

STUDY OF DRY SILICA FUME  
ADMIXTURE ADDITION RATES AND  
BLENDED SILICA FUME CEMENT  
IN CONCRETE

REPORT 94-4  
MAY 1994

REPORTING ON WORK PLAN 93-C-7

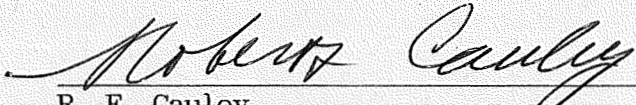
STATE OF VERMONT  
AGENCY OF TRANSPORTATION  
MATERIALS AND RESEARCH DIVISION

PATRICK J. GARAHAN, SECRETARY OF TRANSPORTATION  
R. L. MERCHANT, DIRECTOR OF CONSTRUCTION & MAINTENANCE  
R. F. CAULEY, MATERIALS & RESEARCH ENGINEER  
D. F. HALE, STRUCTURAL CONCRETE ENGINEER

Prepared by:

W. L. Meyer, Technician IV  
Structural Concrete Section

Reviewed By:

  
R. F. Cauley  
Materials & Research Engineer

Date: 10 May 1994



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**Note:** Values shown in the text are presented in SI (International System) units, with US customary units show in parentheses. Generally, SI units are direct conversions and should not be considered as the standard, in referenced specifications.

## EXECUTIVE SUMMARY

As the use of silica fume in concrete and related products grows, the need to gain more knowledge concerning use of this complex material has increased dramatically. Optimum addition rates, densified/compacted versus slurry silica fume products, blended silica fume cements, other admixtures, and batching, mixing and curing practices must all be understood, and proper procedures followed, if this relatively new and important construction tool is to perform as desired.

This evaluation was initiated to gain a better understanding of material performance for various silica fume addition rates and blended silica fume cement. Mixing and testing followed usual laboratory procedures, with less than desired results.

Information obtained subsequent to the mixing and testing portion of this program indicates the reduced performance of some concrete batches containing silica fume may have resulted from failure to use extended mixing periods when a densified/compacted silica fume product was introduced into the mixture.

Subsequently, few of the initial questions have been answered. Instead, new and more comprehensive questions have been raised. More study and research will be needed before procedures can be established to achieve the maximum benefits using silica fume concrete.



## INTRODUCTION

The introduction of silica fume(microsilica), as an additive to portland cement concrete, has presented specifiers and users with many new challenges. Enhanced strength and durability, combined with reduced permeability, have prompted the use of silica fume concrete under the most severe environments.

The Vermont Agency of Transportation (AOT) currently specifies silica fume concrete for bridge curbing and some other structural components exposed to severe weather conditions and repeated applications of deicing chemicals. Silica fume, in dry densified form, or as a slurry, is added to the concrete mixture at the rate of 7.5% by weight of portland cement. One field test also specified silica fume be added to the concrete mixture at a 4% addition rate.

Shotcrete, incorporating silica fume as an admixture, was used in the rehabilitation of piers and pier caps on two recently completed AOT projects. Test specimens yielded excellent results and repairs were generally completed without difficulty. Silica fume quantities of 4% and 5% by weight of cement were used initially in shotcrete applications, with the majority of work performed using the 4% addition rate.

When all the positive aspects of silica fume concrete are examined, there are still many unanswered questions. Some of these questions focus on optimum addition rates that can be reasonably employed under field conditions, and minimum addition rates that will continue to provide improved performance.

Laboratory studies using silica fume quantities of 25% to 40% by weight of cement produced outstanding results. In actual field practice, the higher addition rates may produce concrete with reduced workability and increased shrinkage cracking, causing many concerns among specifiers and users. While some of these disadvantages are overcome with high range water reducing admixtures (HRWR), finishing aids and early application of moist curing, most users specify addition rates well below those examined in laboratory experiments.

To answer some of the questions regarding silica fume addition rates, a program was organized to study reduced quantities and their effect on various concrete properties. Addition rates of 2.5%, 5% and 7.5% were included in the study. This program also examined a blended cement containing 7.5% silica fume. Concrete containing silica fume was compared with an air-entrained reference concrete and with concrete containing a high range water reducing admixture.

Further questions regarding use of silica fume in concrete deal with slurry versus densified (compacted) products, and more recently with blended silica fume cements. Silica fume particles are generally about 0.13 - 0.16 microns in size. Because of the extremely small particle size, silica fume is frequently dispensed as a slurry to reduce dust and facilitate handling. Slurries may be formulated to contain HRWR or other admixtures to enhance placing and finishing characteristics.

Densified (compacted) silica fume particles are agglomerations of individual particles varying in size from 10 microns to 0.1 mm or more. Densifying the particles helps reduce dust and facilitates handling of the material in bags and bulk shipping containers.

More recently, area cement producers are marketing a blended silica fume cement which is manufactured by grinding cement clinker with silica fume pellets. The pellets are formed by introducing humidified air into a revolving chamber of silica fume particles. Silica fume collects on the moisture droplets forming soft pellets with a maximum size of about 12.7 mm (1/2 inch). Silica fume, in this form, can be easily transported and stored, and later blended with cement clinker as it enters the grinding mill. Heat generated in the grinding mill drives the moisture out of the pellets, allowing the silica fume particles to return to their natural size. One area producer is supplying cement containing approximately 7.5% silica fume. Another producer supplies a blended cement with about 8% silica fume.

Data obtained subsequent to this investigation suggests normal concrete mixing practices may not be adequate to achieve total dispersion of densified (compacted) silica fume and pelletized silica fume (silica fume cement) throughout concrete mixtures. Without complete dispersion, many desired benefits of silica fume concrete may not be realized.

To insure total dispersion one supplier recommends extended mixing periods, with a minimum of 120 mixing revolutions, and reduced load size when their densified/compacted product is used in ready mixed concrete operations. For laboratory mixers, blending of the densified product with coarse aggregate and water, and mixing for five minutes prior to addition of the remaining ingredients is recommended to achieve dispersion. This recommendation is based on the reduced mixing energy of laboratory mixers as compared to transit or central mixers.

Failure to address this increased mixing effort may have contributed to reduced performance of mixtures containing densified silica fume in this program. While these mixtures were not severely affected, some of the anticipated benefits were not evident. The silica fume cement used in this evaluation did appear to provide many of the desired benefits. It is unknown, however, if maximum performance was achieved, and how other silica fume cements will perform under similar conditions. Additional research is essential, to establish optimum batching and mixing procedures that will provide maximum benefits from all silica fume products used in concrete.



## **MATERIALS**

The materials selected for this program represent those used, or proposed for use, at the S. T. Griswold & Co. ready mixed concrete facility in Williston, Vermont. The materials are as follows:

### **Aggregates:**

#### 19.05 mm (3/4") Crushed Stone

F. W. Whitcomb Construction Corp.  
Colchester, Vermont

#### Fine Aggregate

Hinesburg Sand & Gravel Company, Inc.  
Hinesburg, Vermont

### **Cements:**

#### Type II Cement

Lafarge Corporation, Northeast Cement  
St. Constant, Quebec

#### Blended Cement (Lafarge Silica Fume Cement)

Lafarge Corporation, Northeast Cement  
St. Constant, Quebec

### **Admixtures:**

#### Air Entraining Admixture

Micro-Air  
Master Builders, Inc.  
Cleveland, Ohio

#### Water Reducing Admixture

WRDA with Hycol  
W. R. Grace & Company  
Cambridge, Massachusetts

#### High Range Water Reducing Admixture

WRDA-19  
W. R. Grace & Company  
Cambridge, Massachusetts

#### Silica Fume (Microsilica) Admixture

Force 10,000 (Dry Densified)  
W. R. Grace & Company  
Cambridge, Massachusetts

## PROCEDURES

AOT Class A concrete was selected as the reference material for this investigation. Class A mixtures are designed with a minimum cement content of  $391.57 \text{ kg/m}^3$  ( $660 \text{ lbs/yd}^3$ ) and a maximum .44 water/cement ratio. A water reducing, retarding, or water reducing and retarding admixture is specified. The required air content is  $6 \pm 1\%$  and a maximum 76.2 mm (3 inch) slump is specified when this class of concrete is used in bridge decks. The minimum compressive strength requirement for Class A is 27.58 MPa (4,000 psi) at 28 days.

Silica fume concrete is currently detailed in project Special Provisions and must meet the requirements of Class A concrete with the following modifications:

1. Water/(Cement & Silica fume) ratio - maximum 0.40
2. Slump -  $127 \pm 50.8 \text{ mm}$  ( $5 \pm 2 \text{ inches}$ ) (after addition of super plasticizer)
3. Air content -  $7 \pm 2\%$
4. Seven day compressive strength no less than 31.03 MPa (4500 psi)
5. 28 day compressive strength no less than 34.48 MPa (5000 psi)

The silica fume shall be added to the concrete mixture at the rate of 7.5% by weight of portland cement or  $29.37 \text{ kg/m}^3$  ( $49.5 \text{ lb/yd}^3$ ) of silica fume. Use of a high range water reducing admixture will be required to produce a workable mix. At least three weeks prior to placement the Contractor shall submit to the Engineer the proposed silica fume concrete mix design for approval.

Aggregates were sampled and tested for compliance with the appropriate sections of AOT specifications. The aggregates were air-dried prior to the start of mixing operations.

Two reference batches were prepared which contained  $391.57 \text{ kg/m}^3$  ( $660 \text{ lb/yd}^3$ ) of cement, an air entraining admixture and a water reducing admixture. Two batches each were also prepared for the concrete containing a high range water reducing admixture and for the three addition rates (2.5%, 5% and 7.5%) of dry silica fume admixture. Four batches were prepared using the blended silica fume cement. Concrete was mixed in a Sears rotary drum mixer with a batch size of  $0.05 \text{ m}^3$  ( $1.8 \text{ ft}^3$ ). Mix designs, including water and admixture quantities, are shown in Tables 1 and 1-M, in Appendix A.

Tests were performed on the fresh concrete to determine slump (AASHTO T 119-82), air content (AASHTO T 152-90), unit weight (AASHTO T 121-86), temperature (ASTM C 1064-86) and time of setting (AASHTO T 197-90).

Hardened concrete was tested for compressive strength (AASHTO T 22-90), resistance to rapid freezing and thawing (AASHTO T161-86) modified, and resistance to chloride ion penetration (AASHTO T 259-80) modified.

Compressive strength, using  $152.4 \times 304.8 \text{ mm}$  ( $6 \times 12$ ") cylinders, was determined at one, three, seven and 28 days. Freeze thaw specimens,  $76.2 \times 76.2 \times 406.4 \text{ mm}$  ( $3 \times 3 \times 16$ ") prisms, were moist cured for 14 days before being subjected to 300 cycles of rapid freezing and thawing in a 3% sodium chloride solution. Tests for resistance to chloride ion penetration were conducted using  $304.8 \times 304.8 \times 127 \text{ mm}$  ( $12 \times 12 \times 5$ ") deep blocks with an  $279.4 \times 279.4 \times 19.1 \text{ mm}$  ( $11 \times 11 \times 3/4$ ") deep reservoir cast into the surface.



The blocks were moist cured for 14 days, followed by 28 days of air drying. During the drying period, the blocks were sampled and tested for base chloride ion levels. At the conclusion of the drying period, the specimens received 90 days of continuous ponding with a 3% sodium chloride solution. Following ponding, the specimens were again sampled and tested for total chloride ion content at depths of 1.6 to 12.7 mm (0.0625 to 0.50"), 12.7 to 25.4 mm (0.50 to 1"), and 25.4 to 50.8 mm (1 to 2").



## RESULTS & DISCUSSION

### GENERAL

Results of tests conducted on the coarse and fine aggregates used in this investigation are shown on Laboratory Report Nos. G9300134 and G9300141, in Appendix B.

Test data for fresh and hardened concrete, for all batches, is outlined in Tables 2 and 2-M in Appendix C. Tables 3 and 3-M show average results for each combination of material examined. Average results for silica fume cement in Tables 3 and 3-M show Batches 1 and 2 combined, and Batches 3 and 4 combined. The data was presented in this manner to compare results when air contents varied approximately 3%.

### COMPRESSIVE STRENGTH

1. Compressive strengths of the HRWR and silica fume cement mixtures were approximately equal at 28 days. These materials yielded strengths that were significantly higher at that age than the reference batches, and exceeded the strengths of batches containing compacted silica fume by a considerable margin. The 28 day strengths of HRWR and silica fume cement batches were 30% to 34% greater than reference batches, while the Force 10000 strengths ranged from 9% to 17% higher than reference strengths. Figures 1 and 1-M, in Appendix C, show the average strength gain characteristics of the various mixes.

2. Batch 1 of Force 10000 at the 7.5% addition rate, failed to achieve the currently specified seven day strength of 31.03 MPa (4500 psi). All other batches containing silica fume complied with both the seven day requirement, and with the 28 day minimum of 34.48 MPa (5000 psi).

### RESISTANCE TO RAPID FREEZING AND THAWING

1. All batches examined in this program performed well in freezing and thawing tests. Results after 300 cycles of freezing and thawing showed weight losses ranging from 0.8% to 5.1%. The best overall performance was displayed by the reference concrete with an average durability factor of 101.9, and an average weight loss of 0.8%, after 300 cycles. Figure 2, in Appendix C, illustrates the average weight loss experienced in freeze/thaw testing.

2. The silica fume cement batches, with an average 8.8% air content performed somewhat better than their companion batches with an average air content of 6.1%. After 300 cycles of freezing and thawing, batches 1 & 2 (8.8% air content) showed 1.8% weight loss while batches 3 & 4 (6.1% air content) exhibited 5.1% weight loss.

3. The HRWR and Force 10000 silica fume batches showed average weight losses ranging from 3.0% to 4.1% after 300 cycles.

### RESISTANCE TO CHLORIDE ION PENETRATION

1. Base level chloride tests, conducted prior to the start of ponding, yielded a broad range of results. The lowest reading obtained was 19 ppm and the greatest reading was 137 ppm, with an average of 63 ppm for 27 tests.



2. Chloride contents after 90 days, obtained with Force 10,000 at the 2.5% and 5% addition rates, were roughly equal to reference concrete results at all depths.

3. Force 10,000 concrete using the 7.5% addition rate had less chloride intrusion at the 1.6 - 12.7 mm (1/16 - 1/2") depth than the reference concrete, but exhibited similar performance at greater depths.

4. The batches containing silica fume cement demonstrated the best overall performance in resistance to chloride intrusion tests. After 90 days of ponding, the chloride contents at 1.6 - 12.7 mm (1/16 - 1/2") were equal to or less than the other concrete mixes. Depths greater than 12.7 mm (1/2") showed chloride levels similar to those obtained prior to the start of testing.

5. At the 1.6 - 12.7 mm (1/16 - 1/2") depth, considerable variation existed between batches of similar concrete. Several of the batches had chloride contents at that depth which were roughly half the chloride content of their counterparts.

6. At the 25.4 - 50.8 mm (1 - 2") depth, chloride contents of all batches, after 90 days of ponding, were comparable to results obtained prior to the start of testing.

7. Following 90 days of ponding, none of the materials had chloride contents below the 12.7 mm (1/2") depth that approached the corrosion threshold of 325 ppm. Average results of chloride ion penetration tests are displayed in Figure 3, in Appendix C.

#### MISCELLANEOUS

1. Batches containing the Force 10,000 silica fume generally had earlier setting times than the other concretes. Conversely, batches containing silica fume cement exhibited later setting times. Difficulty controlling concrete temperatures and storage temperatures of time of set specimens may have had a greater influence on setting times than other variables in the testing program.

## CONCLUSIONS & RECOMMENDATIONS

1. Concrete containing silica fume cement performed well in all tests conducted in this evaluation. It is recommended that this material be approved for use in AOT projects when silica fume concrete is specified. Use of this material will be contingent upon the ready mixed concrete supplier providing adequate storage facilities for handling and dispensing the blended product. Provisions must also be made to insure strict adherence to specified ratios of portland cement and silica fume, i.e. additional cement and silica fume must be available for blending, when non-standard quantities are specified.

2. Due to the strengths experienced with silica fume cement, when compared to other mixtures, further examination of all silica fume products is recommended. Examinations should include, but not be limited to:

a. Compressive strength comparison of concretes or mortars containing "slurry" vs densified (compacted) silica fume products, and blended silica fume cements.

b. Development of laboratory tests to determine the necessity for extended mixing times to achieve full dispersion of densified/compacted silica fume and silica fume cements.

1) Use a constant energy mixer. (Laboratory mixer meeting requirements of AASHTO T 162.)

2) Combine cementitious materials with graded standard sand meeting requirements of ASTM C 778.

3) Blend materials for several prescribed mixing periods, ie. one, two, four, and six minutes.

4) Determine compressive strength, AASHTO T 106, at early ages, ie. one, two, and three days to establish an optimum test age.

3. Prior to completion of laboratory tests, require ready mixed concrete producers to adhere to the following procedures when silica fume concrete is used:

a. Increase mixing periods to a minimum of 150 revolutions of the drum at mixing speed, when transit mixers are used.

b. When central mixers are used, increase mixing times a minimum of 50%.

c. Limit the maximum load size to 80% of rated mixing capacity.

These additional requirements may be waived if the producer elects to use a "slurry" silica fume product.

4. Until more conclusive information is obtained regarding use of silica fume at reduced addition rates, it is recommended the current 7 1/2% addition rate be retained when silica fume concrete is specified.



TABLE 1

**CONCRETE MIX DESIGNS**  
**BATCH QUANTITIES**

| Material                          | Reference |      | HRWR |      | Force 10,000 - Silica Fume |      |      |      |      |      | Silica Fume Cement |       |       |       |
|-----------------------------------|-----------|------|------|------|----------------------------|------|------|------|------|------|--------------------|-------|-------|-------|
|                                   | R1        | R2   | HR1  | HR2  | 1                          | 2    | 1    | 2    | 1    | 2    | 1                  | 2     | 3     | 4     |
| 3/4" Stone, lbs/yd <sup>3</sup>   | 1574      | 1574 | 1574 | 1574 | 1590                       | 1590 | 1590 | 1590 | 1590 | 1590 | 1590               | 1590  | 1590  | 1590  |
| Sand, lbs/yd <sup>3</sup>         | 1327      | 1327 | 1418 | 1418 | 1288                       | 1288 | 1288 | 1288 | 1288 | 1288 | 1288               | 1288  | 1288  | 1288  |
| Cement:                           |           |      |      |      |                            |      |      |      |      |      |                    |       |       |       |
| Type II, lbs/yd <sup>3</sup>      | 660       | 660  | 660  | 660  | 660                        | 660  | 660  | 660  | 660  | 660  |                    |       |       |       |
| Silica Fume, lbs/yd <sup>3</sup>  |           |      |      |      |                            |      |      |      |      |      | 709.5              | 709.5 | 709.5 | 709.5 |
| Force 10,000, lbs/yd <sup>3</sup> |           |      |      |      | 16.5                       | 16.5 | 33.0 | 33.0 | 49.5 | 49.5 |                    |       |       |       |
| Micro-Air, oz/yd <sup>3</sup>     | 6.0       | 5.0  | 3.5  | 2.0  | 3.5                        | 3.5  | 3.5  | 3.5  | 3.5  | 3.5  | 5.0                | 4.0   | 2.0   | 2.0   |
| WRDA/Hycol, oz/cwt                | 3         | 3    | 3    | 3    | 3                          | 3    | 3    | 3    | 3    | 3    | 3                  | 3     | 3     | 3     |
| WRDA-19, oz/cwt                   |           |      | 11   | 11   | 11                         | 11   | 11   | 11   | 11   | 11   | 11                 | 11    | 11    | 11    |
| Net water, gal/yd <sup>3</sup>    | 34.1      | 34.1 | 30.4 | 30.3 | 29.4                       | 29.5 | 30.8 | 30.9 | 33.7 | 33.4 | 29.3               | 27.6  | 29.0  | 29.1  |
| W/C & W/(C+SF)                    | 0.43      | 0.43 | 0.38 | 0.38 | 0.36                       | 0.36 | 0.37 | 0.37 | 0.40 | 0.39 | 0.34               | 0.32  | 0.34  | 0.34  |



TABLE 1-M

CONCRETE MIX DESIGNS  
BATCH QUANTITIES

| Material                         | Force 10,000 - Silica Fume |        |        |        |        |        |        |        |        |        |                    |        |        |        |
|----------------------------------|----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------------------|--------|--------|--------|
|                                  | Reference                  |        | HRWR   |        | 2.5%   |        | 5%     |        | 7.5%   |        | Silica Fume Cement |        |        |        |
|                                  | R1                         | R2     | HR1    | HR2    | 1      | 2      | 1      | 2      | 1      | 2      | 1                  | 2      | 3      | 4      |
| 19.1 mm Stone, kg/m <sup>3</sup> | 933.83                     | 933.83 | 933.83 | 933.83 | 943.32 | 943.32 | 943.32 | 943.32 | 943.32 | 943.32 | 943.32             | 943.32 | 943.32 | 943.32 |
| Sand, kg/m <sup>3</sup>          | 787.29                     | 787.29 | 841.28 | 841.28 | 764.15 | 764.15 | 764.15 | 764.15 | 764.15 | 764.15 | 764.15             | 764.15 | 764.15 | 764.15 |
| Cement:                          |                            |        |        |        |        |        |        |        |        |        |                    |        |        |        |
| Type II, kg/m <sup>3</sup>       | 391.57                     | 391.57 | 391.57 | 391.57 | 391.57 | 391.57 | 391.57 | 391.57 | 391.57 | 391.57 | 391.57             |        |        |        |
| Silica Fume, kg/m <sup>3</sup>   |                            |        |        |        |        |        |        |        |        |        |                    | 420.93 | 420.93 | 420.93 |
| Force 10,000, kg/m <sup>3</sup>  |                            |        |        |        | 9.79   | 9.79   | 19.58  | 19.58  | 29.37  | 29.37  |                    |        |        |        |
| Micro-Air, mL/m <sup>3</sup>     | 232                        | 193    | 135    | 77     | 135    | 135    | 135    | 135    | 135    | 135    | 193                | 155    | 77     | 77     |
| WRDA/Hycol, mL/kg                | 1.96                       | 1.96   | 1.96   | 1.96   | 1.96   | 1.96   | 1.96   | 1.96   | 1.96   | 1.96   | 1.96               | 1.96   | 1.96   | 1.96   |
| WRDA-19, mL/kg                   |                            |        | 7.17   | 7.17   | 7.17   | 7.17   | 7.17   | 7.17   | 7.17   | 7.17   | 7.17               | 7.17   | 7.17   | 7.17   |
| Net water, L/m <sup>3</sup>      | 168.83                     | 168.83 | 150.51 | 150.02 | 145.56 | 146.06 | 152.49 | 152.99 | 166.85 | 165.37 | 145.07             | 136.65 | 143.58 | 144.08 |
| W/C & W/(C+SF)                   | 0.43                       | 0.43   | 0.38   | 0.38   | 0.36   | 0.36   | 0.37   | 0.37   | 0.40   | 0.39   | 0.34               | 0.32   | 0.34   | 0.34   |



TA 419 Rev. 2.5 M 1-92

STATE OF VERMONT  
AGENCY OF TRANSPORTATION  
MATERIALS AND RESEARCH DIVISION

REPORT ON SAMPLE OF STRUCTURAL CONCRETE AGGREGATE CONCRETE  
C.F.

69300134

Laboratory Number \_\_\_\_\_ Pay Item 501  
Project Name POSSIBLE FUTURE USE WORK Project Number 93-C-7  
Sampled By KELLY Date Sampled 5-5-93 Examined For 24.02  
Sampled From STOCKPILE Plant GRISWOLD WILLISTON  
Source of Material WHITCOMB WINDOOSKI  
Quantity Represented \_\_\_\_\_ Sample Type PRELIMINARY  
Sample Comparison NO Cross Reference Number \_\_\_\_\_

MATERIAL TESTED 3/4" CR. STONE FOR CONCRETE

| SIEVE<br>SIZE   | WEIGHT<br>INDIV. | % RETAINED |        | % PASSING<br>CUMUL. |
|-----------------|------------------|------------|--------|---------------------|
|                 |                  | INDIV.     | CUMUL. |                     |
| RET _____       |                  |            |        |                     |
| RET _____       |                  |            |        |                     |
| RET <u>1"</u>   | <u>—</u>         |            |        | <u>100</u>          |
| RET <u>3/4"</u> | <u>0.33</u>      | <u>1</u>   |        | <u>99</u>           |
| RET <u>1/2"</u> | <u>17.91</u>     | <u>53</u>  |        | <u>46</u>           |
| RET <u>3/8"</u> | <u>7.02</u>      | <u>21</u>  |        | <u>25</u>           |
| RET <u>4</u>    | <u>7.28</u>      | <u>22</u>  |        | <u>3</u>            |
| RET <u>8</u>    | <u>0.73</u>      | <u>2</u>   |        | <u>1</u>            |
| PAN             | <u>0.37</u>      | <u>1</u>   |        |                     |
| TOTAL           | <u>33.64</u>     | <u>100</u> |        |                     |

## AGGREGATE MOISTURE CONTENT

WET WEIGHT \_\_\_\_\_

DRY WEIGHT \_\_\_\_\_

MOISTURE CONTENT % \_\_\_\_\_

NOTE: MOISTURE CONTENT (%) =

$$\frac{W_W - W_D}{W_D} \times 100$$

 $W_W$  = WET WEIGHT $W_D$  = DRY WEIGHT

## Fineness Modulus

Cumul. Total Retained/100 \_\_\_\_\_

Organic Impurities: Color \_\_\_\_\_

T&E = 20 = 10.3 % Thin & Elongated PiecesTotal Weight 213Fractures = 213 = 100 % Fractured FacesTotal Weight 213Original Weight 5000gFinal Weight 4129Grading "B"Percent Wear 17.4% AASHTO T96

( ) Test results are in compliance with specifications.

(✓) Test results are outside specifications.

Comments: 0.3% HIGH THIN & ELONGATED PIECES  
MATERIAL NOT RETESTED

Tested By \_\_\_\_\_  
Date Completed \_\_\_\_\_

DAVID F. HALL  
Reviewed By John H. Weaver, P.E.  
Date 5/7/93

Initials

STATE OF VERMONT  
AGENCY OF TRANSPORTATION  
MATERIALS AND RESEARCH DIVISION

REPORT ON SAMPLE OF STRUCTURAL CONCRETE AGGREGATE CONCRETE  
C.F.  
G9300141

Laboratory Number \_\_\_\_\_ Pay Item 501  
Project Name Possible future USE Work Plan Project Number 93-C-7  
Sampled By KELLY Date Sampled 5-6-93 Examined For 704.01  
Sampled From STOCKPILE Plant GRISWOLD LUMBER  
Source of Material HINESBURG  
Quantity Represented \_\_\_\_\_ Sample Type PRELIMINARY  
Sample Comparison NO Cross Reference Number \_\_\_\_\_

MATERIAL TESTED FINE AGGREGATE FOR CONCRETE

| SIEVE<br>SIZE   | WEIGHT<br>INDIV. | % RETAINED |            | % PASSING<br>CUMUL. |
|-----------------|------------------|------------|------------|---------------------|
|                 |                  | INDIV.     | CUMUL.     |                     |
| RET _____       |                  |            |            |                     |
| RET <u>3/8"</u> | <u>—</u>         |            |            | <u>100</u>          |
| RET <u>4</u>    | <u>15</u>        | <u>2</u>   | <u>2</u>   | <u>98</u>           |
| RET <u>8</u>    | <u>79</u>        | <u>14</u>  | <u>16</u>  | <u>84</u>           |
| RET <u>16</u>   | <u>126</u>       | <u>22</u>  | <u>38</u>  | <u>62</u>           |
| RET <u>30</u>   | <u>119</u>       | <u>20</u>  | <u>58</u>  | <u>42</u>           |
| RET <u>50</u>   | <u>118</u>       | <u>20</u>  | <u>78</u>  | <u>22</u>           |
| RET <u>100</u>  | <u>79</u>        | <u>14</u>  | <u>92</u>  | <u>8</u>            |
| PAN             | <u>45</u>        | <u>8</u>   | <u>100</u> |                     |
| TOTAL           | <u>581</u>       | <u>100</u> |            |                     |

AGGREGATE MOISTURE CONTENT <sup>1</sup>

WET WEIGHT \_\_\_\_\_

DRY WEIGHT \_\_\_\_\_

MOISTURE CONTENT % \_\_\_\_\_

<sup>1</sup> NOTE: MOISTURE CONTENT (%) =

$$\frac{W_W - W_D}{W_D} \times 100$$

$W_W$  = WET WEIGHT

$W_D$  = DRY WEIGHT

Fineness Modulus

Cumul. Total Retained/100 2.84

Organic Impurities: Color <1

T&E = \_\_\_\_\_ % Thin & Elongated Pieces

Total Weight \_\_\_\_\_  
Fractures = \_\_\_\_\_ % Fractured Faces

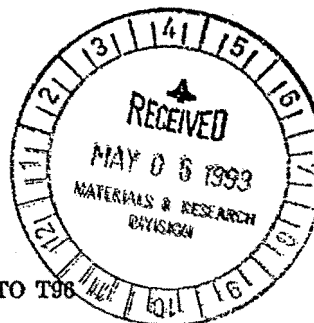
Total Weight \_\_\_\_\_

Original Weight \_\_\_\_\_

Final Weight \_\_\_\_\_

Grading \_\_\_\_\_

Percent Wear \_\_\_\_\_ AASHTO T96



( ☒ ) Test results are in compliance with specifications.

( ☐ ) Test results are outside specifications.

Comments: \_\_\_\_\_

Tested By

Date Completed

Joseph Kelly  
5-6-93

Reviewed By

Date

DAVID F. HALE

John H. Weaver, P.E.

5/7/93

Initials

DFH  
PSZ



TABLE 2  
CONCRETE TEST RESULTS

| Test                       | Reference |       | HRWR  |       | Force 10,000 - Silica Fume |       |       |       |       |       | Silica Fume Cement<br>(7.5% Silica Fume) |       |       |       |
|----------------------------|-----------|-------|-------|-------|----------------------------|-------|-------|-------|-------|-------|--|-------|-------|-------|
|                            | R1        | R2    | HR1   | HR2   | 2.5%                       |       | 5%    |       | 7.5%  |       | (7.5% Silica Fume)                       |       |       |       |
|                            |           |       |       |       | 1                          | 2     | 1     | 2     | 1     | 2     | 1  | 2     | 3     | 4     |
| Slump, in                  | 3.00      | 3.00  | 6.50  | 6.50  | 5.25                       | 5.00  | 4.25  | 4.75  | 5.50  | 5.50  | 7.00                                     | 7.25  | 7.25  | 7.25  |
| Air content, %             | 7.6       | 7.6   | 8.2   | 6.8   | 6.9                        | 6.8   | 6.5   | 6.8   | 6.2   | 6.5   | 8.6                                      | 9.0   | 6.0   | 6.1   |
| Weight, lb/ft <sup>3</sup> | 141.9     | 141.3 | 142.1 | 144.3 | 143.3                      | 143.4 | 142.5 | 142.8 | 141.4 | 141.5 | 140.2                                    | 139.9 | 144.1 | 144.6 |
| Temperature, °F            | 69        | 70    | 68    | 73    | 70                         | 72    | 73    | 73    | 72    | 73    | 68                                       | 68    | 70    | 72    |
| Time of setting:           |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| Initial, hr:min            | 8:10      | 7:55  | 10:00 | 10:00 | 8:00                       | 8:00  | 6:30  | 6:50  | 7:10  | 7:20  | 11:20                                    | 10:30 | ----  | ----  |
| Final, hr:min              | 10:10     | 10:00 | 11:30 | 12:05 | 9:30                       | 9:20  | 7:50  | 8:10  | 8:40  | 8:55  | 13:00                                    | 12:40 | ----  | ----  |
| Compressive strength, psi  |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| 1 day                      | 1839      | 2058  | 3031  | 3003  | 3318                       | 3268  | 3172  | 3360  | 2787  | 2798  | 2660                                     | 2539  | 2748  | 2575  |
| 3 days                     | 3141      | 2914  | 4372  | 4351  | 4145                       | 4269  | 4060  | 4060  | 4043  | 4043  | 4464                                     | 4909  | 5125  | 5210  |
| 7 days                     | 3540      | 3915  | 4844  | 5496  | 5189                       | 5175  | 4732  | 4973  | 4266  | 4665  | 5397                                     | 6112  | 6087  | 6059  |
| 28 days                    | 4973      | 4736  | 6248  | 6731  | 5578                       | 5779  | 5709  | 5475  | 5217  | 5376  | 6321                                     | 6275  | 6519  | 6381  |
| Freeze/thaw resistance:    |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| Weight loss, %             |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| 50 cycles                  | 0.2       | 0.2   | 0.8   | 0.6   | 0.7                        | 0.6   | 0.5   | ---   | ---   | ---   | 0.3                                      | 0.4   | 1.0   | 1.2   |
| 100 cycles                 | 0.2       | 0.3   | 1.2   | 1.0   | 1.3                        | 1.1   | 0.9   | 0.7   | 0.7   | 1.3   | 0.6                                      | 0.6   | 1.7   | 2.0   |
| 150 cycles                 | ---       | 0.3   | 1.8   | 1.4   | ---                        | ---   | ---   | 1.0   | 0.9   | 3.0   | ---                                      | ---   | 2.7   | 3.1   |
| 200 cycles                 | 0.3       | 0.5   | ---   | 1.8   | 2.5                        | 2.2   | 2.1   | 1.5   | 1.3   | 4.1   | 1.2                                      | 1.3   | 3.6   | 4.0   |
| 250 cycles                 | 0.3       | 0.7   | 2.7   | 2.3   | 2.9                        | 2.6   | 2.6   | 2.1   | 1.9   | 5.2   | 1.5                                      | 1.5   | 4.2   | 4.8   |
| 300 cycles                 | 0.5       | 1.0   | 3.3   | 2.7   | 3.4                        | 3.2   | 3.3   | 2.7   | 2.1   | 6.0   | 1.8                                      | 1.8   | 4.9   | 5.3   |
| Durability factor          |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| 50 cycles                  | 100.6     | 98.8  | ----  | 100.7 | 100.0                      | 97.2  | 100.0 | 99.8  | 99.2  | 99.8  | 98.2                                     | 98.6  | 98.4  | 97.9  |
| 100 cycles                 | 101.8     | 99.2  | 97.7  | 100.9 | 100.7                      | 97.9  | 99.5  | 99.5  | 96.9  | 98.7  | 98.6                                     | 98.2  | 97.7  | 96.6  |
| 150 cycles                 | 102.3     | 99.9  | 95.9  | 102.3 | 101.1                      | 97.4  | 99.5  | 98.3  | 98.5  | 99.3  | 98.5                                     | 98.4  | 96.0  | 95.4  |
| 200 cycles                 | 102.4     | 100.5 | 97.1  | 103.1 | 99.0                       | 96.3  | 97.7  | 98.6  | 98.2  | 95.7  | 98.6                                     | 98.1  | 96.3  | 94.9  |
| 250 cycles                 | 103.8     | 101.2 | 96.2  | 103.6 | 100.7                      | 97.7  | 98.9  | 98.7  | 98.2  | 97.4  | 98.7                                     | 98.7  | 96.3  | 94.2  |
| 300 cycles                 | 103.3     | 100.4 | 97.3  | 102.6 | 100.6                      | 97.1  | 98.6  | 99.1  | 98.0  | 98.6  | 99.2                                     | 98.1  | 94.9  | 93.5  |
| Total chloride ion:        |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| Base Level: ppm            |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| Sample depth,              |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| 0.0625-0.5 in              | 46        | 19    | 33    | 60    | --                         | --    | --    | --    | --    | --    | --                                       | --    | --    | --    |
| 0.5 -1.0 in                | 52        | 26    | 50    | --    | 82                         | 64    | 84    | 86    | 84    | 101   | 19                                       | 66    | --    | --    |
| 1.0 -2.0 in                | 24        | 54    | 50    | 34    | 67                         | 68    | 64    | 66    | 79    | 132   | 137                                      | 57    | --    | --    |
| After 90 days: ppm         |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| Sample depth,              |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| 0.0625-0.5 in              | 883       | 1422  | 840   | 561   | 815                        | 1689  | 1524  | 827   | 697   | 1239  | 379                                      | 657   | 464   | 191   |
| 0.5 -1.0 in                | 118       | 199   | 163   | 83    | 84                         | 134   | 69    | 118   | 94    | 174   | 26                                       | 66    | 53    | 51    |
| 1.0 -2.0 in                | 58        | 63    | 31    | 44    | 55                         | 83    | 80    | 95    | 106   | 137   | 110                                      | 43    | 71    | 41    |

TABLE 2M

## CONCRETE TEST RESULTS

| Test                      | Reference |       | HRWR  |       | Force 10,000 - Silica Fume |       |       |       |       |       | Silica Fume Cement<br>(7.5% Silica Fume) |       |       |       |
|---------------------------|-----------|-------|-------|-------|----------------------------|-------|-------|-------|-------|-------|--|-------|-------|-------|
|                           |           |       |       |       | 2.5%                       |       | 5%    |       | 7.5%  |       |  |       |       |       |
|                           | R1        | R2    | HR1   | HR2   | 1                          | 2     | 1     | 2     | 1     | 2     | 1  | 2     | 3     | 4     |
| Slump, mm                 | 76.2      | 76.2  | 165.1 | 165.1 | 133.4                      | 127.0 | 108.0 | 120.7 | 139.7 | 139.7 | 177.8                                    | 184.2 | 184.2 | 184.2 |
| Air content, %            | 7.6       | 7.6   | 8.2   | 6.8   | 6.9                        | 6.8   | 6.5   | 6.8   | 6.2   | 6.5   | 8.6                                      | 9.0   | 6.0   | 6.1   |
| Weight, kg/m <sup>3</sup> | 2273      | 2264  | 2276  | 2312  | 2296                       | 2297  | 2283  | 2288  | 2265  | 2267  | 2246                                     | 2241  | 2308  | 2316  |
| Temperature, °C           | 20.6      | 21.1  | 20.0  | 22.8  | 21.1                       | 22.2  | 22.8  | 22.8  | 22.2  | 22.8  | 20.0                                     | 20.0  | 21.1  | 22.2  |
| Time of setting:          |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| Initial, hr:min           | 8:10      | 7:55  | 10:00 | 10:00 | 8:00                       | 8:00  | 6:30  | 6:50  | 7:10  | 7:20  | 11:20                                    | 10:30 | ----  | ----  |
| Final, hr:min             | 10:10     | 10:00 | 11:30 | 12:05 | 9:30                       | 9:20  | 7:50  | 8:10  | 8:40  | 8:55  | 13:00                                    | 12:40 | ----  | ----  |
| Compressive strength, MPa |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| 1 day                     | 12.68     | 14.19 | 20.90 | 20.71 | 22.88                      | 22.53 | 21.87 | 23.17 | 19.22 | 19.29 | 18.34                                    | 17.51 | 18.95 | 17.75 |
| 3 days                    | 21.66     | 20.09 | 30.14 | 30.00 | 28.58                      | 29.43 | 27.99 | 27.99 | 27.88 | 27.88 | 30.78                                    | 33.85 | 35.34 | 35.92 |
| 7 days                    | 24.41     | 26.99 | 33.40 | 37.89 | 35.78                      | 35.68 | 32.63 | 34.29 | 29.41 | 32.17 | 37.21                                    | 42.14 | 41.97 | 41.78 |
| 28 days                   | 34.29     | 32.65 | 43.08 | 46.41 | 38.46                      | 39.85 | 39.36 | 37.75 | 35.97 | 37.07 | 43.58                                    | 43.27 | 44.95 | 44.00 |
| Freeze/thaw resistance:   |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| Weight loss, %            |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| 50 cycles                 | 0.2       | 0.2   | 0.8   | 0.6   | 0.7                        | 0.6   | 0.5   | ---   | ---   | ---   | 0.3                                      | 0.4   | 1.0   | 1.2   |
| 100 cycles                | 0.2       | 0.3   | 1.2   | 1.0   | 1.3                        | 1.1   | 0.9   | 0.7   | 0.7   | 1.3   | 0.6                                      | 0.6   | 1.7   | 2.0   |
| 150 cycles                | ---       | 0.3   | 1.8   | 1.4   | ---                        | ---   | ---   | 1.0   | 0.9   | 3.0   | ---                                      | ---   | 2.7   | 3.1   |
| 200 cycles                | 0.3       | 0.5   | ---   | 1.8   | 2.5                        | 2.2   | 2.1   | 1.5   | 1.3   | 4.1   | 1.2                                      | 1.3   | 3.6   | 4.0   |
| 250 cycles                | 0.3       | 0.7   | 2.7   | 2.3   | 2.9                        | 2.6   | 2.6   | 2.1   | 1.9   | 5.2   | 1.5                                      | 1.5   | 4.2   | 4.8   |
| 300 cycles                | 0.5       | 1.0   | 3.3   | 2.7   | 3.4                        | 3.2   | 3.3   | 2.7   | 2.1   | 6.0   | 1.8                                      | 1.8   | 4.9   | 5.3   |
| Durability factor         |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| 50 cycles                 | 100.6     | 98.8  | ----  | 100.7 | 100.0                      | 97.2  | 100.0 | 99.8  | 99.2  | 99.8  | 98.2                                     | 98.6  | 98.4  | 97.9  |
| 100 cycles                | 101.8     | 99.2  | 97.7  | 100.9 | 100.7                      | 97.9  | 99.5  | 99.5  | 96.9  | 98.7  | 98.6                                     | 98.2  | 97.7  | 96.6  |
| 150 cycles                | 102.3     | 99.9  | 95.9  | 102.3 | 101.1                      | 97.4  | 99.5  | 98.3  | 98.5  | 99.3  | 98.5                                     | 98.4  | 96.0  | 95.4  |
| 200 cycles                | 102.4     | 100.5 | 97.1  | 103.1 | 99.0                       | 96.3  | 97.7  | 98.6  | 98.2  | 95.7  | 98.6                                     | 98.1  | 96.3  | 94.9  |
| 250 cycles                | 103.8     | 101.2 | 96.2  | 103.6 | 100.7                      | 97.7  | 98.9  | 98.7  | 98.2  | 97.4  | 98.7                                     | 98.7  | 96.3  | 94.2  |
| 300 cycles                | 103.3     | 100.4 | 97.3  | 102.6 | 100.6                      | 97.1  | 98.6  | 99.1  | 98.0  | 98.6  | 99.2                                     | 98.1  | 94.9  | 93.5  |
| Total chloride ion:       |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| Base Level: ppm           |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| Sample depth,             |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| 1.6 - 12.7 mm             | 46        | 19    | 33    | 60    | --                         | --    | --    | --    | --    | --    | --                                       | --    | --    | --    |
| 12.7 - 25.4 mm            | 52        | 26    | 50    | --    | 82                         | 64    | 84    | 86    | 84    | 101   | 19                                       | 66    | --    | --    |
| 25.4 - 50.8 mm            | 24        | 54    | 50    | 34    | 67                         | 68    | 64    | 66    | 79    | 132   | 137                                      | 57    | --    | --    |
| After 90 days: ppm        |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| Sample depth,             |           |       |       |       |                            |       |       |       |       |       |  |       |       |       |
| 1.6 - 12.7 mm             | 883       | 1422  | 840   | 561   | 815                        | 1689  | 1524  | 827   | 697   | 1239  | 379                                      | 657   | 464   | 191   |
| 12.7 - 25.4 mm            | 118       | 199   | 163   | 83    | 84                         | 134   | 69    | 118   | 94    | 174   | 26                                       | 66    | 53    | 51    |
| 25.4 - 50.8 mm            | 58        | 63    | 31    | 44    | 55                         | 83    | 80    | 95    | 106   | 137   | 110                                      | 43    | 71    | 41    |



TABLE 3

## AVERAGE CONCRETE TEST RESULTS

| Test                       | Reference | HRWR  | Force 10,000 - Silica Fume |       |       |       |       | Silica Fume Cement<br>(7.5% Silica Fume) |
|----------------------------|-----------|-------|----------------------------|-------|-------|-------|-------|--|
|                            |           |       | 2.5%                       | 5%    | 7.5%  | 1&2   | 3&4   |  |
| Slump, in                  | 3.00      | 6.50  | 5.25                       | 4.50  | 5.50  | 7.25  | 7.25  |  |
| Air content, %             | 7.6       | 7.5   | 6.9                        | 6.7   | 6.4   | 8.8   | 6.1   |  |
| Weight, lb/ft <sup>3</sup> | 141.6     | 143.2 | 143.4                      | 142.7 | 141.5 | 140.1 | 144.4 |  |
| Temperature, °F            | 70        | 71    | 71                         | 73    | 73    | 68    | 71    |  |
| Time of setting:           |           |       |                            |       |       |       |       |  |
| Initial, hr:min            | 8:02      | 10:00 | 8:00                       | 6:40  | 7:15  | 10:55 | ----  |  |
| Final, hr:min              | 10:05     | 11:47 | 9:25                       | 8:00  | 8:47  | 12:50 | ----  |  |
| Compressive strength, psi  |           |       |                            |       |       |       |       |  |
| 1 day                      | 1949      | 3017  | 3293                       | 3266  | 2793  | 2600  | 2662  |  |
| 3 days                     | 3028      | 4362  | 4207                       | 4060  | 4043  | 4687  | 5168  |  |
| 7 days                     | 3728      | 5170  | 5182                       | 4853  | 4466  | 5755  | 6073  |  |
| 28 days                    | 4855      | 6490  | 5679                       | 5592  | 5297  | 6298  | 6450  |  |
| Freeze/thaw resistance:    |           |       |                            |       |       |       |       |  |
| Weight loss, %             |           |       |                            |       |       |       |       |  |
| 50 cycles                  | 0.2       | 0.7   | 0.7                        | 0.5   | ---   | 0.4   | 1.1   |  |
| 100 cycles                 | 0.3       | 1.1   | 1.2                        | 0.8   | 1.0   | 0.6   | 1.9   |  |
| 150 cycles                 | 0.3       | 1.6   | ---                        | 1.0   | 2.0   | ---   | 2.9   |  |
| 200 cycles                 | 0.4       | 1.8   | 2.4                        | 1.8   | 2.7   | 1.3   | 3.8   |  |
| 250 cycles                 | 0.5       | 2.5   | 2.8                        | 2.4   | 3.6   | 1.5   | 4.6   |  |
| 300 cycles                 | 0.8       | 3.0   | 3.3                        | 3.0   | 4.1   | 1.8   | 5.1   |  |
| Durability factor          |           |       |                            |       |       |       |       |  |
| 50 cycles                  | 99.7      | 100.7 | 98.6                       | 99.9  | 99.5  | 98.4  | 98.2  |  |
| 100 cycles                 | 100.5     | 99.3  | 99.3                       | 99.5  | 97.8  | 98.4  | 97.2  |  |
| 150 cycles                 | 101.1     | 99.1  | 99.3                       | 98.9  | 98.9  | 98.5  | 95.7  |  |
| 200 cycles                 | 101.5     | 100.1 | 97.7                       | 98.2  | 97.0  | 98.4  | 95.6  |  |
| 250 cycles                 | 102.5     | 99.9  | 99.2                       | 98.8  | 97.8  | 98.7  | 95.3  |  |
| 300 cycles                 | 101.9     | 100.0 | 98.9                       | 98.9  | 98.3  | 98.7  | 94.2  |  |
| Total chloride ion         |           |       |                            |       |       |       |       |  |
| Base Level: ppm            |           |       |                            |       |       |       |       |  |
| Sample depth,              |           |       |                            |       |       |       |       |  |
| 0.0625-0.5 in              | 33        | 47    | --                         | --    | --    | --    | --    |  |
| 0.5 -1.0 in                | 39        | 50    | 74                         | 85    | 93    | 43    | --    |  |
| 1.0 -2.0 in                | 39        | 42    | 68                         | 65    | 106   | 97    | --    |  |
| After 90 days: ppm         |           |       |                            |       |       |       |       |  |
| Sample depth,              |           |       |                            |       |       |       |       |  |
| 0.0625-0.5 in              | 1153      | 701   | 1252                       | 1176  | 968   | 518   | 328   |  |
| 0.5 -1.0 in                | 159       | 123   | 109                        | 94    | 134   | 46    | 52    |  |
| 1.0 -2.0 in                | 61        | 38    | 69                         | 88    | 122   | 77    | 56    |  |



TABLE 3H

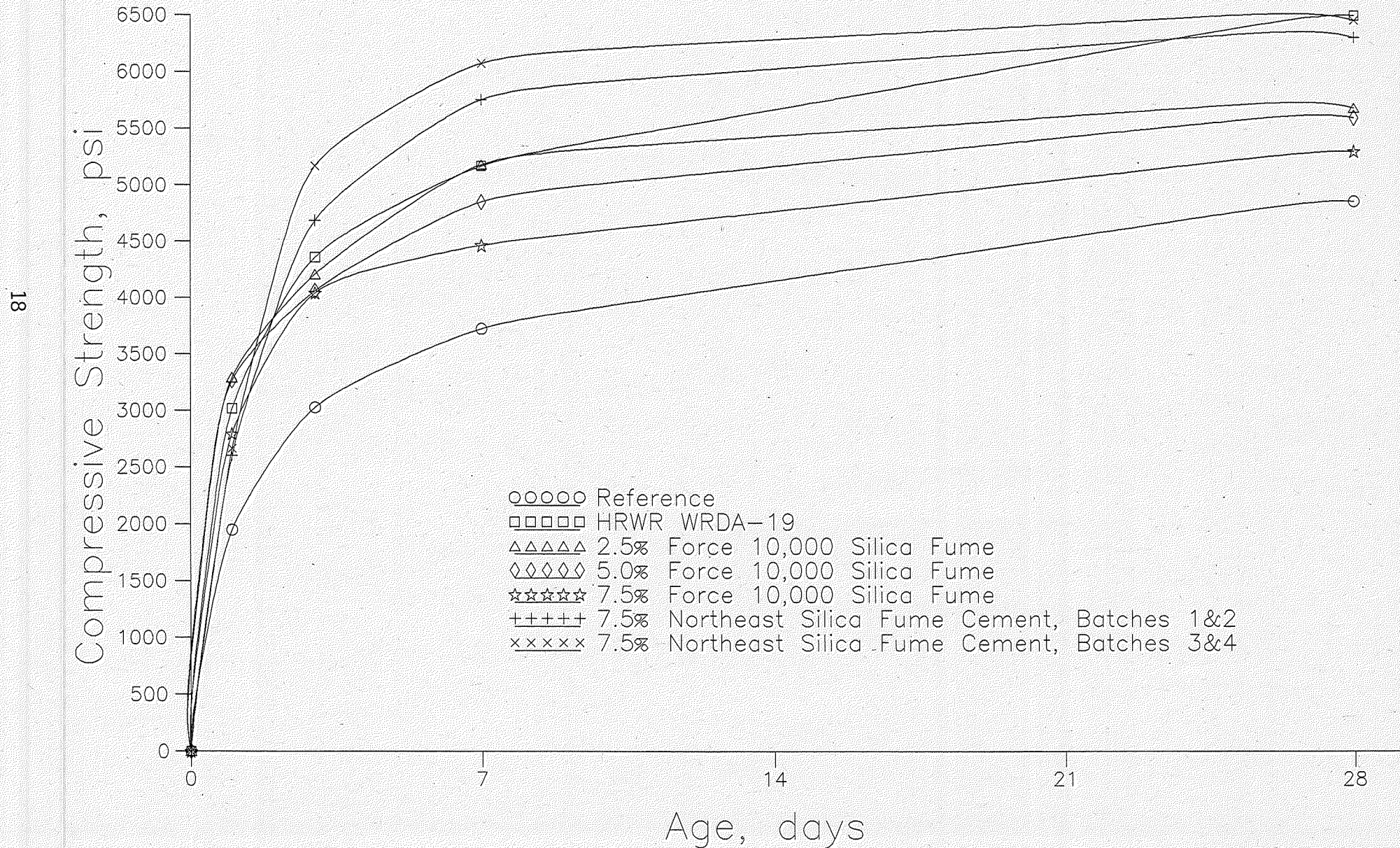
## AVERAGE CONCRETE TEST RESULTS

| Test                      | Reference | HRWR  | Force 10,000 - Silica Fume |       |       | Silica Fume Cement<br>(7.5% Silica Fume) |       |
|---------------------------|-----------|-------|----------------------------|-------|-------|--|-------|
|                           |           |       | 2.5%                       | 5%    | 7.5%  | 1&2                                      | 3&4   |
| Slump, mm                 | 76.2      | 165.1 | 133.4                      | 114.3 | 139.7 | 184.2                                    | 184.2 |
| Air content, %            | 7.6       | 7.5   | 6.9                        | 6.7   | 6.4   | 8.8                                      | 6.1   |
| Weight, kg/m <sup>3</sup> | 2268      | 2294  | 2297                       | 2286  | 2267  | 2244                                     | 2313  |
| Temperature, °C           | 21.1      | 21.7  | 21.7                       | 22.8  | 22.8  | 20.0                                     | 21.7  |
| Time of setting:          |           |       |                            |       |       |  |       |
| Initial, hr:min           | 8:02      | 10:00 | 8:00                       | 6:40  | 7:15  | 10:55                                    | ----  |
| Final, hr:min             | 10:05     | 11:47 | 9:25                       | 8:00  | 8:47  | 12:50                                    | ----  |
| Compressive strength, MPa |           |       |                            |       |       |  |       |
| 1 day                     | 13.44     | 20.80 | 22.71                      | 22.52 | 19.26 | 17.93                                    | 18.35 |
| 3 days                    | 20.88     | 30.08 | 29.01                      | 27.99 | 27.88 | 32.32                                    | 35.63 |
| 7 days                    | 25.70     | 35.65 | 35.73                      | 33.46 | 30.79 | 39.68                                    | 41.87 |
| 28 days                   | 33.48     | 44.75 | 39.16                      | 38.56 | 36.52 | 43.42                                    | 44.47 |
| Freeze/thaw resistance:   |           |       |                            |       |       |  |       |
| Weight loss, %            |           |       |                            |       |       |  |       |
| 50 cycles                 | 0.2       | 0.7   | 0.7                        | 0.5   | ---   | 0.4                                      | 1.1   |
| 100 cycles                | 0.3       | 1.1   | 1.2                        | 0.8   | 1.0   | 0.6                                      | 1.9   |
| 150 cycles                | 0.3       | 1.6   | ---                        | 1.0   | 2.0   | ---                                      | 2.9   |
| 200 cycles                | 0.4       | 1.8   | 2.4                        | 1.8   | 2.7   | 1.3                                      | 3.8   |
| 250 cycles                | 0.5       | 2.5   | 2.8                        | 2.4   | 3.6   | 1.5                                      | 4.6   |
| 300 cycles                | 0.8       | 3.0   | 3.3                        | 3.0   | 4.1   | 1.8                                      | 5.1   |
| Durability factor         |           |       |                            |       |       |  |       |
| 50 cycles                 | 99.7      | 100.7 | 98.6                       | 99.9  | 99.5  | 98.4                                     | 98.2  |
| 100 cycles                | 100.5     | 99.3  | 99.3                       | 99.5  | 97.8  | 98.4                                     | 97.2  |
| 150 cycles                | 101.1     | 99.1  | 99.3                       | 98.9  | 98.9  | 98.5                                     | 95.7  |
| 200 cycles                | 101.5     | 100.1 | 97.7                       | 98.2  | 97.0  | 98.4                                     | 95.6  |
| 250 cycles                | 102.5     | 99.9  | 99.2                       | 98.8  | 97.8  | 98.7                                     | 95.3  |
| 300 cycles                | 101.9     | 100.0 | 98.9                       | 98.9  | 98.3  | 98.7                                     | 94.2  |
| Total chloride ion        |           |       |                            |       |       |  |       |
| Base Level: ppm           |           |       |                            |       |       |  |       |
| Sample depth,             |           |       |                            |       |       |  |       |
| 1.6 - 12.7 mm             | 33        | 47    | --                         | --    | --    | --                                       | --    |
| 12.7 - 25.4 mm            | 39        | 50    | 74                         | 85    | 93    | 43                                       | --    |
| 25.4 - 50.8 mm            | 39        | 42    | 68                         | 65    | 106   | 97                                       | --    |
| After 90 days: ppm        |           |       |                            |       |       |  |       |
| Sample depth,             |           |       |                            |       |       |  |       |
| 1.6 - 12.7 mm             | 1153      | 701   | 1252                       | 1176  | 968   | 518                                      | 328   |
| 12.7 - 25.4 mm            | 159       | 123   | 109                        | 94    | 134   | 46                                       | 52    |
| 25.4 - 50.8 mm            | 61        | 38    | 69                         | 88    | 122   | 77                                       | 56    |



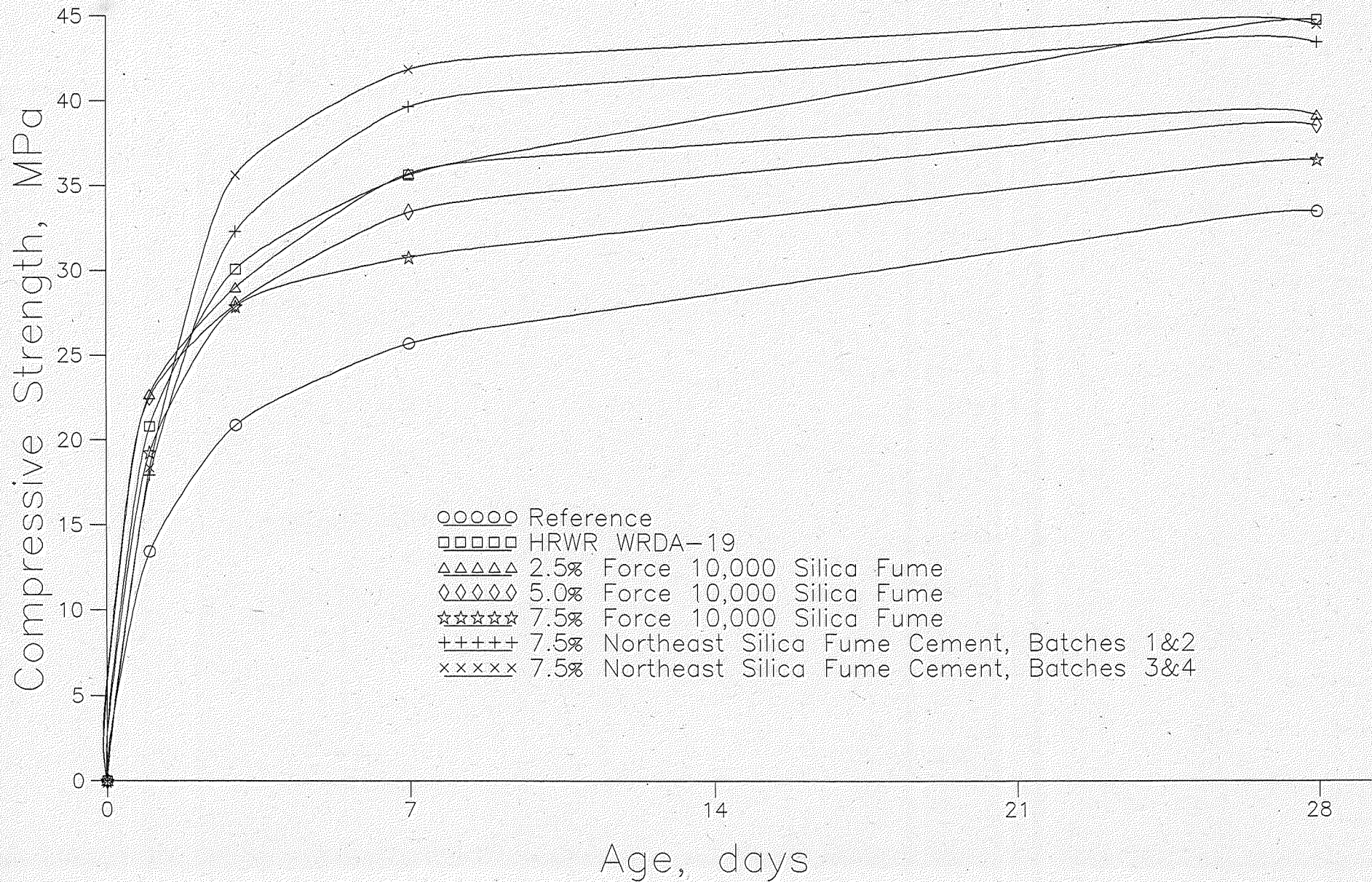
# Average Compressive Strength vs Age

## Figure 1



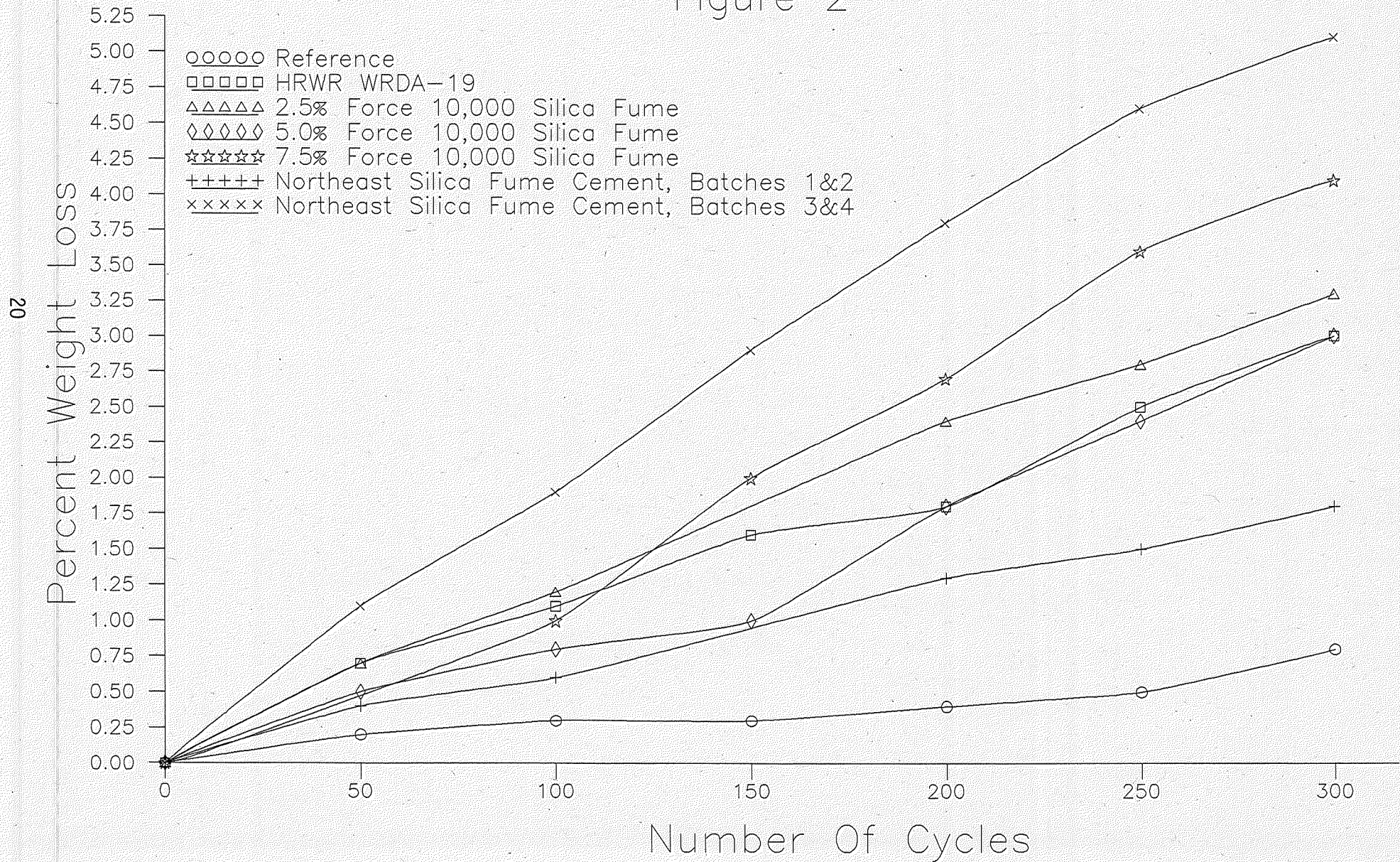
Average Compressive Strength vs Age  
Figure 1-M

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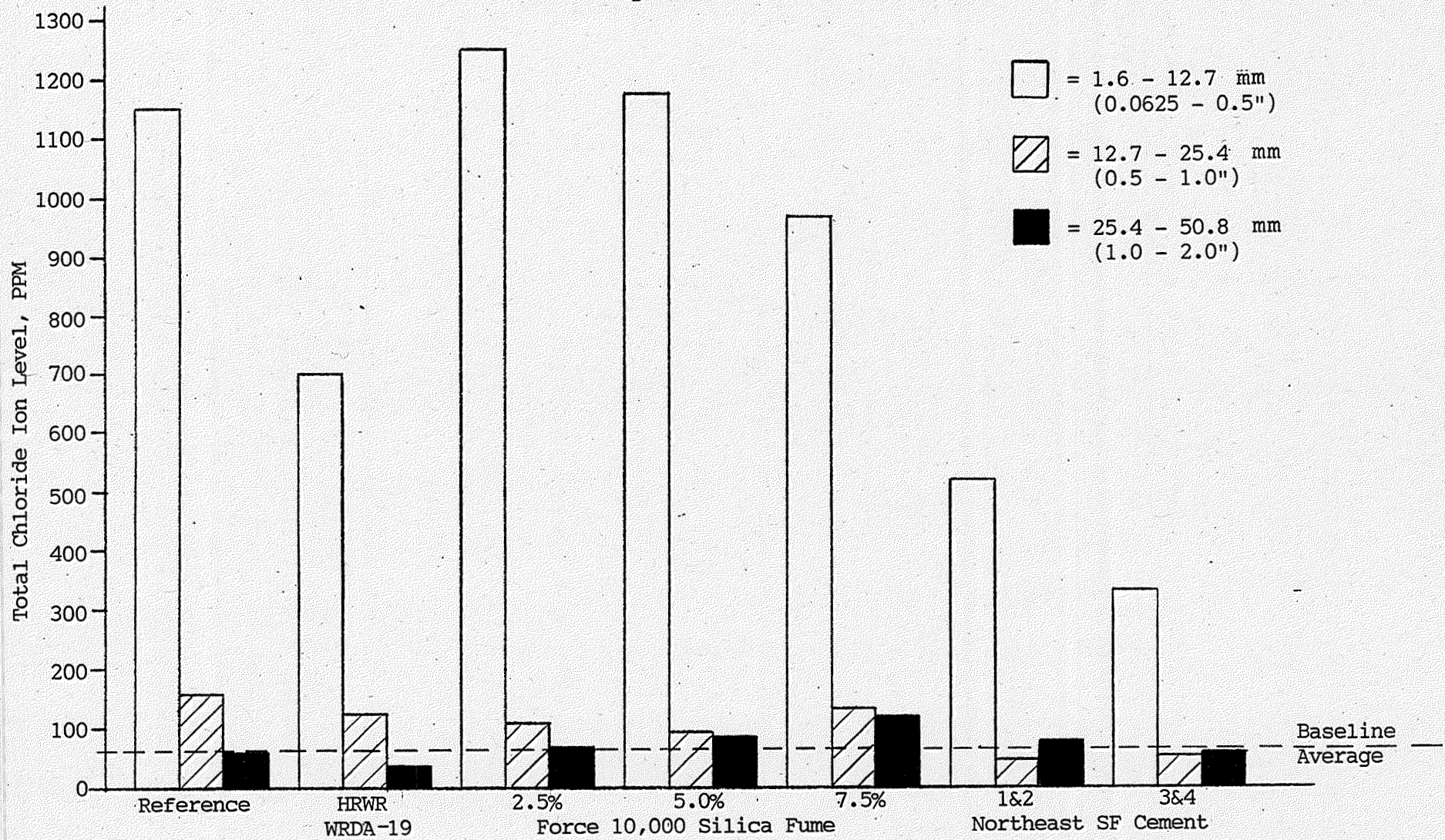




# Resistance To Rapid Freezing & Thawing Average Weight Loss Figure 2



Average Chloride Content After 90 Days of Ponding  
Figure 3





TA 565 Rev. 4/79

Prepared By: <sup>WJM</sup>William Meyer

Date: May 27, 1993

Sheet 1 of 1

STATE OF VERMONT  
AGENCY OF TRANSPORTATION  
MATERIALS & RESEARCHRESEARCH INVESTIGATIONWork Plan No. 93-C -7Subject Silica Fume Concrete (2½%, 5% and 7½% addition rates)Investigation Requested By Warren B. Tripp Date March 18, 1993

Structures Engineer

Date Information Required ASAPPurpose of Investigation To determine performance of silica fume concrete when  
compared to reference concretes. Silica fume addition rates to be 2½%, 5% and 7½%.Proposed Tests or Evaluation Procedure Two batches each of Class A concrete will beprepared using: 1. Water reducing admixture2. High range water reducing admixture3. High range water reducing admixture and 2½%, 5% and 7½% silica fume.4. High range water reducing admixture and 7½% silica fume cement.Testing to include: Slump, air content, unit weight, time of setting, freeze-thawdurability, compressive strength at 1,3,7 and 28 days and resistance to chloride ionpenetration. Initial report will document test results excluding chloride intrusiontests. Final report to include results of all tests.Proposal Discussed With D.F. Hale Projected Mnpr. Requirements 35 mandaysInvestigation To Be Conducted By Structural Concrete Subdivision

Preliminary report-8/30/93

Proposed Starting Date ASAP Estimated Completion Date Final report-12/31/93Approval/Disapproval by Materials & Research Engineer Robert Caudy

Comments by Materials &amp; Research Engineer \_\_\_\_\_

Materials & Research Division  
Agency of Transportation  
Date Typed: