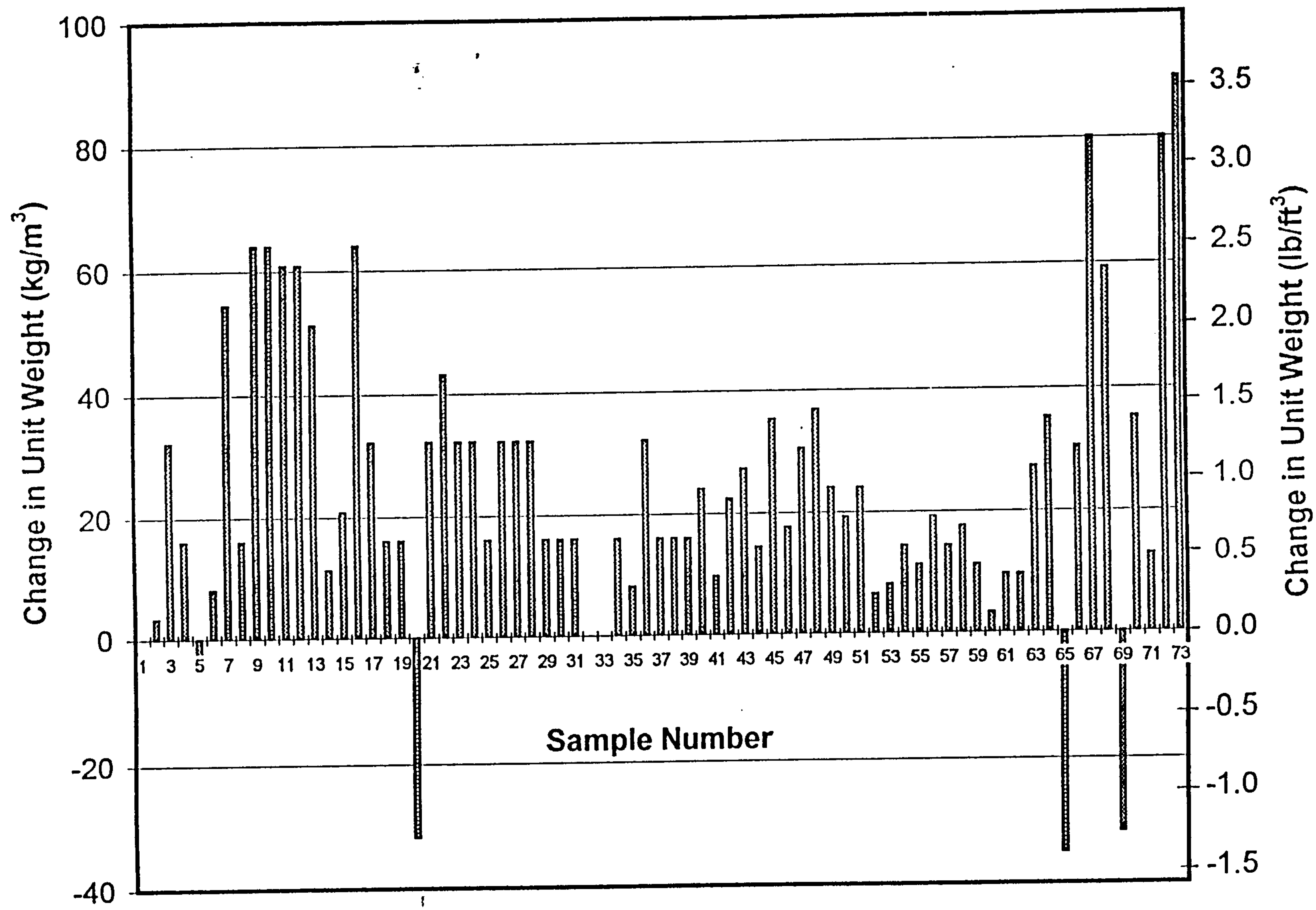

Figure 6.5: Change in Unit Weight Due to Pumping

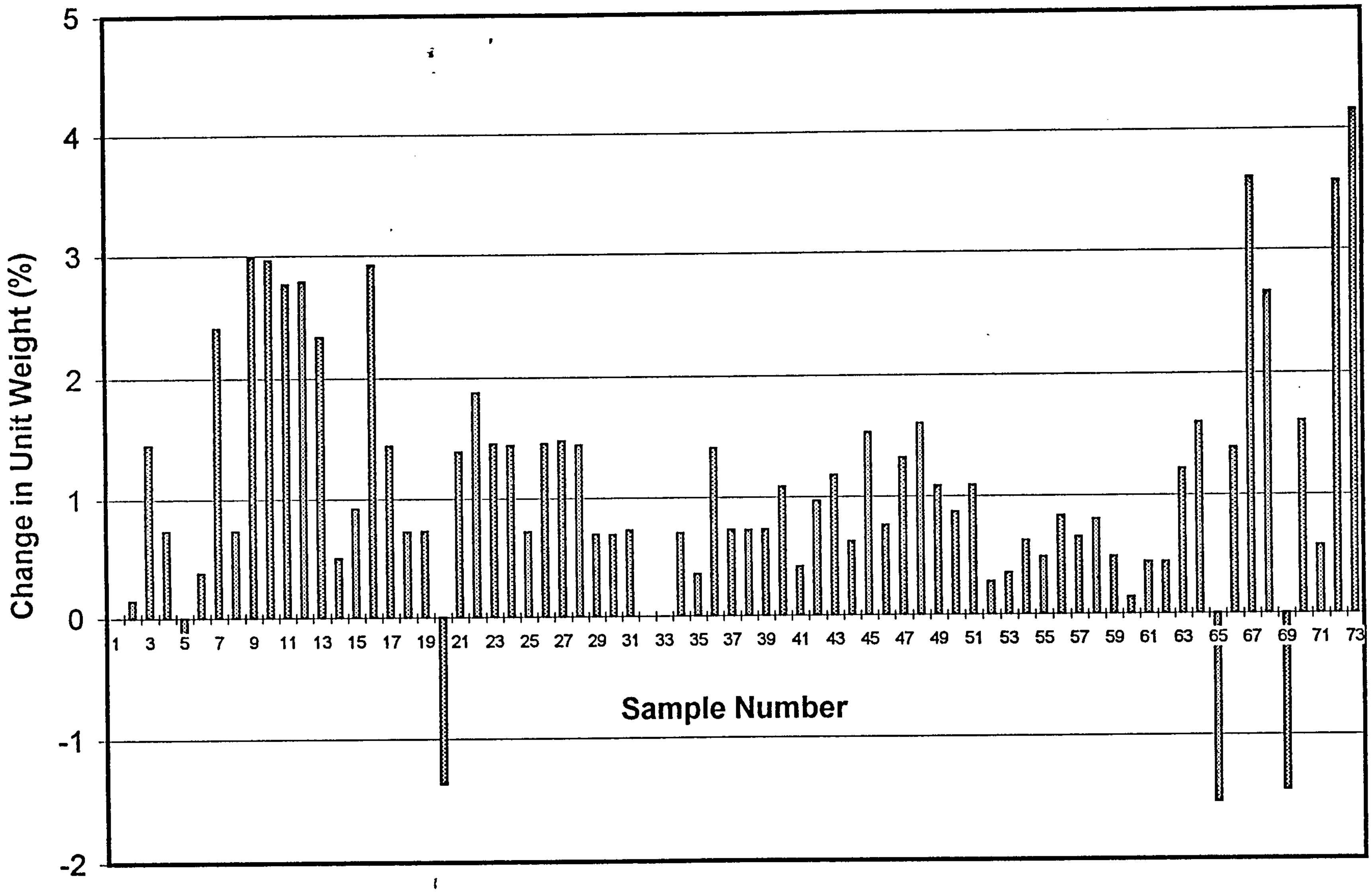

Figure 6.6: Percent Change in Unit Weight Due to Pumping

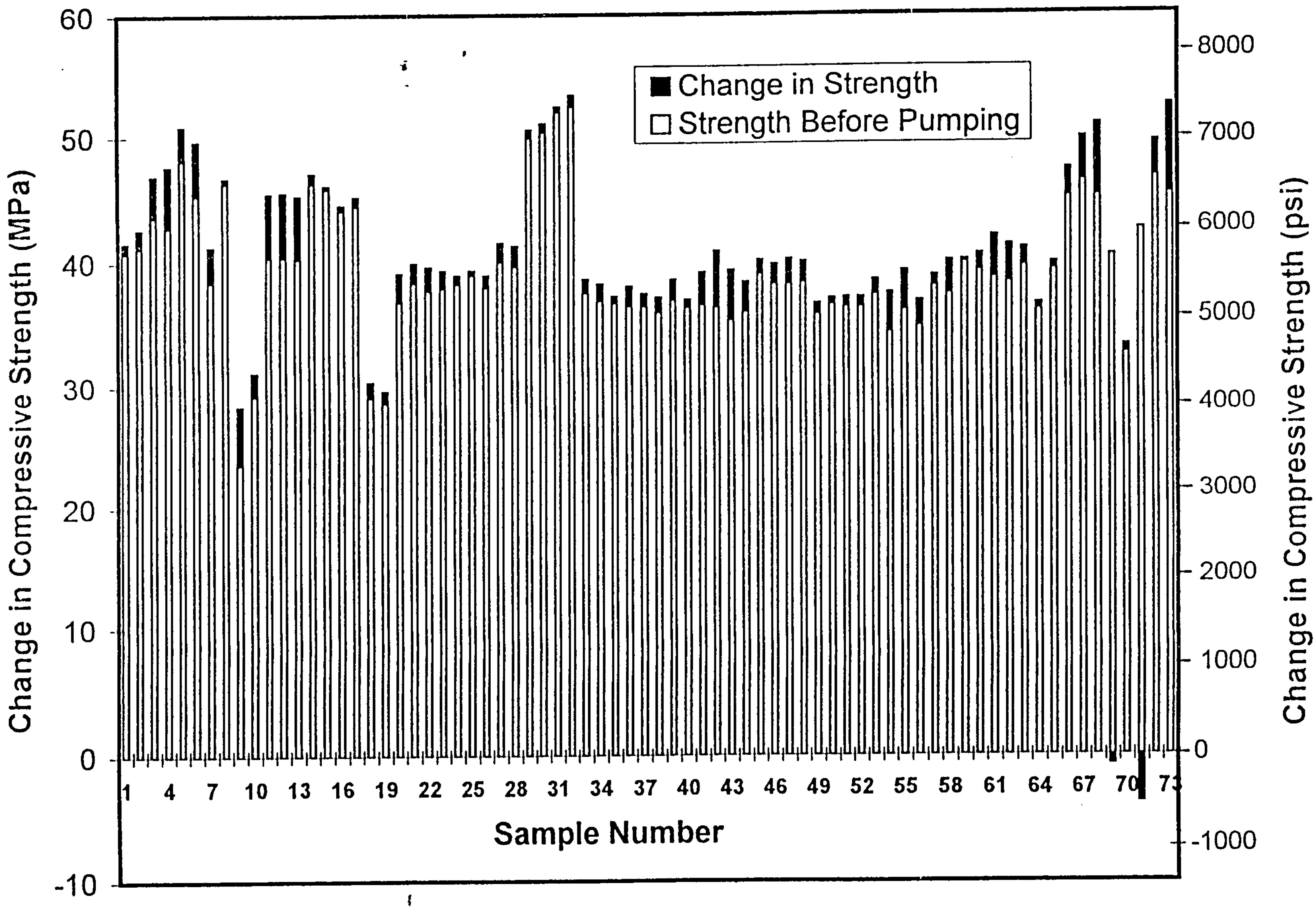

Figure 6.7: Change in Compressive Strength Due to Pumping

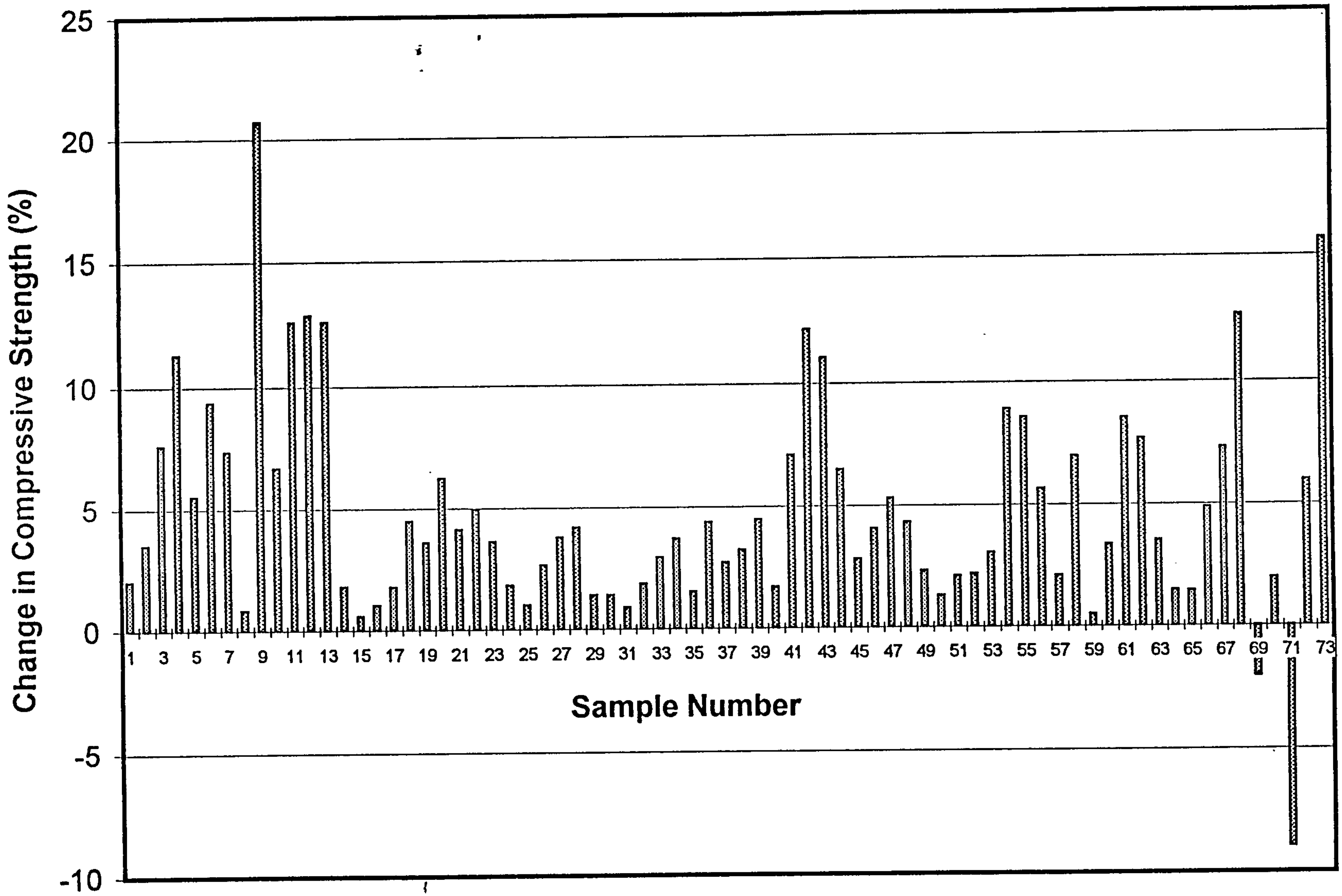

Figure 6.8: Percent Change in Compressive Strength Due to Pumping

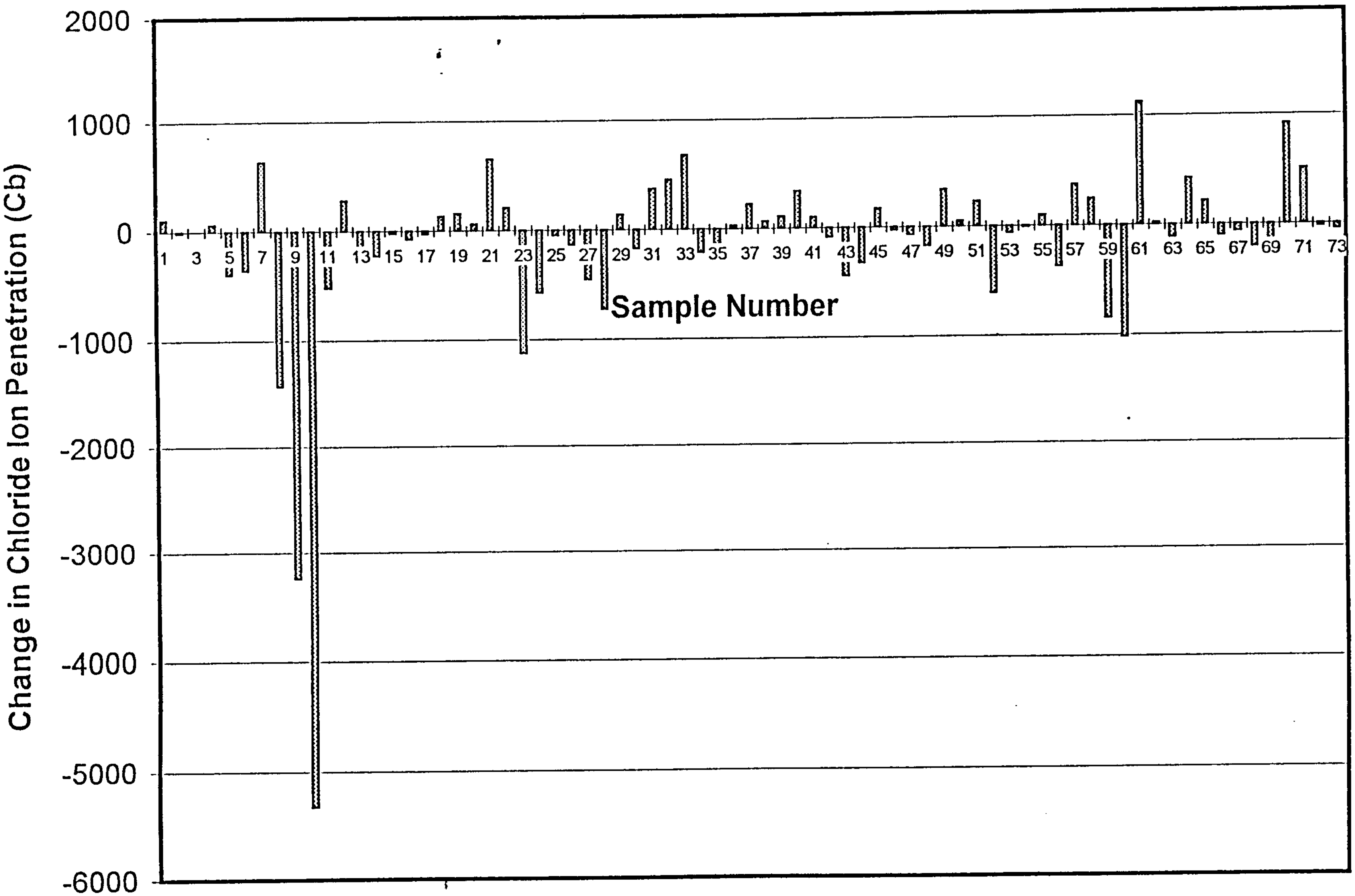

Figure 6.9: Change in Chloride Ion Penetration Due to Pumping

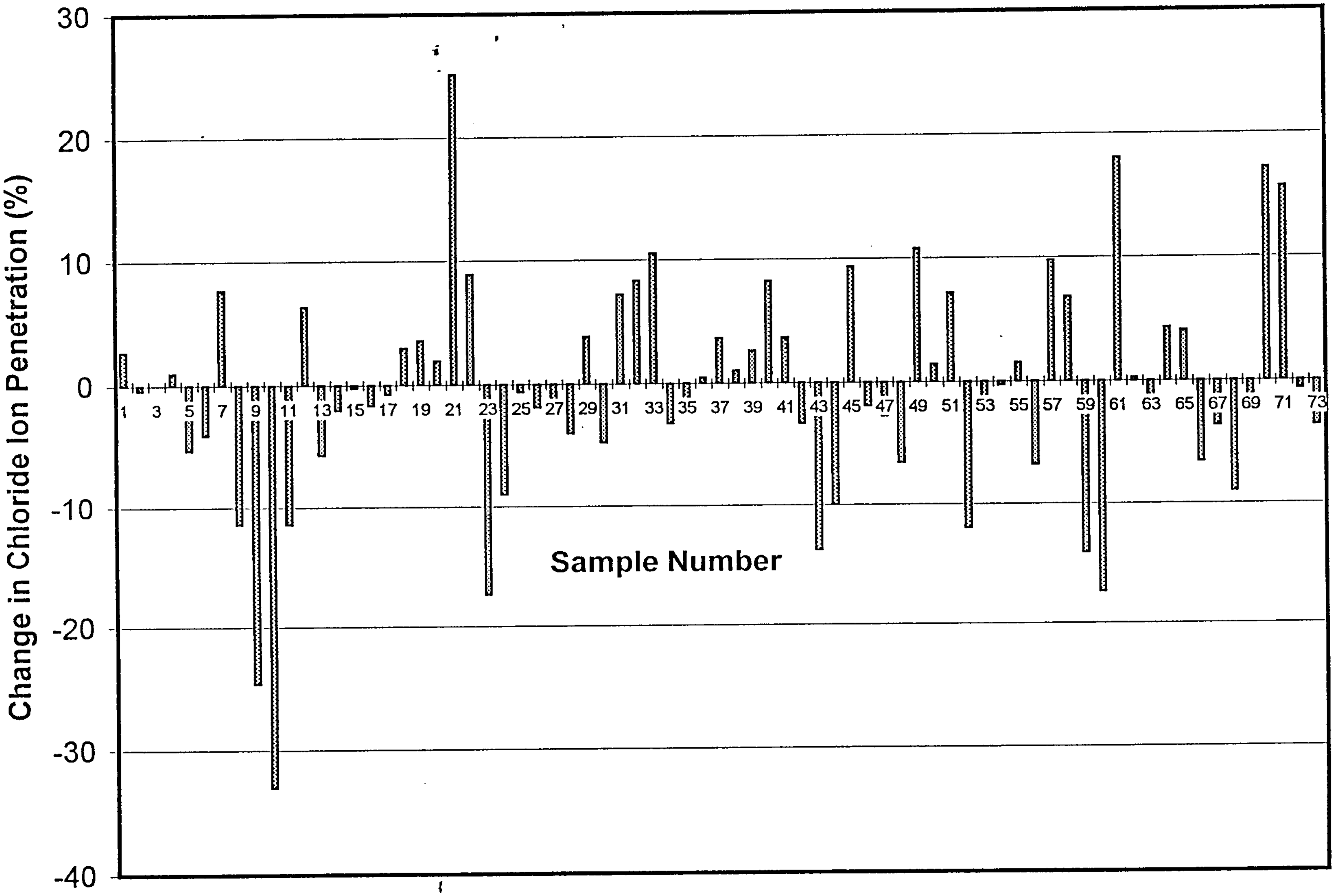

Figure 6.10: Percent Change in Chloride Ion Penetration Due to Pumping

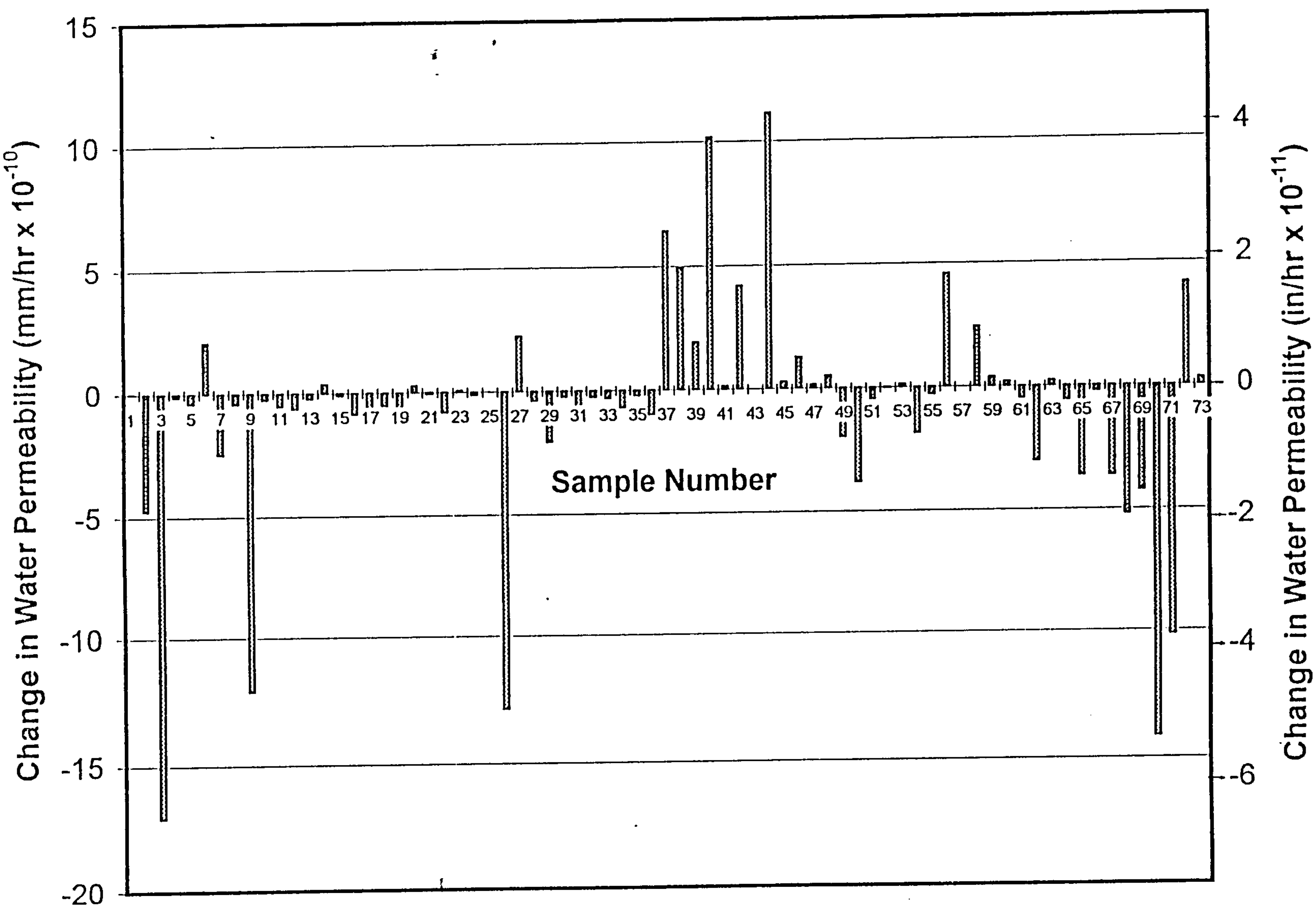

Figure 6.11: Change in Water Permeability Due to Pumping

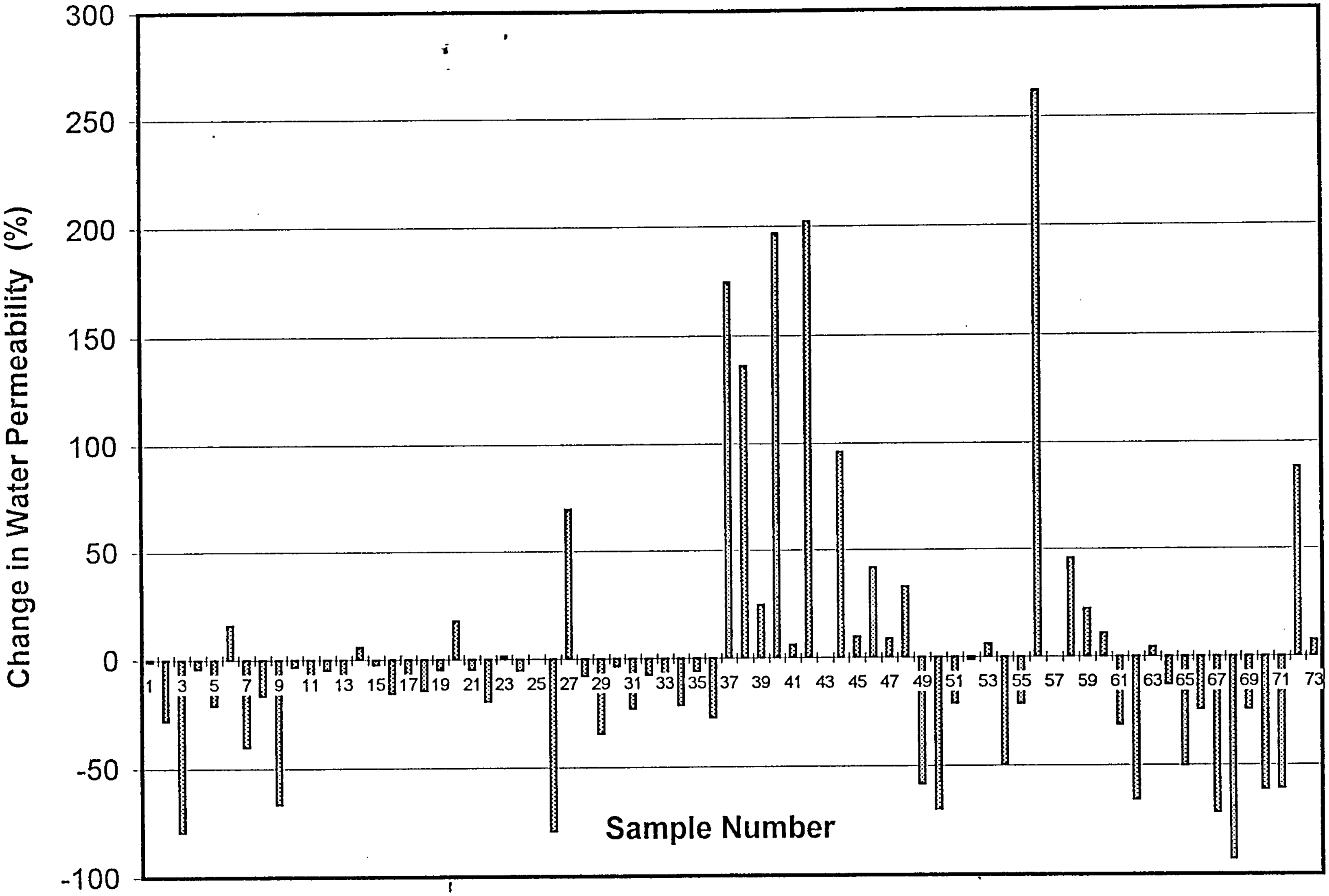

Figure 6.12: Percent Change in Water Permeability Due to Pumping

Appendix A

Appendix A.1

Concrete Mix Designs

CLASS CONCRETE: **IV (37.9 Mpa) 5500PSI**

SOURCE OF MATERIALS

COARSE Aggregate:	FLORIDA ROCK	GRADE:	57 S.G.(SSD):2.490
FINE Aggregate:	FLORIDA ROCK	F.M.:	2.20 S.G.(SSD):2.630
Pit No. (Coarse):	88_004	TYPE:	CRUSHED LIMEST.
Pit No. (Fine)	11_067	TYPE:	SILICA SAND
CEMENT:	FL MIN.& MATRLS	SPEC:	AASHTO M-85 II
AIR ENTR. ADMIX.	MBAR 90 MBLDRS.	SPEC:	AASHTO M-154
1st Admixture:	LL 961 R MBLDRS.	SPEC:	AASHTO M-194 D
2nd Admixture:	POKI 410 N MB.	SPEC:	ASTM C-494 F
3rd Admixture:	NONE	SPEC:	NONE
FLY ASH:	FLORIDA MINING	SPEC:	ASTM C-618 F

HOT WEATHER CONCRETE DESIGN MIX

NOTE: Aggregate correction factor : 0.4

CEMENT (Kg) LBS:	(272.1)	600	**SLUMP RNG:**	127 to 203	mm
COARSE. A. (Kg) LBS:	(790.9)	1744	**SLUMP RNG:**	5.0 to 8.0	inches
FINE AGG (Kg) LBS:	(486.6)	1073	**AIR CONTENT:**	2.4 to 5.6	%
AIR ENT AD.(ml) OZ:		10.00	UNIT WT (WET):		Kg/M3
1st ADMIX. (ml) OZ:		15.00	UNIT WT (WET):	140.20	PCF
2nd ADMIX. (ml) OZ:		101.00	W/C RT (PLNT):	0.36	(Kg/Kg)LB/LB
3rd ADMIX. (ml) OZ:		0.00	W/C RT (FIELD):	0.36	(Kg/Kg)LB/LB
WATER (ML) GAL:		31.10	THEO YIELD:		M3
WATER (Kg) LBS:		200.00	THEO YIELD:	27.11	CU FT
FLY ASH (Kg) LBS:		225.00			

PRODUCER TEST DATA:

CHLORIDE CONT:	( )	0.175	(Kg/M3) LB/CY
SLUMP:	( )	6.5	(mm) IN
AIR CONTENT:		4.3	%
TEMPERATURE:	( )	96	DEG (C) F

COMP. STRENGTH (MPA) PSI:

7 Day:	( )	7136
28 Day:	( )	7650

FDOT ASSIGNED PLANT NO: 80_292

Appendix A.2

Concrete Mix Designs

CLASS CONCRETE: **IV (5500PSI) (MASS)**

SOURCE OF MATERIALS

COARSE Aggregate:	TARMAC FLORIDA	GRADE:	57 S.G.(SSD):2.460
FINE Aggregate:	FLORIDA ROCK IND	F.M.:	2.20 S.G.(SSD):2.630
Pit No. (Coarse):	87_145	TYPE:	CRUSHED LIMEST.
Pit No. (Fine)	36_256	TYPE:	SILICA SAND
CEMENT:	FL MIN.& MATRLS	SPEC:	AASHTO M-85 II
AIR ENTR. ADMIX.	MBVR MASTERBLD.	SPEC:	AASHTO M-154
1st Admixture:	LL 961 R MB.	SPEC:	AASHTO M-194 D
2nd Admixture:	POZZOLITH 440N MB	SPEC:	ASTM C-494 G
3rd Admixture:	NONE	SPEC:	NONE
FLY ASH:	MONEX (CRSTL R.)	SPEC:	ASTM C-618 F

HOT WEATHER CONCRETE DESIGN MIX

NOTE: Aggregate correction factor : 0.4

CEMENT (Kg) LBS:	454.00	**SLUMP RNG:**	5.0 to 8.0	(mm) IN
COARSE. A. (Kg) LBS:	1729.00	**AIR CONTENT:**	2.4 to 5.6	%
FINE AGG (Kg) LBS:	986.00	UNIT WT (WET):	137.80	(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	9.10	W/C RT (PLNT):	0.34	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	18.30	W/C RT (FIELD):	0.34	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:	91.00	THEO YIELD:	27.07	(M3) CU FT
3rd ADMIX. (ml) OZ:	0.00			
WATER (ML) GAL:	31.00			
WATER (Kg) LBS:	258.00			
FLY ASH (Kg) LBS:	303.00			

PRODUCER TEST DATA:

CHLORIDE CONT:	0.147	(Kg/M3) LB/CY
SLUMP:	7.3	(mm) IN
AIR CONTENT:	3.3	%
TEMPERATURE:	99.0	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	5160
	28 Day:	6910

FDOT ASSIGNED PLANT NO.: 73_262

Appendix A.3

Concrete Mix Designs

CLASS CONCRETE: **IV CAL NIT (5500PSI)**

SOURCE OF MATERIALS

COARSE Aggregate:	VULCAN MATERIALS	GRADE:	57 S.G.(SSD):2.460
FINE Aggregate:	VULCAN MATERIALS	F.M.:	2.20 S.G.(SSD):2.630
Pit No. (Coarse):	08_005	TYPE:	CRUSHED LIMEST.
Pit No. (Fine)	16_081	TYPE:	SILICA SAND
CEMENT:	FL MIN.& MATRLS	SPEC:	AASHTO M-85 II
AIR ENTR. ADMIX.	MBVR MASTERBLD.	SPEC:	AASHTO M-154
1st Admixture:	POZZOLITH-80 MB.	SPEC:	AASHTO M-194 D
2nd Admixture:	DCI- W.R. GRACE	SPEC:	ASTM G-109
3rd Admixture:	NONE	SPEC:	NONE
FLY ASH:	FL. FLY ASH	SPEC:	ASTM C-618 F

HOT WEATHER CONCRETE DESIGN MIX

NOTE:Water cement ratio contains 31.5 pounds of water in the DCI_S

CEMENT (Kg) LBS:	610.00	**SLUMP RNG:**	1.5 to 4.5	(mm) IN
COARSE. A. (Kg) LBS:	1780.00	**AIR CONTENT:**	2.4 to 5.6	%
FINE AGG (Kg) LBS:	983.00	UNIT WT (WET):	140.50	(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	7.00	W/C RT (PLNT):	0.35	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	61.00	W/C RT (FIELD):	0.37	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:	576.00	THEO YIELD:	26.90	(M3) CU FT
3rd ADMIX. (ml) OZ:	0.00			
WATER (ML) GAL:	27.76			
WATER (Kg) LBS:	231.20			
FLY ASH (Kg) LBS:	144.00			

PRODUCER TEST DATA:

CHLORIDE CONT:	0.118	(Kg/M3) LB/CY
SLUMP:	3.5	(mm) IN
AIR CONTENT:	3.5	%
TEMPERATURE:	98.0	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	5400
	28 Day:	7650

FDOT ASSIGNED PLANT NO.: 15_020

Appendix A.4

Concrete Mix Designs

CLASS CONCRETE: IV (5500PSI)

SOURCE OF MATERIALS

COARSE Aggregate:	RINKER MATERIALS	GRADE:	57 S.G.(SSD):2.460
FINE Aggregate:	FLORIDA ROCK IND	F.M.:	2.20 S.G.(SSD):2.630
Pit No. (Coarse):	87_090	TYPE:	CRUSHED LIMEST.
Pit No. (Fine)	36_256	TYPE:	SILICA SAND
CEMENT:	FL MIN.& MATRLS	SPEC:	AASHTO M-85 II
AIR ENTR. ADMIX.	MBVR-S MB.	SPEC:	AASHTO M-154
1st Admixture:	LL 961 R MB.	SPEC:	AASHTO M-194 D
2nd Admixture:	NONE	SPEC:	NONE
3rd Admixture:	NONE	SPEC:	NONE
FLY ASH:	MONEX (CRSTL R.)	SPEC:	ASTM C-618 F

HOT WEATHER CONCRETE DESIGN MIX

NOTE: A. C. factor : 0.4; W/C ratio contains 31.5 lbs of water in the DCI_S

CEMENT (Kg) LBS:	584.00	**SLUMP RNG:**	1.5 to 4.5	(mm) IN
COARSE. A. (Kg) LBS:	1708.00	**AIR CONTENT:**	2.4 to 5.6	%
FINE AGG (Kg) LBS:	1050.00	UNIT WT (WET):	139.10	(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	5.80	W/C RT (PLNT):	0.37	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	47.00	W/C RT (FIELD):	0.37	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:	0.00	THEO YIELD:	27.03	(M3) CU FT
3rd ADMIX. (ml) OZ:	0.00			
WATER (ML) GAL:	32.50			
WATER (Kg) LBS:	271.00			
FLY ASH (Kg) LBS:	146.00			

PRODUCER TEST DATA:

CHLORIDE CONT:	0.095	(Kg/M3) LB/CY
SLUMP:	2.3	(mm) IN
AIR CONTENT:	3.4	%
TEMPERATURE:	97.0	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	7620
	28 Day:	6910

FDOT ASSIGNED PLANT NO.: 73_262

Appendix A.5

Concrete Mix Designs

CLASS CONCRETE: IV (3400PSI)

SOURCE OF MATERIALS

COARSE Aggregate:	FL CRUSHED ST.	GRADE:	No data
FINE Aggregate:	STNDRD SAND CO.	F.M.:	No data
Pit No. (Coarse):	08_012	TYPE:	CRUSHED STONE.
Pit No. (Fine)	16_277	TYPE:	SILICA SAND
CEMENT:	FL CRUSHED CEM II	SPEC:	ASTM- C-150
AIR ENTR. ADMIX.	MBAE MASTRBUILD	SPEC:	AASHTO MASTM C-260
1st Admixture:	MBL-80 MB.	SPEC:	ASTM C-494
2nd Admixture:	NONE	SPEC:	NONE
3rd Admixture:	NONE	SPEC:	NONE
FLY ASH:	MONEX RECOURC.	SPEC:	ASTM C-618 F

HOT WEATHER CONCRETE DESIGN MIX

NOTE: None.

CEMENT (Kg) LBS:	523.00	**SLUMP RNG:**	0.0 to 3.5	(mm) IN
COARSE. A. (Kg) LBS:	1730.00	**AIR CONTENT:**	3.0 to 6.0	%
FINE AGG (Kg) LBS:	1096.00	UNIT WT (WET):	No Data	(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	3.00	W/C RT (PLNT):	0.41	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	52.64	W/C RT (FIELD):	0.41	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:	0.00	THEO YIELD:	27.00	(M3) CU FT
3rd ADMIX. (ml) OZ:	0.00			
WATER (ML) GAL:	32.00			
WATER (Kg) LBS:	267.00			
FLY ASH (Kg) LBS:	130.00			

PRODUCER TEST DATA:

CHLORIDE CONT:	No Data	(Kg/M3) LB/CY
SLUMP:	3.5	(mm) IN
AIR CONTENT:	4.0 with +/- 1.5	%
TEMPERATURE:	No Data	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	No Data
	28 Day:	No Data

Appendix A.6

Concrete Mix Designs

CLASS CONCRETE: **II DECK (4500PSI)**

SOURCE OF MATERIALS

COARSE Aggregate:	VULCAN MATERIALS	GRADE:	67 S.G.(SSD):2.760
FINE Aggregate:	FRIESE MATERIALS	F.M.:	2.40 S.G.(SSD):2.630
Pit No. (Coarse):	AL-149	TYPE:	CRUSHED LIMEST.
Pit No. (Fine)	AL-386	TYPE:	SILICA SAND
CEMENT:	FL MIN.& MATRLS	SPEC:	AASHTO M-85 II
AIR ENTR. ADMIX.	DAREX W.R. GRACE	SPEC:	AASHTO M-154
1st Admixture:	WRDA 64 W.R.GRC.	SPEC:	AASHTO M-194 D
2nd Admixture:	NONE	SPEC:	NONE
3rd Admixture:	NONE	SPEC:	NONE
FLY ASH:	MONEX RSC (LROY)	SPEC:	ASTM C-618 F

HOT WEATHER CONCRETE DESIGN MIX

NOTE: None.

CEMENT (Kg) LBS:	650.00	**SLUMP RNG:**	1.5 to 4.5	(mm) IN
COARSE. A. (Kg) LBS:	1889.00	**AIR CONTENT:**	2.4 to 5.6	%
FINE AGG (Kg) LBS:	990.00	UNIT WT (WET):	146.90	(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	12.00	W/C RT (PLNT):	0.37	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	39.00	27	0.37	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:	0.00	THEO YIELD:	26.90	(M3) CU FT
3rd ADMIX. (ml) OZ:	0.00			
WATER (ML) GAL:	35.00			
WATER (Kg) LBS:	291.60			
FLY ASH (Kg) LBS:	145.00			

PRODUCER TEST DATA:

CHLORIDE CONT:	0.211	(Kg/M3) LB/CY
SLUMP:	2.8	(mm) IN
AIR CONTENT:	4.5	%
TEMPERATURE:	96.0	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	4510
	28 Day:	5870

FDOT ASSIGNED PLANT NO.: 48_037

Appendix A.7

Concrete Mix Designs

CLASS CONCRETE: **IV DRILL SHAFT (4000PSI)**

SOURCE OF MATERIALS

COARSE Aggregate:	MARTIN MARIETTA	GRADE:	67 S.G.(SSD):2.630
FINE Aggregate:	ROBERTS SAND CO	F.M.:	2.40 S.G.(SSD):2.640
Pit No. (Coarse):	50_120	TYPE:	RIVER GRAVEL
Pit No. (Fine)	47_314	TYPE:	SILICA SAND
CEMENT:	MEDUSA CEMENT	SPEC:	AASHTO M-85 II
AIR ENTR. ADMIX.	MBAE 90 MB.	SPEC:	AASHTO M-154
1st Admixture:	DELVO MB.	SPEC:	AASHTO M-194 D
2nd Admixture:	NONE	SPEC:	NONE
3rd Admixture:	NONE	SPEC:	NONE
FLY ASH:	MONEX RESOURC.	SPEC:	ASTM C-618 F

HOT WEATHER CONCRETE DESIGN MIX

NOTE: None.

CEMENT (Kg) LBS:	560.00	**SLUMP RNG:**	7.0 to 9.0	(mm) IN
COARSE. A. (Kg) LBS:	1900.00	**AIR CONTENT:**	2.4 to 5.6	%
FINE AGG (Kg) LBS:	1014.00	UNIT WT (WET):	143.80	(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	15.00	W/C RT (PLNT):	0.39	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	79.00	W/C RT (FIELD):	0.39	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:	0.00	THEO YIELD:	27.04	(M3) CU FT
3rd ADMIX. (ml) OZ:	0.00			
WATER (ML) GAL:	33.00			
WATER (Kg) LBS:	275.00			
FLY ASH (Kg) LBS:	140.00			

PRODUCER TEST DATA:

CHLORIDE CONT:	0.050	(Kg/M3) LB/CY
SLUMP:	7.3	(mm) IN
AIR CONTENT:	3.7	%
TEMPERATURE:	100.0	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	3990
	28 Day:	5750

FDOT ASSIGNED PLANT NO.: 47_033

Appendix A.8

Concrete Mix Designs

CLASS CONCRETE: **II DECK (4500PSI)**

SOURCE OF MATERIALS

COARSE Aggregate:	RINKER SOUEAST	GRADE:	57 S.G.(SSD):2.460
FINE Aggregate:	FL.CRUSHED ST.	F.M.:	2.20 S.G.(SSD):2.630
Pit No. (Coarse):	87_090	TYPE:	CRUSHED LIMEST.
Pit No. (Fine)	11_283	TYPE:	SILICA SAND
CEMENT:	FL MIN.& MATRLS		AASHTO M-85 II
AIR ENTR. ADMIX.	MBVR MASTERBLD.	SPEC:	AASHTO M-154
1st Admixture:	LL 961 R MB.	SPEC:	AASHTO M-194 D
2nd Admixture:	NONE	SPEC:	NONE
3rd Admixture:	NONE	SPEC:	NONE
FLY ASH:	MONEX (CSTL RVR.)	SPEC:	ASTM C-618 F

HOT WEATHER CONCRETE DESIGN MIX

NOTE: Aggregate correction factor : 0.3

CEMENT (Kg) LBS:	500.00	**SLUMP RNG:**	1.5 to 4.5	(mm) IN
COARSE. A. (Kg) LBS:	1795.00	**AIR CONTENT:**	2.4 to 5.6	%
FINE AGG (Kg) LBS:	1067.00	UNIT WT (WET):	138.90	(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	7.00	W/C RT (PLNT):	0.43	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	20.00	W/C RT (FIELD):	0.43	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:	0.00	THEO YIELD:	27.03	(M3) CU FT
3rd ADMIX. (ml) OZ:	0.00			
WATER (ML) GAL:	32.05			
WATER (Kg) LBS:	267.00			
FLY ASH (Kg) LBS:	125.00			

PRODUCER TEST DATA:

CHLORIDE CONT:	NONE	(Kg/M3) LB/CY
SLUMP:	3.5	(mm) IN
AIR CONTENT:	3.3	%
TEMPERATURE:	96.0	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	5560
	28 Day:	6660

FDOT ASSIGNED PLANT NO.: 75_408 75_165 92_092

Appendix A.9

Concrete Mix Designs

CLASS CONCRETE: IV (5500PSI)

SOURCE OF MATERIALS

COARSE Aggregate:	VULCAN MATERLS.	GRADE:	67 S.G.(SSD):2.760
FINE Aggregate:	ROBERTS SAND CO	F.M.:	2.40 S.G.(SSD):2.640
Pit No. (Coarse):	AL-149	TYPE:	CRUSHED LIMESTN.
Pit No. (Fine)	47_314	TYPE:	SILICA SAND
CEMENT:	MEDUSA CEMENT	SPEC:	AASHTO M-85 II
AIR ENTR. ADMIX.	MBAE 90 MB.	SPEC:	AASHTO M-154
1st Admixture:	POZZOLITH 300R MB	SPEC:	AASHTO M-194 D
2nd Admixture:	NONE	SPEC:	NONE
3rd Admixture:	NONE	SPEC:	NONE
FLY ASH:	MONEX RESOURC.	SPEC:	ASTM C-618 F

HOT WEATHER CONCRETE DESIGN MIX

NOTE:Water cement ratio contains 31.5 pounds of water in the DCI_S

CEMENT (Kg) LBS:	600.00	**SLUMP RNG:**	1.5 to 4.5	(mm) IN
COARSE. A. (Kg) LBS:	2000.00	**AIR CONTENT:**	2.4 to 5.6	%
FINE AGG (Kg) LBS:	919.00	UNIT WT (WET):	146.40	(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	16.00	W/C RT (PLNT):	0.39	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	38.00	W/C RT (FIELD):	0.39	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:	0.00	THEO YIELD:	27.05	(M3) CU FT
3rd ADMIX. (ml) OZ:	0.00			
WATER (ML) GAL:	35.00			
WATER (Kg) LBS:	292.00			
FLY ASH (Kg) LBS:	150.00			

PRODUCER TEST DATA:

CHLORIDE CONT:	0.256	(Kg/M3) LB/CY
SLUMP:	3.3	(mm) IN
AIR CONTENT:	3.0	%
TEMPERATURE:	98.0	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	5520
	28 Day:	7440

FDOT ASSIGNED PLANT NO.: 47_033

Appendix A.10

Concrete Mix Designs

CLASS CONCRETE: **II DECK (4500 PSI)**

SOURCE OF MATERIALS

COARSE Aggregate:	MARTIN MARRIETTA	GRADE:	67 S.G.(SSD):2.630
FINE Aggregate:	ROBERTS SAND CO	F.M.:	2.40 S.G.(SSD):2.640
Pit No. (Coarse):	50 - 120	TYPE:	RIVER GRAVEL
Pit No. (Fine)	47 - 314	TYPE:	SILICA SAND
CEMENT:	MEDUSA CEMENT	SPEC:	AASHTO M-85 II
AIR ENTR. ADMIX.	MBAE 90 MBLDRS.	SPEC:	AASHTO M-154
1st Admixture:	POZZ 300R MBLDRS.	SPEC:	AASHTO M-194 D
2nd Admixture:	NONE	SPEC:	NONE
3rd Admixture:	NONE	SPEC:	NONE
FLY ASH:	MONEX RESOURCE	SPEC:	ASTM C-618 F

HOT WEATHER CONCRETE DESIGN MIX

NOTE: None.

CEMENT (Kg) LBS:	560.00	**SLUMP RNG:**	1.5 TO 4.5	(mm) IN
COARSE. A. (Kg) LBS:	1970.00	**AIR CONTENT:**	2.4 to 5.6	%
FINE AGG (Kg) LBS:	943.00	UNIT WT (WET):	143.90	(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	6.00	W/C RT (PLNT):	0.39	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	35.00	W/C RT (FIELD):	0.39	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:	0.00	THEO YIELD:	27.02	(M3) CU FT
3rd ADMIX. (ml) OZ:	0.00			
WATER (ML) GAL:	33.00			
WATER (Kg) LBS:	275.00			
FLY ASH (Kg) LBS:	140.00			

PRODUCER TEST DATA:

CHLORIDE CONT:	0.049	(Kg/M3) LB/CY
SLUMP:	2.5	(mm) IN
AIR CONTENT:	3.5	%
TEMPERATURE:	98.0	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	4730
	28 Day:	5740

FDOT ASSIGNED PLANT NO: 47_033

Appendix A.11

Concrete Mix Designs

CLASS CONCRETE: **II DECK (4500 PSI)**

SOURCE OF MATERIALS

COARSE Aggregate:	FLORIDA ROCK IND	GRADE:	57 S.G.(SSD):2.370
FINE Aggregate:	FLORIDA ROCK IND	F.M.:	2.25 S.G.(SSD):2.630
Pit No. (Coarse):	TM - 469	TYPE:	CRUSHED LIMEST.
Pit No. (Fine)	11 - 067	TYPE:	SILICA SAND
CEMENT:	BROOKSVILLE CMT	SPEC:	AASHTO M-85 II
AIR ENTR. ADMIX.	DAREX W.R. GRC	SPEC:	AASHTO M-154
1st Admixture:	WRDA 64 W.R. GRC	SPEC:	AASHTO M-194 D
2nd Admixture:	NONE	SPEC:	NONE
3rd Admixture:	NONE	SPEC:	NONE
FLY ASH:	MONEX RESOURCE	SPEC:	ASTM C-618 F

HOT WEATHER CONCRETE DESIGN MIX

NOTE: None

CEMENT (Kg) LBS:	530.00	**SLUMP RNG:**	1.5 to 4.5	(mm) IN
COARSE. A. (Kg) LBS:	1680.00	**AIR CONTENT:**	2.4 to 5.6	%
FINE AGG (Kg) LBS:	1101.00	UNIT WT (WET):	137.10	(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	13.20	W/C RT (PLNT):	0.40	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	26.40	W/C RT (FIELD):	0.41	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:	0.00	THEO YIELD:	27.01	(M3) CU FT
3rd ADMIX. (ml) OZ:	0.00			
WATER (ML) GAL:	31.50			
WATER (Kg) LBS:	262.00			
FLY ASH (Kg) LBS:	130.00			

PRODUCER TEST DATA:

CHLORIDE CONT:	0.082	(Kg/M3) LB/CY
SLUMP:	3.75	(mm) IN
AIR CONTENT:	3.9	%
TEMPERATURE:	97.0	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	No Data
	28 Day:	5780

FDOT ASSIGNED PLANT NO: 75_432

Appendix A.12

Concrete Mix Designs

CLASS CONCRETE: **I**

SOURCE OF MATERIALS

COARSE Aggregate:		GRADE:	57
FINE Aggregate:		F.M.:	2.21
Pit No. (Coarse):	87-145	TYPE:	CRUSHED LIMESTONE
Pit No. (Fine)	76-349	TYPE:	SILICA SAND
CEMENT:		SPEC:	
AIR ENTR. ADMIX.	DAREX	SPEC:	
1st Admixture:	WRDA 79	SPEC:	
2nd Admixture:		SPEC:	
3rd Admixture:		SPEC:	
FLY ASH:		SPEC:	

NOTE: None

CEMENT (Kg) LBS:	363.00	**SLUMP RNG:**	3	(mm) IN
COARSE. A. (Kg) LBS:	994.00	**AIR CONTENT:**	4.6	%
FINE AGG (Kg) LBS:	741.00	UNIT WT (WET):		(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	4.50	W/C RT (PLNT):	0.42	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	61.00	W/C RT (FIELD):	0.42	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:		THEO YIELD:		(M3) CU FT
3rd ADMIX. (ml) OZ:				
WATER (ML) GAL:				
WATER (Kg) LBS:				
FLY ASH (Kg) LBS:				

PRODUCER TEST DATA:

CHLORIDE CONT:		(Kg/M3) LB/CY
SLUMP:	3.00	(mm) IN
AIR CONTENT:	4.6	%
TEMPERATURE:	97.0	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	6030
	14 Day:	6160

FDOT ASSIGNED PLANT NO:

Appendix A.13

Concrete Mix Designs

CLASS CONCRETE: **II**

SOURCE OF MATERIALS

COARSE Aggregate:		GRADE:	57
FINE Aggregate:		F.M.:	2.83
Pit No. (Coarse):	87-145	TYPE:	CRUSHED LIMESTONE
Pit No. (Fine)	87-145	TYPE:	LIMESTONE SCEENINGS
CEMENT:		SPEC:	
AIR ENTR. ADMIX.	DAREX	SPEC:	
1st Admixture:	WRDA 79	SPEC:	
2nd Admixture:		SPEC:	
3rd Admixture:		SPEC:	
FLY ASH:	MONEX	SPEC:	

NOTE: None

CEMENT (Kg) LBS:	341.00	**SLUMP RNG:**	2.5	(mm) IN
COARSE. A. (Kg) LBS:	950.00	**AIR CONTENT:**	3	%
FINE AGG (Kg) LBS:	684.00	UNIT WT (WET):		(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	6.00	W/C RT (PLNT):	0.38	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	63.50	W/C RT (FIELD):	0.38	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:		THEO YIELD:		(M3) CU FT
3rd ADMIX. (ml) OZ:				
WATER (ML) GAL:				
WATER (Kg) LBS:				
FLY ASH (Kg) LBS:	77.00			

PRODUCER TEST DATA:

CHLORIDE CONT:		(Kg/M3) LB/CY	
SLUMP:	2.50	(mm) IN	
AIR CONTENT:	3.0	%	
TEMPERATURE:	95.0	DEG (C) F	
COMP. STRENGTH (MPA) PSI:			
	7 Day:		
	28 Day:		7230

FDOT ASSIGNED PLANT NO:

Appendix A.14

Concrete Mix Designs

CLASS CONCRETE: **I**

SOURCE OF MATERIALS

COARSE Aggregate:		GRADE:	57
FINE Aggregate:		F.M.:	2.1
Pit No. (Coarse):	08-005	TYPE:	CRUSHED LIMESTONE
Pit No. (Fine)	16-081	TYPE:	SILICA SAND
CEMENT:		SPEC:	
AIR ENTR. ADMIX.	Air-Mix	SPEC:	
1st Admixture:	EUCON WR	SPEC:	
2nd Admixture:		SPEC:	
3rd Admixture:		SPEC:	
FLY ASH:	FLORIDA FLY ASH	SPEC:	

NOTE: None

CEMENT (Kg) LBS:	342.00	**SLUMP RNG:**	3.25	(mm) IN
COARSE. A. (Kg) LBS:	1024.00	**AIR CONTENT:**	3.2	%
FINE AGG (Kg) LBS:	580.00	UNIT WT (WET):		(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	4.00	W/C RT (PLNT):	0.41	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	45.10	W/C RT (FIELD):	0.41	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:		THEO YIELD:		(M3) CU FT
3rd ADMIX. (ml) OZ:				
WATER (ML) GAL:				
WATER (Kg) LBS:				
FLY ASH (Kg) LBS:	85.00			

PRODUCER TEST DATA:

CHLORIDE CONT:		(Kg/M3) LB/CY
SLUMP:	3.25	(mm) IN
AIR CONTENT:	3.2	%
TEMPERATURE:	95.0	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	6060
	28 Day:	7120

FDOT ASSIGNED PLANT NO:

Appendix A.15

Concrete Mix Designs

CLASS CONCRETE: **I**

SOURCE OF MATERIALS

COARSE Aggregate:		GRADE:	67
FINE Aggregate:		F.M.:	2.41
Pit No. (Coarse):	87-090	TYPE:	CRUSHED LIMESTONE
Pit No. (Fine)	76-349	TYPE:	SILICA SAND
CEMENT:		SPEC:	
AIR ENTR. ADMIX.	DAREX	SPEC:	
1st Admixture:	WRDA 79	SPEC:	
2nd Admixture:		SPEC:	
3rd Admixture:		SPEC:	
FLY ASH:		SPEC:	

NOTE: None

CEMENT (Kg) LBS:	182.00	**SLUMP RNG:**	3.5	(mm) IN
COARSE. A. (Kg) LBS:	1056.00	**AIR CONTENT:**	4.5	%
FINE AGG (Kg) LBS:	687.00	UNIT WT (WET):		(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	4.10	W/C RT (PLNT):	0.39	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	47.00	W/C RT (FIELD):	0.39	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:		THEO YIELD:		(M3) CU FT
3rd ADMIX. (ml) OZ:				
WATER (ML) GAL:				
WATER (Kg) LBS:				
FLY ASH (Kg) LBS:	182.00			

PRODUCER TEST DATA:

CHLORIDE CONT:		(Kg/M3) LB/CY	
SLUMP:	3.50	(mm) IN	
AIR CONTENT:	4.5	%	
TEMPERATURE:	97.0	DEG (C) F	
COMP. STRENGTH (MPA) PSI:			
	7 Day:		
	28 Day:		7660

FDOT ASSIGNED PLANT NO:

Appendix A.16

Concrete Mix Designs

CLASS CONCRETE: **II**

SOURCE OF MATERIALS

COARSE Aggregate:		GRADE:	57
FINE Aggregate:		F.M.:	2.21
Pit No. (Coarse):	87-145	TYPE:	CRUSHED LIMESTONE
Pit No. (Fine)	87-145	TYPE:	SILICA SAND
CEMENT:		SPEC:	
AIR ENTR. ADMIX.	DAREX	SPEC:	
1st Admixture:	WRDA 79	SPEC:	
2nd Admixture:		SPEC:	
3rd Admixture:		SPEC:	
FLY ASH:	BLUE CIRCLE	SPEC:	

NOTE:None

CEMENT (Kg) LBS:	195.00	**SLUMP RNG:**	3.5	(mm) IN
COARSE. A. (Kg) LBS:	1039.00	**AIR CONTENT:**	3.3	%
FINE AGG (Kg) LBS:	645.00	UNIT WT (WET):		(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	6.00	W/C RT (PLNT):	0.40	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	59.00	W/C RT (FIELD):	0.40	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:		THEO YIELD:		(M3) CU FT
3rd ADMIX. (ml) OZ:				
WATER (ML) GAL:				
WATER (Kg) LBS:				
FLY ASH (Kg) LBS:	195.00			

PRODUCER TEST DATA:

CHLORIDE CONT:		(Kg/M3) LB/CY	
SLUMP:	3.50	(mm) IN	
AIR CONTENT:	3.3	%	
TEMPERATURE:	95.0	DEG (C) F	
COMP. STRENGTH (MPA) PSI:			
	7 Day:		
	21 Day:		7120

FDOT ASSIGNED PLANT NO:

Appendix A.17

Concrete Mix Designs

CLASS CONCRETE: **I**

SOURCE OF MATERIALS

COARSE Aggregate:		GRADE:	57
FINE Aggregate:		F.M.:	2.2
Pit No. (Coarse):	87-090	TYPE:	CRUSHED LIMESTONE
Pit No. (Fine)	11-067	TYPE:	SILICA SAND
CEMENT:		SPEC:	
AIR ENTR. ADMIX.	DAREX	SPEC:	
1st Admixture:	WRDA 79	SPEC:	
2nd Admixture:		SPEC:	
3rd Admixture:		SPEC:	
FLY ASH:	FLORIDA FLY ASH	SPEC:	

NOTE: None

CEMENT (Kg) LBS:	279.00	**SLUMP RNG:**	2.25	(mm) IN
COARSE. A. (Kg) LBS:	1049.00	**AIR CONTENT:**	5	%
FINE AGG (Kg) LBS:	672.00	UNIT WT (WET):		(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	6.00	W/C RT (PLNT):	0.41	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	38.80	W/C RT (FLD):	0.41	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:		THEO YIELD:		(M3) CU FT
3rd ADMIX. (ml) OZ:				
WATER (ML) GAL:				
WATER (Kg) LBS:				
FLY ASH (Kg) LBS:	66.00			

PRODUCER TEST DATA:

CHLORIDE CONT:		(Kg/M3) LB/CY	
SLUMP:	2.25	(mm) IN	
AIR CONTENT:	5.0	%	
TEMPERATURE:	95.0	DEG (C) F	
COMP. STRENGTH (MPA) PSI:			
	7 Day:		
	28 Day:		5480

FDOT ASSIGNED PLANT NO:

Appendix A.18

Concrete Mix Designs

CLASS CONCRETE: I

SOURCE OF MATERIALS

COARSE Aggregate:		GRADE:	57
FINE Aggregate:		F.M.:	2.2
Pit No. (Coarse):	87-089	TYPE:	CRUSHED LIMESTONE
Pit No. (Fine)	11-057	TYPE:	SILICA SAND
CEMENT:		SPEC:	
AIR ENTR. ADMIX.	MBVR	SPEC:	
1st Admixture:	LL 961 R	SPEC:	
2nd Admixture:		SPEC:	
3rd Admixture:		SPEC:	
FLY ASH:	MONEX	SPEC:	

NOTE: None

CEMENT (Kg) LBS:	273.00	**SLUMP RNG:**	3.5	(mm) IN
COARSE. A. (Kg) LBS:	1021.00	**AIR CONTENT:**	5	%
FINE AGG (Kg) LBS:	674.00	UNIT WT (WET):		(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	9.20	W/C RT (PLNT):	0.47	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	27.60	W/C RT (FLD):	0.47	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:		THEO YIELD:		(M3) CU FT
3rd ADMIX. (ml) OZ:				
WATER (ML) GAL:				
WATER (Kg) LBS:				
FLY ASH (Kg) LBS:	68.00			

PRODUCER TEST DATA:

CHLORIDE CONT:		(Kg/M3) LB/CY
SLUMP:	3.50	(mm) IN
AIR CONTENT:	5.0	%
TEMPERATURE:	96.0	DEG (C) F
COMP. STRENGTH (MPA) PSI:		
	7 Day:	5190
	28 Day:	5870

FDOT ASSIGNED PLANT NO:

Appendix A.19

Concrete Mix Designs

CLASS CONCRETE: **IP**

SOURCE OF MATERIALS

COARSE Aggregate:		GRADE:	57
FINE Aggregate:		F.M.:	2.4
Pit No. (Coarse):	87-090	TYPE:	CRUSHED LIMESTONE
Pit No. (Fine)	05-045	TYPE:	SILICA SAND
CEMENT:		SPEC:	
AIR ENTR. ADMIX.	MBVR	SPEC:	
1st Admixture:	LL 961 R	SPEC:	
2nd Admixture:		SPEC:	
3rd Admixture:		SPEC:	
FLY ASH:		SPEC:	

NOTE: None

CEMENT (Kg) LBS:	366.00	**SLUMP RNG:**	3	(mm) IN
COARSE. A. (Kg) LBS:	1052.00	**AIR CONTENT:**	3.8	%
FINE AGG (Kg) LBS:	687.00	UNIT WT (WET):		(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	24.70	W/C RT (PLNT):	0.41	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	37.00	W/C RT (FLD):	0.41	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:		THEO YIELD:		(M3) CU FT
3rd ADMIX. (ml) OZ:				
WATER (ML) GAL:				
WATER (Kg) LBS:				
FLY ASH (Kg) LBS:				

PRODUCER TEST DATA:

CHLORIDE CONT:		(Kg/M3) LB/CY	
SLUMP:	3.00	(mm) IN	
AIR CONTENT:	3.8	%	
TEMPERATURE:	97.0	DEG (C) F	
COMP. STRENGTH (MPA) PSI:			
	7 Day:		5270
	28 Day:		7570

FDOT ASSIGNED PLANT NO:

Appendix A.20

Concrete Mix Designs

CLASS CONCRETE: **I**

SOURCE OF MATERIALS

COARSE Aggregate:		GRADE:	57
FINE Aggregate:		F.M.:	2.86
Pit No. (Coarse):	87-145	TYPE:	CRUSHED LIMESTONE
Pit No. (Fine)	87-145	TYPE:	SILICA SAND
CEMENT:		SPEC:	
AIR ENTR. ADMIX.	DAREX	SPEC:	
1st Admixture:	WRDA 79	SPEC:	
2nd Admixture:		SPEC:	
3rd Admixture:		SPEC:	
FLY ASH:		SPEC:	

NOTE: None

CEMENT (Kg) LBS:	418.00	**SLUMP RNG:**	3.25	(mm) IN
COARSE. A. (Kg) LBS:	961.00	**AIR CONTENT:**	3.6	%
FINE AGG (Kg) LBS:	700.00	UNIT WT (WET):		(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	5.00	W/C RT (PLNT):	0.38	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	63.50	W/C RT (FIELD):	0.38	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:		THEO YIELD:		(M3) CU FT
3rd ADMIX. (ml) OZ:				
WATER (ML) GAL:				
WATER (Kg) LBS:				
FLY ASH (Kg) LBS:				

PRODUCER TEST DATA:

CHLORIDE CONT:		(Kg/M3) LB/CY	
SLUMP:	3.25	(mm) IN	
AIR CONTENT:	3.6	%	
TEMPERATURE:	97.0	DEG (C) F	
COMP. STRENGTH (MPA) PSI:			
	7 Day:		
	28 Day:		7700

FDOT ASSIGNED PLANT NO:

Appendix A.21

Concrete Mix Designs

CLASS CONCRETE: **II**

SOURCE OF MATERIALS

COARSE Aggregate:		GRADE:	67
FINE Aggregate:		F.M.:	2.41
Pit No. (Coarse):	87-145	TYPE:	CRUSHED LIMESTONE
Pit No. (Fine)	76-349	TYPE:	SILICA SAND
CEMENT:		SPEC:	
AIR ENTR. ADMIX.	MBVR	SPEC:	
1st Admixture:	MBL-80	SPEC:	
2nd Admixture:		SPEC:	
3rd Admixture:		SPEC:	
FLY ASH:	BLUE CIRCLE	SPEC:	

NOTE:None

CEMENT (Kg) LBS:	202.00	**SLUMP RNG:**	3.25	(mm) IN
COARSE. A. (Kg) LBS:	1056.00	**AIR CONTENT:**	3	%
FINE AGG (Kg) LBS:	606.00	UNIT WT (WET):		(Kg/M3) PCF
AIR ENT AD.(ml) OZ:	8.50	W/C RT (PLNT):	0.40	(Kg/Kg)LB/LB
1st ADMIX. (ml) OZ:	68.00	W/C RT (FIELD):	0.40	(Kg/Kg)LB/LB
2nd ADMIX. (ml) OZ:		THEO YIELD:		(M3) CU FT
3rd ADMIX. (ml) OZ:				
WATER (ML) GAL:				
WATER (Kg) LBS:				
FLY ASH (Kg) LBS:	202.00			

PRODUCER TEST DATA:

CHLORIDE CONT:		(Kg/M3) LB/CY	
SLUMP:	3.25	(mm) IN	
AIR CONTENT:	3.0	%	
TEMPERATURE:	97.0	DEG (C) F	
COMP. STRENGTH (MPA) PSI:			
	7 Day:		
	14 Day:		6920

FDOT ASSIGNED PLANT NO:

Appendix B

TABLE B.1
Statistical Analysis of Air Content Data

	Before Pumping	*After Pumping*
Mean (%)	4.4849	3.591781
Variance (%)	1.1196	0.701876
Observations	73	73
Pooled Variance (%)	0.9108	
Hyp. Mean Diff.	0	
df	144	
t Stat	5.6542	
P(T<=t) one-tail	0.0000	
t Critical one-tail	1.6555	
P(T<=t) two-tail	0.0000	
t Critical two-tail	1.9766	

TABLE B.2
Statictical Analysis of Slump Data

	Before Pumping	*After Pumping*
Mean (in)	4.48562	3.955479
Variance (in)	1.94892	1.634692
Observations	73	73
Pooled Variance (in)	1.79181	
Hyp.Mean Difference (in)	0	
df	144	
t Stat	2.39270	
P(T<=t) one-tail	0.00901	
t Critical one-tail	1.65550	
P(T<=t) two-tail	0.01801	
t Critical two-tail	1.97658	

TABLE B.3
Statistical Analysis of Unit Weight Data

	Before Pumping	*After Pumping*
Mean (lb/ft^3)	139.8548	141.3534
Variance (lb/ft^3)	11.2031	10.5461
Observations	73	73
Pooled Variance (lb/ft^3)	10.8746	
Hyp. Mean Diff.	0	
df	144	
t Stat	-2.7456	
P(T<=t) one-tail	0.0034	
t Critical one-tail	1.6555	
P(T<=t) two-tail	0.0068	
t Critical two-tail	1.97658	

TABLE B.4
Statistical Analysis of Compressive Strength Data

	Before Pumping	*After Pumping*
Mean (psi)	5721	5987
Variance (psi)	575903	625784
Observations	73	73
Pooled Variance (psi)	600844	
Hyp. Mean Diff	0	
df	144	
t Stat	-2.0762	
P(T<=t) one-tail	0.0198	
t Critical one-tail	1.6555	
P(T<=t) two-tail	0.0397	
t Critical two-tail	1.97658	

TABLE B.5
Statistical Analysis of Chloride Ion Penetration Data

	Before Pumping	*After Pumping*
Mean (C_b)	5566	5408
Variance (C_b)	11828916	9368447
Observations	73	73
Pooled Difference (C_b)	10598682	
Hyp. Mean Diff. (C_b)	0	
df	144	
t Stat	0.2947	
P(T<=t) one-tail	0.3843	
t Critical one-tail	1.6555	
P(T<=t) two-tail	0.7686	
t Critical two-tail	1.97658	

TABLE B.6
Statistical Analysis of Water Permeability Data

	Before Pumping	*After Pumping*
Mean (in/hr x 10^{-11})	2.2546	1.9724
Variance (in/hr x 10^{-11})	3.8334	2.5103
Observations	73	73
Pooled Variance (in/hr x 10^{-11})	3.1719	
Hyp. Mean Diff. (in/hr x 10^{-11})	0	
df	144	
t Stat	0.9573	
P(T<=t) one-tail	0.1700	
t Critical one-tail	1.6555	
P(T<=t) two-tail	0.3400	
t Critical two-tail	1.97658	

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