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Final Report

# FIELD PERFORMANCE AND EVALUATION OF SLURRY SEALS

Submitted to
Highway Division
Iowa Department of Transportation
and Iowa Highway Research Board
HR-195

ISU-ERI-AMES-81131
Project 1306

ENGINEERING RESEARCH INSTITUTE
IOWA STATE UNIVERSITY
AMES, IOWA 50010 USA

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# EXECUTIVE SUMMARY

As part of the overall research program of evaluating asphalt emulsion slurry seal as a pavement maintenance material, 31 duplicate 500-ft test sections were constructed on U.S. 6 between Adel and Waukee in Dallas County during September and October of 1978. These test sections included combinations of eight aggregates, two gradings, three asphalt emulsions, two mineral fillers, and a range of emulsion contents determined by laboratory mix designs. The emulsion contents of the test sections varied from 10.3% for Section 7A (Ferguson coarse) to 32.9% for Section 31A (lightweight aggregate). The post-construction performance evaluation of the test sections, consisting primarily of the friction tests and surface appearance observations, was conducted at different time intervals up to 24 months after construction. At the 24-month final evaluation, most of the test sections had carried a total of 1.4 million vehicles.

Based on testing and evaluation performed in the laboratory, experiences gained during construction, and post-construction performance evaluations, the following major conclusions were drawn:

1. Quality slurry seals of good appearances with satisfactory wear and frictional characteristics can be produced, provided the aggregates are suitable and the mixes are properly designed, evaluated, and applied.
2. Coarse-graded slurries had consistently higher friction numbers than did fine-graded slurries of the same material combinations and at the same emulsion contents.

3. Coarse-graded limestones from Ferguson and Moscow at proper emulsion contents and quartzite produced slurries of satisfactory performance with respect to surface appearance and frictional characteristics.
4. Lightweight aggregate slurries resulted in very good frictional characteristics in all sections.
5. None of the fine-graded materials, neither limestone from Garner nor crushed gravels, produced any sections with combinations of satisfactory appearance and frictional characteristics. Garner limestone was the only aggregate used in the test program with a sand equivalent less than 45.
6. Although laboratory tests showed lower wet track abrasion loss for anionic emulsion slurries than for corresponding cationic slurries, there were no noticeable differences in the appearance or performance factors of the two types of emulsions. Nor was there a difference in field cure time. The same can be said about the difference between CSS-1h (40-90 penetration) (standard specifications) and CSS-1h (85-100 penetration) (Iowa specification).
7. Friction number is significantly related to loaded wheel test sand adhesion.

In light of the findings and conclusions resulting from this field-test project, the following recommendations are made:

1. Aggregate for asphalt emulsion slurry should be limited to limestone sources that will produce surfaces with good frictional characteristics.

2. Additional research is needed to evaluate quartzite and lightweight aggregate in slurry surfaces.
3. A sand equivalency factor of 45 or better should be established as a specification for aggregates to be used in slurry work.
4. The procedure outlined in Appendix G, HR-185 Final Report, should be used in designing slurry seal mixes. The emulsion content should be based on washed sieve analysis of job aggregate and a 6.5 μm film thickness.
5. The type of emulsion should be determined on a project-by-project basis, not automatically ruling out the use of anionic emulsion.
6. Additional research is needed to determine the upper limit of emulsion content as a function of traffic in terms of loaded wheel test results.
7. The slurry seal sampling and extraction methods currently being used should be reviewed.
8. Only coarse-graded slurry seal should be used where friction number is a major concern.

# 1. INTRODUCTION

## 1.1. Background

In recent years, the rapid growth of the new pavement construction started in the 1950's with the initiation of the Interstate System has leveled off, and emphasis has been placed on maintaining existing pavements. According to estimates made by the Federal Highway Administration, state highway agencies currently spend $4.3 billion for highway maintenance, and the cost of maintaining the nation's highways is increasing at an annual rate of about $300 million a year. In Iowa, the highway maintenance expenditures increased from about $35 million in fiscal year 1976 to an estimated $54 million for the fiscal year 1981, an increase of more than 50% in five years. In addition to the increased need for highway maintenance, state and local agencies are also faced with the problems of inflation, reduction in available funds, and increasing emphasis on conserving material and energy resources. Because of these considerations, there is an urgent need to identify and adopt maintenance alternatives that will provide the desired level of pavement performance and, at the same time, be the most cost-effective. Research projects HR-185 and HR-195 were aimed at evaluating such a maintenance alternative: asphalt emulsion slurry seals.

## 1.2. Objectives

The overall objective of this research was to review, evaluate, develop, and verify necessary information for successful design and application of asphalt emulsion slurry seals in Iowa. The research was conducted in two phases. Phase I of the study, conducted under HR-185 (1976-1977), dealt with laboratory evaluation of slurry seals. Phase II, HR-195 (1977-1980), is a field performance evaluation. It was envisioned that the two phases together would form the basis for the development and preparation of slurry seal design methods, criteria, and construction procedures for the successful application of slurry seal as an economic pavement maintenance alternative. The specific objectives of the Phase I (HR-185) study were [1]:

1. To provide a comprehensive literature search on the material characteristics, design procedures, criteria for and field experiences with slurry seals.
2. To conduct a programmed laboratory study of slurry seal design procedures and criteria, testing and evaluation methods, and material and mixture characteristics.
3. To formulate tentative slurry seal laboratory design, testing and evaluation procedures, and recommendations on the desirability and design of field study.

The results of HR-185 based on the testing of 40 material combinations showed that [1]:

- Although not all of the aggregates studied met current specifications, nearly all of them can be made into a creamy, stable, homogeneous, free-flowing slurry seal, with proper selections of emulsion type, emulsion content, pre-wet water content, and mineral filler type and content.

- Not all of the slurries made with aggregates meeting specifications gave satisfactory abrasion and wear resistance.
- Although anionic emulsion SS-1h is not included in current Iowa specifications, mainly due to its slow curing rate, it is by far the easiest emulsion to work with and often resulted in slurries with better overall qualities.

A field performance and evaluation was undertaken to a) test these findings, b) determine limitations of some materials and applicability of other materials in slurry seals, c) correlate laboratory tests with field performances, and d) establish material and construction control specifications and design criteria for Iowa weather, traffic, and materials.

## 1.3. Field-Test Program

The proposed slurry seal field-test factorial arrangement is shown in Fig. 1. The test program consisted of two sets of 31 identical 500 ft × 12 ft sections. The test sections (2 × 31 × 500 ft = 31,000 ft or 5.87 mi) were applied to one traffic lane. The adjoining lane was slurry sealed with a slurry mix, following current design and specifications. The variables and their respective levels are as follows:

PROPOSED SLURRY SEAL FIELD TEST FACTORIAL ARRANGEMENT

| AGGREGATE | | | GARNER | | | | | | | | FERGUSON | | | | QUARTZITE | | | | CONCRETE SAND AND FLY ASH | | | | MOSCOW DOLOMITE | | | | GRAVEL | | | | HAYDITE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GRADATION(a) | | | FINE | | | | COARSE | | | | FINE | | COARSE | | FINE | | COARSE | | FINE | | COARSE | | FINE | | COARSE | | DALLAS COARSE | | DIKINSON COARSE | | FINE | | COARSE | | |
| SAND EQUIVALENT | | | 50- | | 50+ | | 50- | | 50+ | | 50- | 50+ | 50- | 50+ | 50- | 50+ | 50- | 50+ | 50- | 50+ | 50- | 50+ | 50- | 50+ | 50- | 50+ | 50- | 50+ | 50- | 50+ | 50- | 50+ | 50- | 50+ | |
| EMULSION | EMULSION CONTENT(c) | FILLER TYPE(b) / FLOW, cm | P | L | P | L | P | L | P | L | P | P | P | P | P | P | P | P | P | P | P | P | L | L | L | L | L | L | L | L | P | P | P | P | L |
| CSS-1h (IOWA) | 0.8 $E_a$ | 2-3 | | | | | | | | | | ▨ | | ▨ | | | | | | | | | | | | | | | | | | | | | |
| | | 4-5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1.0 $E_t$ | 2-3 | ▨ | ▨ | | | ▨ | ▨ | | | | ▨ | | ▨ | | | | ▨ | | | | ▨ | | ▨ | | ▨ | ▨ | | | ▨ | | | | ▨ | ▨ |
| | | 4-5 | | | | | | | | | | ▨ | | ▨ | | | | | | | | | | | | | | | | | | | | | |
| | 1.2 $E_l$ | 2-3 | | | | | | | | | | ▨ | | ▨ | | | | | | | | | | | | | | | | | | | | | |
| | | 4-5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CSS-1h (40-90) | 0.8 $E_a$ | 2-3 | | | | | | | | | | | | ▨ | | | | | | | | | | | | | | | | | | | | | |
| | | 4-5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1.0 $E_t$ | 2-3 | | | | | | | | | | | | ▨ | | | | ▨ | | | | | | | | | | | | | | | | | |
| | | 4-5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1.2 $E_l$ | 2-3 | | | | | | | | | | | | ▨ | | | | | | | | | | | | | | | | | | | | | |
| | | 4-5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SS-1h | 0.8 $E_a$ | 2-3 | | | | | | | | | | | | ▨ | | | | | | | | | | | | | | | | | | | | | |
| | | 4-5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1.0 $E_t$ | 2-3 | | | | | | | | | | | | ▨ | | | | | | | | | | | | ▨ | | | | ▨ | | | | ▨ | ▨ |
| | | 4-5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1.2 $E_l$ | 2-3 | | | | | | | | | | | | ▨ | | | | | | | | | | | | | | | | | | | | | |
| | | 4-5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

▨ INDICATE TREATMENT COMBINATIONS TO BE TESTED

(a) FINE: FINE SIDE OF IOWA SPECS; COARSE: COARSE SIDE OF IOWA SPECS

(b) P: TYPE 1 PORTLAND CEMENT; L: HYDRATED LIME

(c) EMULSION CONTENT: $E_t$: THEORETICAL EMULSION CONTENT BASED ON U.S. ARMY SURFACE AREA METHOD AND 8 μm FILM

$E_l$: *HIGHEST EMULSION CONTENT DETERMINED BY LOADED WHEEL TESTER;*

$E_a$: LOWEST EMULSION CONTENT DETERMINED BY WTAT

Fig. 1. Slurry seal field-test factorial arrangement.

| Factor | Variables | Levels |
| --- | --- | --- |
| Aggregate type | Garner limestone; Ferguson limestone; Moscow dolomite; quartzite; concrete sand plus fly ash; Dallas gravel; Dickinson gravel; and Haydite (lightweight aggregate) | 7 |
| Gradation | fine; coarse | 2 |
| Sand equivalent | <40; >60 | 2 |
| Emulsion type | CSS-1h (85-100 penetration)<br>CSS-1h (40-90 penetration)<br>SS-1h | 3 |
| Emulsion content* | 80% theoretical emulsion content<br>100% theoretical emulsion content<br>120% theoretical emulsion content | 3 |
| Filler type | Type 1 Portland cement; hydrated lime | 2 |
| Slurry consistency | 2-3 cm cone flow; 4-5 cm cone flow | 2 |

It was envisioned that factorial arrangement would allow testing and comparison of slurry seals in terms of:

- Field versus laboratory behavior with respect to mixing stability, set and cure time, wear resistance (durability), and flushing (bleeding) susceptibility under traffic.
- Adequacy of current Iowa materials specifications.
- Coarse versus fine-graded slurry seals.
- High versus low sand equivalent aggregates.
- Portland cement versus hydrated lime as fillers.

*These were the original target values. As noted in Section 3 and Table 4, these values were reduced by 2% during construction for most sections. The actual applied emulsion contents as percent of theoretical emulsion content (Et) ranged from 0.5 to 1.4 Et (Table 5).

- Soft versus hard base asphalt emulsions.
- Cationic versus anionic emulsions.
- Field performance versus emulsion content.
- Feasibility of using fly ash in slurry seal.

## 2. TEST SECTIONS

The project was located on U.S. 6 between Adel and Waukee in Dallas County. The selected test site was based on consideration of:

- Proximity to Ames, so participating researchers from the Iowa Department of Transportation and Iowa State University could conveniently make frequent visits.
- Structurally sound to simplify slurry seal performance evaluation.
- High daily traffic and relatively low friction numbers.

The traffic count on this section of road in 1978 was 3760 vehicles per day (vpd).

Friction testing and present serviceability index (psi) determinations were conducted prior to slurry seal applications in August 1978. The average friction numbers of the eastbound lane (test sections) were 24.4 for normal surfaces and 32.1 for the heater-planed surface; the respective average friction numbers for the westbound lane (control section) were 27.1 and 36.3. The present serviceability index was 3.00 for the eastbound lane and 3.10 for the westbound lane.

The eastbound lane of the two-lane 24-ft asphalt over concrete pavement was divided into sixty-two 500 ft test sections. Thirty-one mix designs (Table 1) were to be placed; each mix design was used twice (Fig. 2). The actual length of the test sections varied depending on the amount of material loaded into the slurry machine. The full length of the adjacent westbound lane (31,285 ft or 5.92 mi) was used as control and was slurry sealed at about the same time. Ferguson coarse

Table 1. Mix Identification.

| Mix Number | Aggregate Identification Code | Emulsion Type | Mineral Filler | Percent of[a] Theoretical Emulsion Content | Proposed Flow (cm) |
|---|---|---|---|---|---|
| 1 | GFLS | CSS-1h(Iowa) | P | 100 | 2-3 |
| 2 | GFLS | CSS-1h(Iowa) | L | 100 | 2-3 |
| 3 | GCLS | CSS-1h(Iowa) | P | 100 | 2-3 |
| 4 | GCLS | CSS-1h(Iowa) | L | 100 | 2-3 |
| 5 | FFLS | CSS-1h(Iowa) | P | 80 | 2-3 |
| 6 | FFLS | CSS-1h(Iowa) | P | 100 | 2-3 |
| 7 | FFLS | CSS-1h(Iowa) | P | 100 | 4-5 |
| 8 | FFLS | CSS-1h(Iowa) | P | 120 | 2-3 |
| 9 | FCLS | CSS-1h(Iowa) | P | 80 | 2-3 |
| 10 | FCLS | CSS-1h(Iowa) | P | 100 | 2-3 |
| 11 | FCLS | CSS-1h(Iowa) | P | 100 | 4-5 |
| 12 | FCLS | CSS-1h(Iowa) | P | 120 | 2-3 |
| 13 | Q | CSS-1h(Iowa) | P | 100 | 2-3 |
| 14 | CS | CSS-1h(Iowa) | P | 100 | 2-3 |

Table 1. Continued.

| Mix Number | Aggregate Identification Code | Emulsion Type | Mineral Filler | Percent of Theoretical Emulsion Content | Proposed Flow (cm) |
|---|---|---|---|---|---|
| 15 | MFD | CSS-1h(Iowa) | L | 100 | 2-3 |
| 16 | MCD | CSS-1h(Iowa) | L | 100 | 2-3 |
| 17 | DA | CSS-1h(Iowa) | L | 100 | 2-3 |
| 18 | DI | CSS-1h(Iowa) | L | 100 | 2-3 |
| 19 | LW | CSS-1h(Iowa) | P | 100 | 2-3 |
| 20 | LW | CSS-1h(Iowa) | L | 100 | 2-3 |
| 21 | FCLS | CSS-1h(Standard) | P | 80 | 2-3 |
| 22 | FCLS | CSS-1h(Standard) | P | 100 | 2-3 |
| 23 | FCLS | CSS-1h(Standard) | P | 120 | 2-3 |
| 24 | Q | CSS-1h(Standard) | P | 100 | 2-3 |
| 25 | FCLS | SS-1h(Standard) | P | 80 | 2-3 |
| 26 | FCLS | SS-1h(Standard) | P | 100 | 2-3 |
| 27 | FCLS | SS-1h(Standard) | P | 120 | 2-3 |
| 28 | MCD | SS-1h(Standard) | L | 100 | 2-3 |

Table 1. Continued.

| Mix Number | Aggregate Identification Code | Emulsion Type | Mineral Filler | Percent of Theoretical Emulsion Content | Proposed Flow (cm) |
|---|---|---|---|---|---|
| 29 | DI | SS-1h(Standard) | L | 100 | 2-3 |
| 30 | LW | SS-1h(Standard) | P | 100 | 2-3 |
| 31 | LW | SS-1h(Standard) | L | 100 | 2-3 |

[a]These were the original target values. As noted in Section 3 and Table 4, these values were reduced by 2% during construction for most sections. The actual applied emulsion contents as percent of theoretical emulsion content (Et) ranged between 0.5 and 1.4 Et (Table 5).

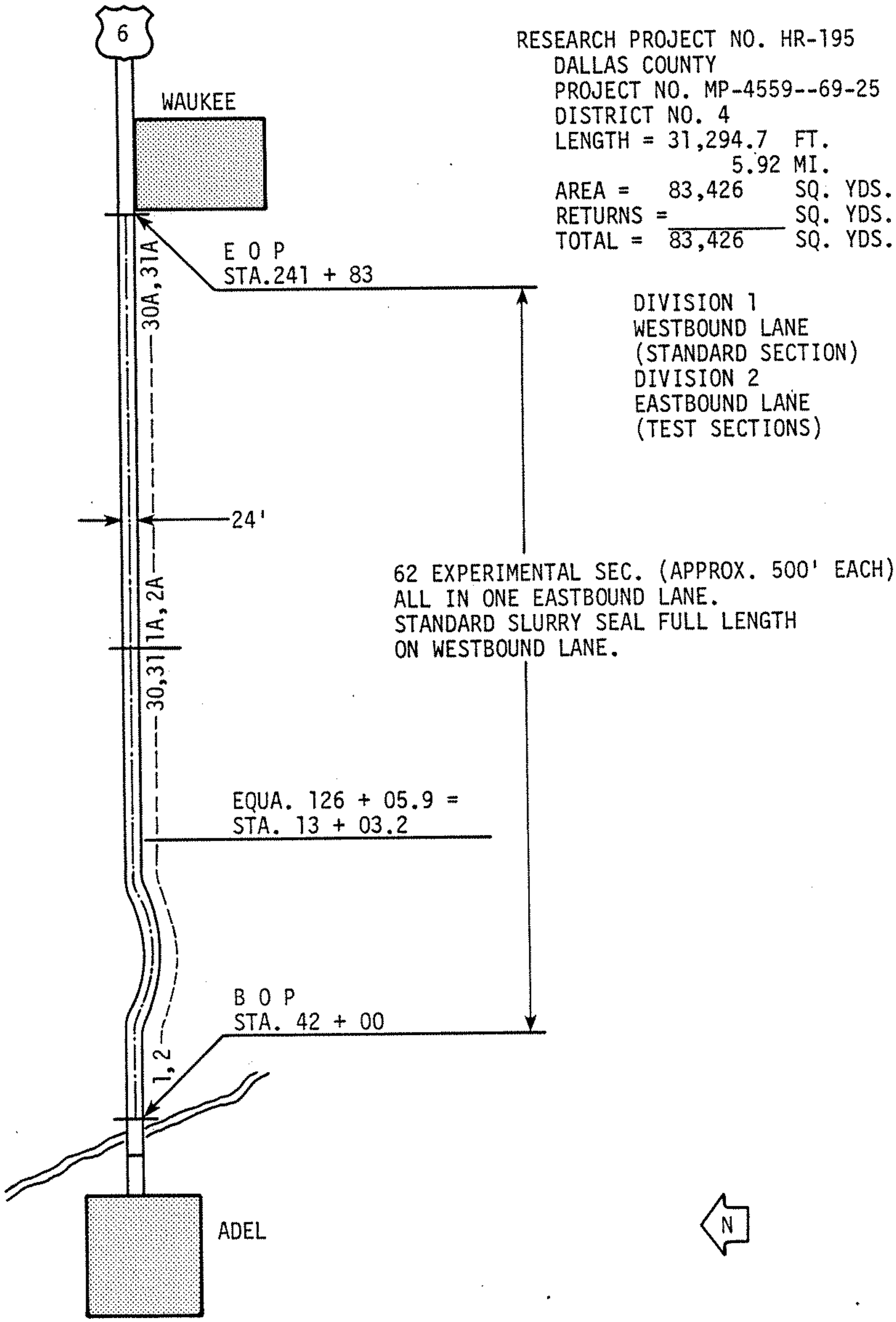


Fig. 2. Location of test sections.

aggregate and cationic emulsion CSS-1h were used in the standard mix (Iowa Department of Transportation Specification 793). The emulsion content ranged between 12.48 and 14.16% with 1% Portland cement as filler.

# 3. SLURRY MIX DESIGN

## 3.1. Materials

Aggregate type and source locations are given in Table 2. Concrete sand from Martin Marietta, West Des Moines, was blended with 10% fly ash from Chicago Fly Ash, Clinton, Iowa, and used for Sections 14 and 14A. Lightweight aggregate from New Market, Missouri, was blended with 20% locally available agricultural lime and used in Sections 19, 19A, 20, 20A, 30, 30A, 31 and 31A. The characteristics of the aggregates and aggregate blends are given in Table 3.

Cationic emulsions meeting standard (CSS-1h) and Iowa specifications (85-100 penetration base asphalt) were supplied by Bitucote Products of Des Moines. The anionic emulsion was supplied by Union Asphalt Company of Kansas City, Kansas.

Representative samples of all materials were delivered to the Bituminous Research Laboratory, Iowa State University, between July 26, 1978 and September 28, 1978.

## 3.2. Design Method and Procedure

Since the material combinations and levels of emulsion content (as percent of theoretical emulsion content) of the 31 mixes were predetermined based on results of Phase I laboratory study (HR-185) and factorial arrangements (Fig. 1), the laboratory slurry design for the test sections became a matter of [1-5]:

1. Determination of the surface area based on washed sieve analysis.

Table 2. Material Source Locations.

| Code | Type | Source Location |
|---|---|---|
| Aggregate | | |
| GFLS and GCLS | Crushed Limestone | 13-95-24 Hancock County<br>14-95-24 Hancock County<br>11-95-24 Hancock County |
| FFLS | Crushed Limestone | 5-82-17 Marshall County |
| FCLS | Crushed Limestone | 5-82-17 Marshall County |
| Q | Quartzite | 35-110-31 New Ulm, Minnesota |
| CS | Concrete Sand | Finley at Adel, Dallas County |
| MFD | Dolomite | 08-78-02 Muscatine County |
| MCD | Dolomite | 08-78-02 Muscatine County |
| DA | Crushed Gravel | 29-79-27 Dallas County |
| DI | Crushed Gravel | 6-98-36 Dickinson County |
| LW | Lightweight Aggregate | New Market, Missouri |
| Mineral Filler | | |
| P | Type 1 Portland Cement as specified in AASHTO M-85 | Atlas, St. Louis, Missouri |
| L | Hydrated Lime as specified in AASHTO M-216 | Ash Grove Snowflake,<br>Ash Grove Cement Company<br>Kansas City, Missouri |

Table 3. Properties of Test Section Aggregates.

| | Aggregate | | | | | | | | | | | Specifications | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GF | GC | FF | FC | Q | CS[a] | MF | MC | DA | D1 | LW[b] | Fine | Coarse |
| Gradation (percent passing) 3/8 inch | 100 | 100 | 100 | 99 | 100 | 100 | 100 | 100 | 98 | 100 | 100 | 100 | 100 |
| No. 4 | 94 | 91 | 80 | 78 | 97 | 99 | 92 | 77 | 68 | 100 | 99 | 95-100 | 80-100 |
| No. 8 | 66 | 67 | 52 | 51 | 86 | 89 | 68 | 54 | 49 | 76 | 74 | 55-80 | 55-80 |
| No. 16 | 44 | 48 | 36 | 38 | 68 | 76 | 48 | 39 | 38 | 53 | 45 | -- | -- |
| No. 30 | 33 | 26 | 28 | 31 | 48 | 57 | 37 | 31 | 29 | 35 | 28 | 24-43 | 24-43 |
| No. 50 | 26 | 26 | 23 | 24 | 29 | 24 | 30 | 25 | 22 | 22 | 18 | -- | 14-30 |
| No. 100 | 20 | 19 | 19 | 20 | 18 | 11 | 23 | 19 | 17 | 13 | 14 | -- | -- |
| No. 200 | 16 | 14 | 15 | 16 | 10 | 8 | 17 | 14 | 13 | 7 | 12 | 14-20 | 8-15 |
| Specific Gravity | 2.812 | 2.812 | 2.712 | 2.712 | 2.649 | 2.667 | 2.793 | 2.793 | 2.714 | 2.739 | 1.902 | -- | -- |
| CKE | 3.7 | 3.7 | 4.3 | 4.3 | 2.5 | 2.7 | 3.7 | 3.7 | 4.5 | 3.5 | 6.3 | -- | -- |
| Sand Equivalent | 28 | 31 | 53 | 53 | 81 | 98 | 54 | 54 | 48 | 74 | 87 | -- | -- |

[a]CS = 90% concrete sand, plus 10% fly ash.

[b]LW = 80% lightweight aggregate, plus 20% agricultural lime.

2. Calculation of theoretical emulsion content required for 8 μm film thickness (Appendix E, HR-185 Report).
3. Conversion to actual emulsion content from percent of theoretical emulsion content.
4. Determination of pre-wet moisture content for desired flow by trial mixing and consistency tests (Appendix D, HR-185 Report).
5. Performance of wet track abrasion test (WTAT), loaded wheel test (LWT) and cure time and cohesion test on laboratory-prepared slurry mixes (Appendices C, D, and F, HR-185 Report).

## 3.3. Slurry Seal Design Formulas

Three sets of designs were made for the 31 mixes to be used in the field test sections. The first set of designs was made between August 1977 and March 1978, using materials obtained in HR-185 from the same aggregate sources proposed for HR-195. These formulas were submitted to Mr. Vernon Marks, Research Engineer, Highway Division of the Iowa Department of Transportation in April 1978, together with results performed on these slurry mixes, including cone flow, shaker test, WTAT and LWT. However, because the field-stockpiled materials were different from those materials used in HR-185, these formulas were not used.

A second set of job-mix formulas was designed the last half of August 1978 and the first week of September 1978, using field-stockpiled materials. The emulsion contents of most of these designs were considered to be too high by Iowa DOT engineers and the contractor. Therefore, a third set of designs was made at emulsion contents 2% less than the calculations based on 8 μm film thickness requirements. This was done during the second week of September 1978 and delivered to the job on September 19, 1978, and was used as target values for the field test sections.

The job-mix formulas at both the theoretically calculated emulsion contents and at 2% less than the calculated emulsion contents are given in Table 4.

After completion of the field test sections, 62 slurry mixes were prepared in the laboratory using the slurry compositions actually used in the test sections and tested for WTAT, LWT, cure time, cured moisture content and cohesion. These results are presented in Table 5, together with field slurry compositions and the results of the friction tests.

Table 4. Laboratory-Designed and Field Target Slurry Mix Compositions.

| Mix Number | Aggregate Type | Aggregate (g) | Filler (g) | Moisture Content (g) | Emulsion (g) | Emulsion Type | Percent Theoretical Emulsion | Cone Flow (cm) |
|---|---|---|---|---|---|---|---|---|
| 1 | GFLS | 100 | 1 PC | 5 | 22 | CSS-1h(85) | 100 | 2.8 |
| 1L[a] | GFLS | 100 | 1 PC | 3 | 20 | CSS-1h(85) | | 2.5 |
| 2 | GFLS | 100 | 1 HL | 3.5 | 22 | CSS-1h(85) | 100 | 2.5 |
| 2L | GFLS | 100 | 1 HL | 5 | 20 | CSS-1h(85) | | 2.9 |
| 3 | GCLS | 100 | 1 PC | 3 | 20 | CSS-1h(85) | 100 | 3.0 |
| 3L | GCLS | 100 | 1 PC | 4 | 18 | CSS-1h(85) | | 2.8 |
| 4 | GCLS | 100 | 1 HL | 4 | 20 | CSS-1h(85) | 100 | 2.9 |
| 4L | GCLS | 100 | 1 HL | 4.5 | 18 | CSS-1h(85) | | 2.8 |
| 5 | FFLS | 100 | 1 PC | 6 | 17 | CSS-1h(85) | 80 | 2.8 |
| 5L | FFLS | 100 | 1 PC | 6 | 15 | CSS-1h(85) | | 2.8 |
| 6 | FFLS | 100 | 1 PC | 4 | 21 | CSS-1h(85) | 100 | 2.9 |
| 6L | FFLS | 100 | 1 PC | 4 | 19 | CSS-1h(85) | | 2.6 |
| 7 | FFLS | 100 | 1 PC | 5 | 21 | CSS-1h(85) | 100 | 4.1 |
| 7L | FFLS | 100 | 1 PC | 6 | 19 | CSS-1h(85) | | 4.2 |

Table 4. Continued.

| Mix Number | Aggregate Type | Aggregate (g) | Filler (g) | Moisture Content (g) | Emulsion (g) | Emulsion Type | Percent Theoretical Emulsion | Cone Flow (cm) |
|---|---|---|---|---|---|---|---|---|
| 8 | FFLS | 100 | 1 PC | 2.5 | 25 | CSS-1h(85) | 120 | 2.7 |
| 8L | FFLS | 100 | 1 PC | 3 | 23 | CSS-1h(85) | | 2.4 |
| 9 | FCLS | 100 | 1 PC | 6.5 | 18 | CSS-1h(85) | 80 | 2.6 |
| 9L | FCLS | 100 | 1 PC | 6 | 16 | CSS-1h(85) | | 2.3 |
| 10 | FCLS | 100 | 1 PC | 4 | 22 | CSS-1h(85) | 100 | 2.5 |
| 10L | FCLS | 100 | 1 PC | 5 | 20 | CSS-1h(85) | | 2.4 |
| 11 | FCLS | 100 | 1 PC | 6.5 | 22 | CSS-1h(85) | 100 | 4.1 |
| 11L | FCLS | 100 | 1 PC | 7.5 | 20 | CSS-1h(85) | | 4.6 |
| 12 | FCLS | 100 | 1 PC | 3 | 26 | CSS-1h(85) | 120 | 2.4 |
| 12L | FCLS | 100 | 1 PC | 4 | 24 | CSS-1h(85) | | 2.6 |
| 13 | Q | 100 | 1 PC | 6 | 19 | CSS-1h(85) | 100 | 2.2 |
| 13L | Q | 100 | 1 PC | 7 | 17 | CSS-1h(85) | | 2.8 |
| 14 | CS[b] | 100 | 1 PC | 6.5 | 14 | CSS-1h(85) | 100 | 2.1 |
| 15 | MFD | 100 | 1 HL | 6 | 22 | CSS-1h(85) | 100 | 2.7 |

Table 4. Continued.

| Mix Number | Aggregate Type | Aggregate (g) | Filler (g) | Moisture Content (g) | Emulsion (g) | Emulsion Type | Percent Theoretical Emulsion | Cone Flow (cm) |
|---|---|---|---|---|---|---|---|---|
| 16 | MCD | 100 | 1 HL | 5 | 22 | CSS-1h(85) | 100 | 2.7 |
| 16L | MCD | 100 | 1 HL | 5 | 20 | CSS-1h(85) | | 2.4 |
| 17 | DA | 100 | 1 HL | 7.5 | 22 | CSS-1h(85) | 100 | 2.4 |
| 18 | DI | 100 | 1 HL | 6.5 | 19 | CSS-1h(85) | 100 | 2.9 |
| 19 | LW[c] | 100 | 1 PC | 10 | 34 | CSS-1h(85) | 100 | 2.4 |
| 19L | LW | 100 | 1 PC | 14 | 27 | CSS-1h(85) | | 2.8 |
| 20 | LW | 100 | 1 HL | 10 | 34 | CSS-1h(85) | 100 | 2.7 |
| 20L | LW | 100 | 1 HL | 14 | 27 | CSS-1h(85) | | 2.9 |
| 21 | FCLS | 100 | 1 PC | 6.5 | 18 | CSS-1h(40-90) | 80 | 2.3 |
| 21L | FCLS | 100 | 1 PC | 6 | 16 | CSS-1h(40-90) | | 2.3 |
| 22 | FCLS | 100 | 1 PC | 4.5 | 22 | CSS-1h(40-90) | 100 | 2.2 |
| 22L | FCLS | 100 | 1 PC | 4.5 | 20 | CSS-1h(40-90) | | 2.9 |
| 23 | FCLS | 100 | 1 PC | 3 | 26 | CSS-1h(40-90) | 120 | 2.7 |
| 23L | FCLS | 100 | 1 PC | 3 | 24 | CSS-1h(40-90) | | 2.8 |

Table 4. Continued.

| Mix Number | Aggregate Type | Aggregate (g) | Filler (g) | Moisture Content (g) | Emulsion (g) | Emulsion Type | Percent Theoretical Emulsion | Cone Flow (cm) |
|---|---|---|---|---|---|---|---|---|
| 24 | Q | 100 | 1 PC | 6 | 19 | CSS-1h(40-90) | 100 | 2.2 |
| 24L | Q | 100 | 1 PC | 6.5 | 17 | CSS-1h(40-90) | | 2.3 |
| 25 | FCLS | 100 | 1 PC | 14 | 18 | SS-1h | 80 | 2.6 |
| 25L | FCLS | 100 | 1 PC | 14 | 16 | SS-1h | | 2.9 |
| 26 | FCLS | 100 | 1 PC | 13 | 22 | SS-1h | 100 | 2.4 |
| 26L | FCLS | 100 | 1 PC | 13 | 20 | SS-1h | | 2.8 |
| 27 | FCLS | 100 | 1 PC | 12 | 26 | SS-1h | 120 | 2.2 |
| 27L | FCLS | 100 | 1 PC | 12 | 24 | SS-1h | | 2.5 |
| 28 | MCD | 100 | 1 HL | 17 | 20 | SS-1h | 100 | 2.2 |
| 28L | MCD | 100 | 1 HL | 17 | 18 | SS-1h | | 2.8 |
| 29 | DI | 100 | 1 HL | 16.5 | 17 | SS-1h | 100 | 2.8 |
| 30 | LW | 100 | 1 PC | 19 | 34 | SS-1h | 100 | 2.3 |
| 30L | LW | 100 | 1 PC | 23 | 27 | SS-1h | | 2.5 |
| 31 | LW | 100 | 1 HL | 30 | 34 | SS-1h | 100 | 2.5 |

Table 4. Continued.

| Mix Number | Aggregate Type | Aggregate (g) | Filler (g) | Moisture Content (g) | Emulsion (g) | Emulsion Type | Percent Theoretical Emulsion | Cone Flow (cm) |
|---|---|---|---|---|---|---|---|---|
| 31L | LW | 100 | 1 HL | 28 | 27 | SS-1h | | 2.7 |

[a]L = field target mix designs, 2% less emulsion than laboratory-designed emulsion content.

[b]CS = 90% CS plus 10% fly ash.

[c]LW = 80% lightweight aggregate plus 20% agricultural lime.

Table 5. HR-195 Slurry Seal Test Section Results.

| OBS | SECTION[a] | REP[a] | AGG_TYPE[b] | SE[c] | FILLER[d] | P_FILLER[e] | EMULTYPE[f] | BASE_AC[g] | P_THEO[h] | P_EMUL[i] | WTAT[j] | LWT[k] | CMC[l] | C_TIME[m] | COHESION[n] | FLOW[o] | AGE[p] | FN40A[q] | FN55A[q] | FN40B[q] | FN55B[q] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | FC | 53 | P | 1.2 | C | S | 0.7 | 16.0 | 31 | 21.9 | 1.1 | 12 | 8 | 3 | 2 | 44 | 34 | 43 | 39 |
| 2 | 1 | 1 | FC | 53 | P | 1.2 | C | S | 0.7 | 16.0 | 31 | 21.9 | 1.1 | 12 | 8 | 3 | 9 | 25 | 25 | 56 | 43 |
| 3 | 1 | 1 | FC | 53 | P | 1.2 | C | S | 0.7 | 16.0 | 31 | 21.9 | 1.1 | 12 | 8 | 3 | 12 | 24 | 19 | 42 | 39 |
| 4 | 1 | 1 | FC | 53 | P | 1.2 | C | S | 0.7 | 16.0 | 31 | 21.9 | 1.1 | 12 | 8 | 3 | 20 | 20 | 15 | 36 | 27 |
| 5 | 1 | 1 | FC | 53 | P | 1.2 | C | S | 0.7 | 16.0 | 31 | 21.9 | 1.1 | 12 | 8 | 3 | 24 | 25 | 18 | 47 | 37 |
| 6 | 2 | 2 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.2 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 2 | 54 | 42 | 47 | 37 |
| 7 | 2 | 2 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.2 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 9 | 40 | 41 | 53 | 44 |
| 8 | 2 | 2 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.2 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 12 | 38 | 32 | 43 | 41 |
| 9 | 2 | 2 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.2 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 20 | 28 | 30 | 39 | 32 |
| 10 | 2 | 2 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.2 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 24 | 41 | 33 | 50 | 37 |
| 11 | 3 | 3 | GC | 31 | P | . | . | . | . | . | . | . | . | . | . | . | 3 | 14 | 11 | 46 | 34 |
| 12 | 3 | 3 | GC | 31 | P | . | . | . | . | . | . | . | . | . | . | . | 6 | 14 | 8 | 37 | 29 |
| 13 | 3 | 3 | GC | 31 | P | . | . | . | . | . | . | . | . | . | . | . | 14 | 11 | 9 | 27 | 20 |
| 14 | 3 | 3 | GC | 31 | P | . | . | . | . | . | . | . | . | . | . | . | 18 | 19 | 8 | 35 | 22 |
| 15 | 4 | 4 | GC | 31 | L | 1.0 | C | S | 0.8 | 16.7 | 10 | 24.4 | 1.2 | 15 | 10 | 3 | 2 | 28 | 22 | 33 | 27 |
| 16 | 4 | 4 | GC | 31 | L | 1.0 | C | S | 0.8 | 16.7 | 10 | 24.4 | 1.2 | 15 | 10 | 3 | 9 | 25 | 18 | 38 | 31 |
| 17 | 4 | 4 | GC | 31 | L | 1.0 | C | S | 0.8 | 16.7 | 10 | 24.4 | 1.2 | 15 | 10 | 3 | 12 | 23 | 17 | 33 | 28 |
| 18 | 4 | 4 | GC | 31 | L | 1.0 | C | S | 0.8 | 16.7 | 10 | 24.4 | 1.2 | 15 | 10 | 3 | 20 | 23 | 16 | 33 | 23 |
| 19 | 4 | 4 | GC | 31 | L | 1.0 | C | S | 0.8 | 16.7 | 10 | 24.4 | 1.2 | 15 | 10 | 3 | 24 | 25 | 20 | 40 | 31 |
| 20 | 5 | 5 | FF | 53 | P | 0.8 | C | S | 0.7 | 15.0 | 52 | 25.8 | 1.9 | 14 | 8 | 4 | 2 | 30 | 21 | 31 | 29 |
| 21 | 5 | 5 | FF | 53 | P | 0.8 | C | S | 0.7 | 15.0 | 52 | 25.8 | 1.9 | 14 | 8 | 4 | 9 | 29 | 21 | 45 | 27 |
| 22 | 5 | 5 | FF | 53 | P | 0.8 | C | S | 0.7 | 15.0 | 52 | 25.8 | 1.9 | 14 | 8 | 4 | 12 | 24 | 20 | 39 | 34 |
| 23 | 5 | 5 | FF | 53 | P | 0.8 | C | S | 0.7 | 15.0 | 52 | 25.8 | 1.9 | 14 | 8 | 4 | 20 | 21 | 17 | 29 | 20 |
| 24 | 5 | 5 | FF | 53 | P | 0.8 | C | S | 0.7 | 15.0 | 52 | 25.8 | 1.9 | 14 | 8 | 4 | 24 | 23 | 19 | 43 | 26 |
| 25 | 6 | 6 | GC | 53 | P | . | . | . | . | . | . | . | . | . | . | . | 3 | 18 | 22 | 52 | 44 |
| 26 | 6 | 6 | GC | 53 | P | . | . | . | . | . | . | . | . | . | . | . | 6 | 15 | 13 | 43 | 34 |
| 27 | 6 | 6 | GC | 53 | P | . | . | . | . | . | . | . | . | . | . | . | 14 | 15 | 10 | 31 | 23 |
| 28 | 6 | 6 | GC | 53 | P | . | . | . | . | . | . | . | . | . | . | . | 18 | 16 | 13 | 39 | 36 |
| 29 | 7 | 7 | FC | 53 | P | 1.4 | C | S | 0.6 | 12.5 | 45 | 7.5 | 0.6 | 17 | 10 | 3 | 2 | 53 | 40 | 57 | 42 |
| 30 | 7 | 7 | FC | 53 | P | 1.4 | C | S | 0.6 | 12.5 | 45 | 7.5 | 0.6 | 17 | 10 | 3 | 9 | 34 | 31 | 52 | 42 |
| 31 | 7 | 7 | FC | 53 | P | 1.4 | C | S | 0.6 | 12.5 | 45 | 7.5 | 0.6 | 17 | 10 | 3 | 12 | 36 | 30 | 47 | 39 |
| 32 | 7 | 7 | FC | 53 | P | 1.4 | C | S | 0.6 | 12.5 | 45 | 7.5 | 0.6 | 17 | 10 | 3 | 20 | 27 | 23 | 35 | 28 |
| 33 | 7 | 7 | FC | 53 | P | 1.4 | C | S | 0.6 | 12.5 | 45 | 7.5 | 0.6 | 17 | 10 | 3 | 24 | 38 | 29 | 50 | 35 |
| 34 | 8 | 8 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.2 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 2 | 51 | 41 | 50 | 39 |
| 35 | 8 | 8 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.2 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 9 | 44 | 39 | 58 | 47 |
| 36 | 8 | 8 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.2 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 12 | 37 | 32 | 49 | 33 |
| 37 | 8 | 8 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.2 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 20 | 28 | 26 | 41 | 30 |
| 38 | 8 | 8 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.2 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 24 | 39 | 32 | 49 | 41 |
| 39 | 9 | 9 | FC | 53 | P | 1.3 | C | S | 0.9 | 19.0 | 27 | 34.8 | 1.0 | 15 | 8 | 3 | 2 | 44 | 31 | 46 | 32 |
| 40 | 9 | 9 | FC | 53 | P | 1.3 | C | S | 0.9 | 19.0 | 27 | 34.8 | 1.0 | 15 | 8 | 3 | 9 | 35 | 27 | 50 | 45 |
| 41 | 9 | 9 | FC | 53 | P | 1.3 | C | S | 0.9 | 19.0 | 27 | 34.8 | 1.0 | 15 | 8 | 3 | 12 | 31 | 24 | 31 | 31 |
| 42 | 9 | 9 | FC | 53 | P | 1.3 | C | S | 0.9 | 19.0 | 27 | 34.8 | 1.0 | 15 | 8 | 3 | 20 | 24 | 20 | 26 | 21 |
| 43 | 9 | 9 | FC | 53 | P | 1.3 | C | S | 0.9 | 19.0 | 27 | 34.8 | 1.0 | 15 | 8 | 3 | 24 | 31 | 21 | 38 | 33 |
| 44 | 10 | 10 | FC | 53 | P | 0.6 | C | S | 1.0 | 22.0 | 21 | 55.1 | 1.5 | 29 | 8 | 4 | 2 | 32 | 28 | 35 | 31 |
| 45 | 10 | 10 | FC | 53 | P | 0.6 | C | S | 1.0 | 22.0 | 21 | 55.1 | 1.5 | 29 | 8 | 4 | 9 | 26 | 18 | 32 | 18 |
| 46 | 10 | 10 | FC | 53 | P | 0.6 | C | S | 1.0 | 22.0 | 21 | 55.1 | 1.5 | 29 | 8 | 4 | 12 | 22 | 16 | 26 | 20 |
| 47 | 10 | 10 | FC | 53 | P | 0.6 | C | S | 1.0 | 22.0 | 21 | 55.1 | 1.5 | 29 | 8 | 4 | 20 | 20 | 15 | 21 | 12 |
| 48 | 10 | 10 | FC | 53 | P | 0.6 | C | S | 1.0 | 22.0 | 21 | 55.1 | 1.5 | 29 | 8 | 4 | 24 | 23 | 16 | 28 | 16 |
| 49 | 11 | 11 | FC | 53 | P | 1.7 | C | S | 0.9 | 19.6 | 19 | 34.0 | 1.5 | 17 | 7 | 4 | 2 | 29 | 24 | 35 | 27 |

| OBS | SECTION | REP | AG_TYPE | SE | FILLER | P_FILLER | EMULTYPE | BASE_AC | P_THEO | P_EMUL | WAT | LWT | CMC | C_TIME | COHESION | FLOW | AGE | FN40A | FN55A | FN40B | FN55B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | 11 | 11 | FC | 53 | P | 1.7 | C | S | 0.9 | 19.6 | 19 | 34.0 | 1.5 | 17 | 7 | 4 | 9 | 22 | 16 | 35 | 27 |
| 51 | 11 | 11 | FC | 53 | P | 1.7 | C | S | 0.9 | 19.6 | 19 | 34.0 | 1.5 | 17 | 7 | 4 | 12 | 22 | 15 | 29 | 24 |
| 52 | 11 | 11 | FC | 53 | P | 1.7 | C | S | 0.9 | 19.6 | 19 | 34.0 | 1.5 | 17 | 7 | 4 | 20 | 17 | 13 | 28 | 22 |
| 53 | 11 | 11 | FC | 53 | P | 1.7 | C | S | 0.9 | 19.6 | 19 | 34.0 | 1.5 | 17 | 7 | 4 | 24 | 23 | 16 | 33 | 26 |
| 54 | 12 | 12 | LW | 87 | P | . | . | . | . | . | . | . | . | . | . | . | 3 | 45 | 40 | 57 | 48 |
| 55 | 12 | 12 | LW | 87 | P | . | . | . | . | . | . | . | . | . | . | . | 6 | 38 | 23 | 54 | 52 |
| 56 | 12 | 12 | LW | 87 | P | . | . | . | . | . | . | . | . | . | . | . | 14 | 38 | 31 | 56 | 42 |
| 57 | 12 | 12 | LW | 87 | P | . | . | . | . | . | . | . | . | . | . | . | 18 | 46 | 25 | 62 | 46 |
| 58 | 13 | 13 | QS | 81 | P | 1.5 | C | S | 0.8 | 15.8 | 93 | 19.0 | 1.1 | 16 | 7 | 4 | 2 | 41 | 32 | 43 | 34 |
| 59 | 13 | 13 | QS | 81 | P | 1.5 | C | S | 0.8 | 15.8 | 93 | 19.0 | 1.1 | 16 | 7 | 4 | 9 | 35 | 29 | 48 | 37 |
| 60 | 13 | 13 | QS | 81 | P | 1.5 | C | S | 0.8 | 15.8 | 93 | 19.0 | 1.1 | 16 | 7 | 4 | 12 | 35 | 31 | 45 | 38 |
| 61 | 13 | 13 | QS | 81 | P | 1.5 | C | S | 0.8 | 15.8 | 93 | 19.0 | 1.1 | 16 | 7 | 4 | 20 | 40 | 33 | 43 | 32 |
| 62 | 13 | 13 | QS | 81 | P | 1.5 | C | S | 0.8 | 15.8 | 93 | 19.0 | 1.1 | 16 | 7 | 4 | 24 | 43 | 33 | 47 | 37 |
| 63 | 14 | 14 | CS | 98 | P | 0.5 | C | S | 0.9 | 12.3 | 36 | 12.7 | 1.7 | 25 | 5 | 2 | 2 | 37 | 33 | 40 | 33 |
| 64 | 14 | 14 | CS | 98 | P | 0.5 | C | S | 0.9 | 12.3 | 36 | 12.7 | 1.7 | 25 | 5 | 2 | 9 | 40 | 35 | 53 | 42 |
| 65 | 14 | 14 | CS | 98 | P | 0.5 | C | S | 0.9 | 12.3 | 36 | 12.7 | 1.7 | 25 | 5 | 2 | 12 | 42 | 37 | 49 | 46 |
| 66 | 14 | 14 | CS | 98 | P | 0.5 | C | S | 0.9 | 12.3 | 36 | 12.7 | 1.7 | 25 | 5 | 2 | 20 | 34 | 35 | 52 | 39 |
| 67 | 14 | 14 | CS | 98 | P | 0.5 | C | S | 0.9 | 12.3 | 36 | 12.7 | 1.7 | 25 | 5 | 2 | 24 | 45 | 35 | 56 | 45 |
| 68 | 15 | 15 | MF | 54 | L | 0.6 | C | S | 0.9 | 20.0 | 40 | 22.9 | 1.2 | 16 | 8 | 4 | 2 | 30 | 30 | 39 | 31 |
| 69 | 15 | 15 | MF | 54 | L | 0.6 | C | S | 0.9 | 20.0 | 40 | 22.9 | 1.2 | 16 | 8 | 4 | 9 | 22 | 20 | 46 | 32 |
| 70 | 15 | 15 | MF | 54 | L | 0.6 | C | S | 0.9 | 20.0 | 40 | 22.9 | 1.2 | 16 | 8 | 4 | 12 | 21 | 15 | 39 | 35 |
| 71 | 15 | 15 | MF | 54 | L | 0.6 | C | S | 0.9 | 20.0 | 40 | 22.9 | 1.2 | 16 | 8 | 4 | 20 | 21 | 15 | 34 | 27 |
| 72 | 15 | 15 | MF | 54 | L | 0.6 | C | S | 0.9 | 20.0 | 40 | 22.9 | 1.2 | 16 | 8 | 4 | 24 | 23 | 20 | 39 | 30 |
| 73 | 16 | 16 | MC | 54 | L | 0.4 | C | S | 0.7 | 15.6 | 57 | 26.7 | 0.8 | 15 | 10 | 2 | 2 | 38 | 35 | 41 | 34 |
| 74 | 16 | 16 | MC | 54 | L | 0.4 | C | S | 0.7 | 15.6 | 57 | 26.7 | 0.8 | 15 | 10 | 2 | 9 | 30 | 30 | 50 | 22 |
| 75 | 16 | 16 | MC | 54 | L | 0.4 | C | S | 0.7 | 15.6 | 57 | 26.7 | 0.8 | 15 | 10 | 2 | 12 | 25 | 23 | 46 | 39 |
| 76 | 16 | 16 | MC | 54 | L | 0.4 | C | S | 0.7 | 15.6 | 57 | 26.7 | 0.8 | 15 | 10 | 2 | 20 | 25 | 20 | 40 | 29 |
| 77 | 16 | 16 | MC | 54 | L | 0.4 | C | S | 0.7 | 15.6 | 57 | 26.7 | 0.8 | 15 | 10 | 2 | 24 | 27 | 25 | 43 | 35 |
| 78 | 17 | 17 | LW | 87 | L | . | . | . | . | . | . | . | . | . | . | . | 3 | 44 | 34 | 47 | 40 |
| 79 | 17 | 17 | LW | 87 | L | . | . | . | . | . | . | . | . | . | . | . | 6 | 36 | 25 | 52 | 42 |
| 80 | 17 | 17 | LW | 87 | L | . | . | . | . | . | . | . | . | . | . | . | 14 | 36 | 22 | 51 | 44 |
| 81 | 17 | 17 | LW | 87 | L | . | . | . | . | . | . | . | . | . | . | . | 18 | 34 | 23 | 56 | 46 |
| 82 | 18 | 18 | DI | 74 | L | 0.6 | C | S | 0.9 | 18.0 | 8 | 21.5 | 1.7 | 15 | 6 | 4 | 2 | 32 | 23 | 32 | 25 |
| 83 | 18 | 18 | DI | 74 | L | 0.6 | C | S | 0.9 | 18.0 | 8 | 21.5 | 1.7 | 15 | 6 | 4 | 9 | 29 | 26 | 39 | 30 |
| 84 | 18 | 18 | DI | 74 | L | 0.6 | C | S | 0.9 | 18.0 | 8 | 21.5 | 1.7 | 15 | 6 | 4 | 12 | 23 | 16 | 34 | 25 |
| 85 | 18 | 18 | DI | 74 | L | 0.6 | C | S | 0.9 | 18.0 | 8 | 21.5 | 1.7 | 15 | 6 | 4 | 20 | 32 | 22 | 32 | 22 |
| 86 | 18 | 18 | DI | 74 | L | 0.6 | C | S | 0.9 | 18.0 | 8 | 21.5 | 1.7 | 15 | 6 | 4 | 24 | 33 | 20 | 36 | 28 |
| 87 | 19 | 19 | LW | 87 | P | 0.7 | C | H | 1.0 | 27.8 | 213 | 39.8 | 1.4 | 19 | 7 | 4 | 2 | 51 | 43 | 39 | 35 |
| 88 | 19 | 19 | LW | 87 | P | 0.7 | C | H | 1.0 | 27.8 | 213 | 39.8 | 1.4 | 19 | 7 | 4 | 9 | 47 | 43 | 57 | 51 |
| 89 | 19 | 19 | LW | 87 | P | 0.7 | C | H | 1.0 | 27.8 | 213 | 39.8 | 1.4 | 19 | 7 | 4 | 12 | 50 | 39 | 44 | 48 |
| 90 | 19 | 19 | LW | 87 | P | 0.7 | C | H | 1.0 | 27.8 | 213 | 39.8 | 1.4 | 19 | 7 | 4 | 20 | 44 | 32 | 44 | 26 |
| 91 | 19 | 19 | LW | 87 | P | 0.7 | C | H | 1.0 | 27.8 | 213 | 39.8 | 1.4 | 19 | 7 | 4 | 24 | 40 | 29 | 54 | 39 |
| 92 | 20 | 20 | LW | 87 | L | 0.8 | C | H | 0.9 | 22.9 | 404 | 27.7 | 3.5 | 18 | 9 | . | 2 | 50 | 46 | 47 | 39 |
| 93 | 20 | 20 | LW | 87 | L | 0.8 | C | H | 0.9 | 22.9 | 404 | 27.7 | 3.5 | 18 | 9 | . | 9 | 55 | 44 | 63 | 50 |
| 94 | 20 | 20 | LW | 87 | L | 0.8 | C | H | 0.9 | 22.9 | 404 | 27.7 | 3.5 | 18 | 9 | . | 12 | 53 | 41 | 55 | 59 |
| 95 | 20 | 20 | LW | 87 | L | 0.8 | C | H | 0.9 | 22.9 | 404 | 27.7 | 3.5 | 18 | 9 | . | 20 | 43 | 35 | 50 | 31 |
| 96 | 20 | 20 | LW | 87 | L | 0.8 | C | H | 0.9 | 22.9 | 404 | 27.7 | 3.5 | 18 | 9 | . | 24 | 49 | 32 | 49 | 51 |
| 97 | 21 | 21 | FC | 53 | P | 0.7 | C | H | 0.8 | 17.0 | 25 | 14.2 | 1.5 | 19 | 9 | 2 | 2 | 46 | 37 | 47 | 39 |
| 98 | 21 | 21 | FC | 53 | P | 0.7 | C | H | 0.8 | 17.0 | 25 | 14.2 | 1.5 | 19 | 9 | 2 | 9 | 38 | 35 | 54 | 46 |

| OBS | SECTION | REP | AGG_TYPE | SE | FILLER | P_FILLER | EMULTYPE | BASE_AC | P_THEO | P_EMUL | WTAT | L*T | CMC | C_TIME | COHESION | FLOW | AGE | FN40A | FN55A | FN40B | FN55B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 99 | 21 | 21 | FC | 53 | P | 0.7 | C | H | 0.8 | 17.0 | 25 | 14.2 | 1.5 | 19 | 9 | 2 | 12 | 32 | 25 | 48 | 42 |
| 100 | 21 | 21 | FC | 53 | P | 0.7 | C | H | 0.8 | 17.0 | 25 | 14.2 | 1.5 | 19 | 9 | 2 | 20 | 30 | 24 | 44 | 32 |
| 101 | 21 | 21 | FC | 53 | P | 0.7 | C | H | 0.8 | 17.0 | 25 | 14.2 | 1.5 | 19 | 9 | 2 | 24 | 33 | 25 | 51 | 39 |
| 102 | 22 | 22 | FC | 53 | P | 0.4 | C | H | 0.7 | 15.1 | 28 | 14.2 | 2.1 | 18 | 8 | 4 | 2 | 40 | 33 | 37 | 32 |
| 103 | 22 | 22 | FC | 53 | P | 0.4 | C | H | 0.7 | 15.1 | 28 | 14.2 | 2.1 | 18 | 8 | 4 | 9 | 37 | 31 | 51 | 43 |
| 104 | 22 | 22 | FC | 53 | P | 0.4 | C | H | 0.7 | 15.1 | 28 | 14.2 | 2.1 | 18 | 8 | 4 | 12 | 28 | 23 | 48 | 40 |
| 105 | 22 | 22 | FC | 53 | P | 0.4 | C | H | 0.7 | 15.1 | 28 | 14.2 | 2.1 | 18 | 8 | 4 | 20 | 26 | 23 | 44 | 32 |
| 106 | 22 | 22 | FC | 53 | P | 0.4 | C | H | 0.7 | 15.1 | 28 | 14.2 | 2.1 | 18 | 8 | 4 | 24 | 28 | 22 | 49 | 37 |
| 107 | 23 | 23 | FC | 53 | P | 1.0 | C | H | 1.3 | 28.5 | 9 | 74.0 | 2.2 | 19 | 5 | 4 | 2 | 38 | 31 | 33 | 27 |
| 108 | 23 | 23 | FC | 53 | P | 1.0 | C | H | 1.3 | 28.5 | 9 | 74.0 | 2.2 | 19 | 5 | 4 | 9 | 25 | 26 | 45 | 34 |
| 109 | 23 | 23 | FC | 53 | P | 1.0 | C | H | 1.3 | 28.5 | 9 | 74.0 | 2.2 | 19 | 5 | 4 | 12 | 18 | 20 | 36 | 36 |
| 110 | 23 | 23 | FC | 53 | P | 1.0 | C | H | 1.3 | 28.5 | 9 | 74.0 | 2.2 | 19 | 5 | 4 | 20 | 20 | 16 | 31 | 19 |
| 111 | 23 | 23 | FC | 53 | P | 1.0 | C | H | 1.3 | 28.5 | 9 | 74.0 | 2.2 | 19 | 5 | 4 | 24 | 21 | 16 | 57 | 25 |
| 112 | 24 | 24 | QS | 81 | P | 0.7 | C | H | 1.0 | 18.8 | 208 | 12.7 | 1.0 | 20 | 6 | 2 | 2 | 34 | 29 | 41 | 31 |
| 113 | 24 | 24 | QS | 81 | P | 0.7 | C | H | 1.0 | 18.8 | 208 | 12.7 | 1.0 | 20 | 6 | 2 | 9 | 41 | 31 | 53 | 40 |
| 114 | 24 | 24 | QS | 81 | P | 0.7 | C | H | 1.0 | 18.8 | 208 | 12.7 | 1.0 | 20 | 6 | 2 | 12 | 42 | 34 | 50 | 41 |
| 115 | 24 | 24 | QS | 81 | P | 0.7 | C | H | 1.0 | 18.8 | 208 | 12.7 | 1.0 | 20 | 6 | 2 | 20 | 47 | 33 | 50 | 35 |
| 116 | 24 | 24 | QS | 81 | P | 0.7 | C | H | 1.0 | 18.8 | 208 | 12.7 | 1.0 | 20 | 6 | 2 | 24 | 40 | 36 | 53 | 41 |
| 117 | 25 | 25 | FC | 53 | P | 1.4 | S | S | 0.8 | 16.7 | 18 | 16.0 | 1.6 | 14 | 9 | 1 | 2 | 48 | 39 | 54 | 47 |
| 118 | 25 | 25 | FC | 53 | P | 1.4 | S | S | 0.8 | 16.7 | 18 | 16.0 | 1.6 | 14 | 9 | 1 | 9 | 42 | 37 | 58 | 48 |
| 119 | 25 | 25 | FC | 53 | P | 1.4 | S | S | 0.8 | 16.7 | 18 | 16.0 | 1.6 | 14 | 9 | 1 | 12 | 42 | 37 | 54 | 41 |
| 120 | 25 | 25 | FC | 53 | P | 1.4 | S | S | 0.8 | 16.7 | 18 | 16.0 | 1.6 | 14 | 9 | 1 | 20 | 37 | 29 | 48 | 40 |
| 121 | 25 | 25 | FC | 53 | P | 1.4 | S | S | 0.8 | 16.7 | 18 | 16.0 | 1.6 | 14 | 9 | 1 | 24 | 47 | 32 | 48 | 44 |
| 122 | 26 | 26 | FC | 53 | P | 0.9 | S | S | 0.9 | 18.8 | 13 | 20.8 | 1.4 | 16 | 7 | 1 | 2 | 46 | 38 | 45 | 35 |
| 123 | 26 | 26 | FC | 53 | P | 0.9 | S | S | 0.9 | 18.8 | 13 | 20.8 | 1.4 | 16 | 7 | 1 | 9 | 24 | 22 | 35 | 35 |
| 124 | 26 | 26 | FC | 53 | P | 0.9 | S | S | 0.9 | 18.8 | 13 | 20.8 | 1.4 | 16 | 7 | 1 | 12 | 19 | 16 | 32 | 25 |
| 125 | 26 | 26 | FC | 53 | P | 0.9 | S | S | 0.9 | 18.8 | 13 | 20.8 | 1.4 | 16 | 7 | 1 | 20 | 19 | 13 | 23 | 22 |
| 126 | 26 | 26 | FC | 53 | P | 0.9 | S | S | 0.9 | 18.8 | 13 | 20.8 | 1.4 | 16 | 7 | 1 | 24 | 19 | 15 | 26 | 25 |
| 127 | 27 | 27 | FC | 53 | P | 0.4 | S | S | 1.0 | 20.9 | 12 | 35.6 | 2.1 | 16 | 8 | 1 | 2 | 40 | 33 | 34 | 31 |
| 128 | 27 | 27 | FC | 53 | P | 0.4 | S | S | 1.0 | 20.9 | 12 | 35.6 | 2.1 | 16 | 8 | 1 | 9 | 26 | 23 | 41 | 33 |
| 129 | 27 | 27 | FC | 53 | P | 0.4 | S | S | 1.0 | 20.9 | 12 | 35.6 | 2.1 | 16 | 8 | 1 | 12 | 27 | 17 | 43 | 35 |
| 130 | 27 | 27 | FC | 53 | P | 0.4 | S | S | 1.0 | 20.9 | 12 | 35.6 | 2.1 | 16 | 8 | 1 | 20 | 25 | 19 | 36 | 19 |
| 131 | 27 | 27 | FC | 53 | P | 0.4 | S | S | 1.0 | 20.9 | 12 | 35.6 | 2.1 | 16 | 8 | 1 | 24 | 25 | 18 | 40 | 28 |
| 132 | 28 | 28 | MC | 54 | L | 0.1 | S | S | 0.9 | 18.5 | 18 | 25.0 | 1.9 | 15 | 8 | 0 | 2 | 49 | 41 | 49 | 42 |
| 133 | 28 | 28 | MC | 54 | L | 0.1 | S | S | 0.9 | 18.5 | 18 | 25.0 | 1.9 | 15 | 8 | 0 | 9 | 41 | 37 | 50 | 42 |
| 134 | 28 | 28 | MC | 54 | L | 0.1 | S | S | 0.9 | 18.5 | 18 | 25.0 | 1.9 | 15 | 8 | 0 | 12 | 41 | 36 | 45 | 42 |
| 135 | 28 | 28 | MC | 54 | L | 0.1 | S | S | 0.9 | 18.5 | 18 | 25.0 | 1.9 | 15 | 8 | 0 | 20 | 36 | 29 | 42 | 31 |
| 136 | 28 | 28 | MC | 54 | L | 0.1 | S | S | 0.9 | 18.5 | 18 | 25.0 | 1.9 | 15 | 8 | 0 | 24 | 42 | 35 | 47 | 36 |
| 137 | 29 | 29 | DI | 74 | L | 0.0 | S | S | 1.1 | 19.7 | 55 | 28.1 | 2.9 | 14 | 8 | 0 | 2 | 50 | 44 | 48 | 42 |
| 138 | 29 | 29 | DI | 74 | L | 0.0 | S | S | 1.1 | 19.7 | 55 | 28.1 | 2.9 | 14 | 8 | 0 | 9 | 26 | 18 | 49 | 28 |
| 139 | 29 | 29 | DI | 74 | L | 0.0 | S | S | 1.1 | 19.7 | 55 | 28.1 | 2.9 | 14 | 8 | 0 | 12 | 35 | 18 | 41 | 42 |
| 140 | 29 | 29 | DI | 74 | L | 0.0 | S | S | 1.1 | 19.7 | 55 | 28.1 | 2.9 | 14 | 8 | 0 | 20 | 23 | 16 | 40 | 24 |
| 141 | 29 | 29 | DI | 74 | L | 0.0 | S | S | 1.1 | 19.7 | 55 | 28.1 | 2.9 | 14 | 8 | 0 | 24 | 27 | 21 | 48 | 33 |
| 142 | 30 | 30 | LW | 87 | P | 2.4 | S | S | 1.2 | 31.3 | 86 | 20.0 | 3.4 | 19 | 10 | 1 | 2 | 52 | 48 | 47 | 45 |
| 143 | 30 | 30 | LW | 87 | P | 2.4 | S | S | 1.2 | 31.3 | 86 | 20.0 | 3.4 | 19 | 10 | 1 | 9 | 48 | 41 | 60 | 42 |
| 144 | 30 | 30 | LW | 87 | P | 2.4 | S | S | 1.2 | 31.3 | 86 | 20.0 | 3.4 | 19 | 10 | 1 | 12 | 48 | 42 | 60 | 41 |
| 145 | 30 | 30 | LW | 87 | P | 2.4 | S | S | 1.2 | 31.3 | 86 | 20.0 | 3.4 | 19 | 10 | 1 | 20 | 41 | 33 | 51 | 39 |
| 146 | 30 | 30 | LW | 87 | P | 2.4 | S | S | 1.2 | 31.3 | 86 | 20.0 | 3.4 | 19 | 10 | 1 | 24 | 49 | 31 | 66 | 39 |
| 147 | 31 | 31 | LW | 87 | L | 0.5 | S | S | 0.5 | 13.6 | 276 | 9.7 | 1.6 | 22 | 9 | 1 | 2 | 56 | 49 | 52 | 45 |

| OBS | SECTION | REP | AGG_TYPE | SE | FILLER | P_FILLER | EMULTYPE | BASE_AC | P_THEO | P_EMUL | WTAT | LWT | CMC | C_TIME | COHESION | FLOW | AGE | FN40A | FN55A | FN40B | FN55B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 148 | 31 | 31 | LW | 87 | L | 0.5 | S | S | 0.5 | 13.6 | 276 | 9.7 | 1.6 | 22 | 9 | 1 | 9 | 59 | 49 | 60 | 39 |
| 149 | 31 | 31 | LW | 87 | L | 0.5 | S | S | 0.5 | 13.6 | 276 | 9.7 | 1.6 | 22 | 9 | 1 | 12 | 50 | 47 | 56 | 40 |
| 150 | 31 | 31 | LW | 87 | L | 0.5 | S | S | 0.5 | 13.6 | 276 | 9.7 | 1.6 | 22 | 9 | 1 | 20 | 54 | 41 | 52 | 32 |
| 151 | 31 | 31 | LW | 87 | L | 0.5 | S | S | 0.5 | 13.6 | 276 | 9.7 | 1.6 | 22 | 9 | 1 | 24 | 53 | 39 | 56 | 46 |
| 152 | 1 | 41 | FC | 53 | P | . | . | . | . | . | . | . | . | . | . | . | 3 | 34 | 27 | 41 | 42 |
| 153 | 1 | 41 | FC | 53 | P | . | . | . | . | . | . | . | . | . | . | . | 6 | 17 | 15 | 42 | 34 |
| 154 | 1 | 41 | FC | 53 | P | . | . | . | . | . | . | . | . | . | . | . | 14 | 18 | 11 | 37 | 28 |
| 155 | 1 | 41 | FC | 53 | P | . | . | . | . | . | . | . | . | . | . | . | 18 | 18 | 16 | 46 | 34 |
| 156 | 2 | 42 | MC | 54 | L | . | . | . | . | . | . | . | . | . | . | . | 3 | 34 | 32 | 45 | 39 |
| 157 | 2 | 42 | MC | 54 | L | . | . | . | . | . | . | . | . | . | . | . | 6 | 20 | 25 | 45 | 40 |
| 158 | 2 | 42 | MC | 54 | L | . | . | . | . | . | . | . | . | . | . | . | 14 | 25 | 26 | 45 | 35 |
| 159 | 2 | 42 | MC | 54 | L | . | . | . | . | . | . | . | . | . | . | . | 18 | 21 | 22 | 52 | 38 |
| 160 | 3 | 43 | GC | 31 | P | 1.9 | C | S | 0.8 | 15.0 | 19 | 17.7 | 1.3 | 16 | 12 | 5 | 2 | 31 | 25 | 44 | 36 |
| 161 | 3 | 43 | GC | 31 | P | 1.9 | C | S | 0.8 | 15.0 | 19 | 17.7 | 1.3 | 16 | 12 | 5 | 9 | 28 | 23 | 47 | 39 |
| 162 | 3 | 43 | GC | 31 | P | 1.9 | C | S | 0.8 | 15.0 | 19 | 17.7 | 1.3 | 16 | 12 | 5 | 12 | 27 | 23 | 46 | 36 |
| 163 | 3 | 43 | GC | 31 | P | 1.9 | C | S | 0.8 | 15.0 | 19 | 17.7 | 1.3 | 16 | 12 | 5 | 20 | 29 | 23 | 41 | 33 |
| 164 | 3 | 43 | GC | 31 | P | 1.9 | C | S | 0.8 | 15.0 | 19 | 17.7 | 1.3 | 16 | 12 | 5 | 24 | 30 | 23 | 47 | 33 |
| 165 | 4 | 44 | GC | 31 | L | 0.5 | C | S | 0.6 | 13.0 | 51 | 17.7 | 0.8 | 15 | 10 | 3 | 2 | 32 | 28 | 45 | 37 |
| 166 | 4 | 44 | GC | 31 | L | 0.5 | C | S | 0.6 | 13.0 | 51 | 17.7 | 0.8 | 15 | 10 | 3 | 9 | 30 | 23 | 51 | 44 |
| 167 | 4 | 44 | GC | 31 | L | 0.5 | C | S | 0.6 | 13.0 | 51 | 17.7 | 0.8 | 15 | 10 | 3 | 12 | 30 | 23 | 52 | 43 |
| 168 | 4 | 44 | GC | 31 | L | 0.5 | C | S | 0.6 | 13.0 | 51 | 17.7 | 0.8 | 15 | 10 | 3 | 20 | 27 | 19 | 48 | 37 |
| 169 | 4 | 44 | GC | 31 | L | 0.5 | C | S | 0.6 | 13.0 | 51 | 17.7 | 0.8 | 15 | 10 | 3 | 24 | 30 | 21 | 48 | 43 |
| 170 | 5 | 45 | FF | 53 | P | 2.0 | C | S | 0.6 | 13.4 | 51 | 16.0 | 1.5 | 15 | 9 | 4 | 2 | 38 | 29 | 46 | 37 |
| 171 | 5 | 45 | FF | 53 | P | 2.0 | C | S | 0.6 | 13.4 | 51 | 16.0 | 1.5 | 15 | 9 | 4 | 9 | 35 | 29 | 54 | 45 |
| 172 | 5 | 45 | FF | 53 | P | 2.0 | C | S | 0.6 | 13.4 | 51 | 16.0 | 1.5 | 15 | 9 | 4 | 12 | 34 | 30 | 50 | 44 |
| 173 | 5 | 45 | FF | 53 | P | 2.0 | C | S | 0.6 | 13.4 | 51 | 16.0 | 1.5 | 15 | 9 | 4 | 20 | 31 | 21 | 50 | 34 |
| 174 | 5 | 45 | FF | 53 | P | 2.0 | C | S | 0.6 | 13.4 | 51 | 16.0 | 1.5 | 15 | 9 | 4 | 24 | 32 | 26 | 56 | 37 |
| 175 | 6 | 46 | FF | 53 | P | 1.1 | C | S | 0.9 | 18.6 | 39 | 29.2 | 2.2 | 14 | 9 | 5 | 2 | 29 | 22 | 42 | 33 |
| 176 | 6 | 46 | FF | 53 | P | 1.1 | C | S | 0.9 | 18.6 | 39 | 29.2 | 2.2 | 14 | 9 | 5 | 9 | 25 | 17 | 50 | 39 |
| 177 | 6 | 46 | FF | 53 | P | 1.1 | C | S | 0.9 | 18.6 | 39 | 29.2 | 2.2 | 14 | 9 | 5 | 12 | 27 | 19 | 46 | 32 |
| 178 | 6 | 46 | FF | 53 | P | 1.1 | C | S | 0.9 | 18.6 | 39 | 29.2 | 2.2 | 14 | 9 | 5 | 20 | 22 | 16 | 39 | 28 |
| 179 | 6 | 46 | FF | 53 | P | 1.1 | C | S | 0.9 | 18.6 | 39 | 29.2 | 2.2 | 14 | 9 | 5 | 24 | 26 | 17 | 49 | 34 |
| 180 | 7 | 47 | FC | 53 | P | 1.0 | C | H | 0.5 | 10.3 | 42 | 9.0 | 4.4 | 27 | 9 | 4 | 2 | 62 | 48 | 69 | 50 |
| 181 | 7 | 47 | FC | 53 | P | 1.0 | C | H | 0.5 | 10.3 | 42 | 9.0 | 4.4 | 27 | 9 | 4 | 9 | 52 | 46 | 64 | 53 |
| 182 | 7 | 47 | FC | 53 | P | 1.0 | C | H | 0.5 | 10.3 | 42 | 9.0 | 4.4 | 27 | 9 | 4 | 12 | 52 | 45 | 63 | 56 |
| 183 | 7 | 47 | FC | 53 | P | 1.0 | C | H | 0.5 | 10.3 | 42 | 9.0 | 4.4 | 27 | 9 | 4 | 20 | 42 | 36 | 59 | 51 |
| 184 | 7 | 47 | FC | 53 | P | 1.0 | C | H | 0.5 | 10.3 | 42 | 9.0 | 4.4 | 27 | 9 | 4 | 24 | 51 | 38 | 62 | 54 |
| 185 | 8 | 48 | FC | 53 | P | 0.4 | C | H | 0.7 | 13.8 | 33 | 11.8 | 4.0 | 18 | 7 | 3 | 2 | 54 | 46 | 56 | 42 |
| 186 | 8 | 48 | FC | 53 | P | 0.4 | C | H | 0.7 | 13.8 | 33 | 11.8 | 4.0 | 18 | 7 | 3 | 9 | 42 | 38 | 56 | 49 |
| 187 | 8 | 48 | FC | 53 | P | 0.4 | C | H | 0.7 | 13.8 | 33 | 11.8 | 4.0 | 18 | 7 | 3 | 12 | 38 | 37 | 55 | 46 |
| 188 | 8 | 48 | FC | 53 | P | 0.4 | C | H | 0.7 | 13.8 | 33 | 11.8 | 4.0 | 18 | 7 | 3 | 20 | 43 | 37 | 56 | 48 |
| 189 | 8 | 48 | FC | 53 | P | 0.4 | C | H | 0.7 | 13.8 | 33 | 11.8 | 4.0 | 18 | 7 | 3 | 24 | 38 | 35 | 57 | 44 |
| 190 | 9 | 49 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.6 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 2 | 44 | 33 | 43 | 34 |
| 191 | 9 | 49 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.6 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 9 | 36 | 33 | 54 | 43 |
| 192 | 9 | 49 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.6 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 12 | 35 | 30 | 49 | 38 |
| 193 | 9 | 49 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.6 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 20 | 32 | 22 | 46 | 35 |
| 194 | 9 | 49 | FC | 53 | P | 1.2 | C | S | 0.7 | 15.6 | 23 | 21.9 | 1.1 | 12 | 8 | 3 | 24 | 36 | 24 | 55 | 42 |
| 195 | 10 | 50 | FC | 53 | P | 1.0 | C | S | 0.8 | 16.6 | 28 | 22.9 | 1.4 | 16 | 7 | 3 | 2 | 30 | 28 | 32 | 28 |
| 196 | 10 | 50 | FC | 53 | P | 1.0 | C | S | 0.8 | 16.6 | 28 | 22.9 | 1.4 | 16 | 7 | 3 | 9 | 25 | 19 | 42 | 33 |

| OBS | SECTION | REP | AGG_TYPE | SE | FILLER | P_FILLER | FMULTYPE | BASE_AC | P_THEO | P_EMUL | WTAT | LWT | CMC | C_TIME | COHESION | FLOW | AGE | FN40A | FN55A | FN40B | FN55B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 197 | 10 | 50 | FC | 53 | P | 1.0 | C | S | 0.8 | 16.6 | 28 | 22.9 | 1.4 | 16 | 7 | 3 | 12 | 25 | 25 | 41 | 32 |
| 198 | 10 | 50 | FC | 53 | P | 1.0 | C | S | 0.8 | 16.6 | 28 | 22.9 | 1.4 | 16 | 7 | 3 | 20 | 29 | 19 | 36 | 24 |
| 199 | 10 | 50 | FC | 53 | P | 1.0 | C | S | 0.8 | 16.6 | 28 | 22.9 | 1.4 | 16 | 7 | 3 | 24 | 25 | 17 | 43 | 29 |
| 200 | 11 | 51 | FC | 53 | P | 0.8 | C | S | 0.9 | 19.0 | 36 | 30.4 | 1.4 | 27 | 9 | 4 | 2 | 30 | 27 | 38 | 30 |
| 201 | 11 | 51 | FC | 53 | P | 0.8 | C | S | 0.9 | 19.0 | 36 | 30.4 | 1.4 | 27 | 9 | 4 | 9 | 26 | 20 | 46 | 33 |
| 202 | 11 | 51 | FC | 53 | P | 0.8 | C | S | 0.9 | 19.0 | 36 | 30.4 | 1.4 | 27 | 9 | 4 | 12 | 23 | 20 | 49 | 36 |
| 203 | 11 | 51 | FC | 53 | P | 0.8 | C | S | 0.9 | 19.0 | 36 | 30.4 | 1.4 | 27 | 9 | 4 | 20 | 25 | 17 | 32 | 30 |
| 204 | 11 | 51 | FC | 53 | P | 0.8 | C | S | 0.9 | 19.0 | 36 | 30.4 | 1.4 | 27 | 9 | 4 | 24 | 27 | 20 | 41 | 36 |
| 205 | 12 | 52 | LW | 87 | P | . | . | . | . | . | . | . | . | . | . | . | 3 | 45 | 37 | 41 | 37 |
| 206 | 12 | 52 | LW | 87 | P | . | . | . | . | . | . | . | . | . | . | . | 6 | 47 | 33 | 50 | 45 |
| 207 | 12 | 52 | LW | 87 | P | . | . | . | . | . | . | . | . | . | . | . | 14 | 39 | 31 | 48 | 40 |
| 208 | 12 | 52 | LW | 87 | P | . | . | . | . | . | . | . | . | . | . | . | 18 | 45 | 27 | 51 | 47 |
| 209 | 13 | 53 | QS | 81 | P | 1.5 | C | S | 0.8 | 15.8 | 93 | 19.0 | 1.1 | 16 | 7 | 5 | 2 | 41 | 29 | 46 | 37 |
| 210 | 13 | 53 | QS | 81 | P | 1.5 | C | S | 0.8 | 15.8 | 93 | 19.0 | 1.1 | 16 | 7 | 5 | 9 | 38 | 30 | 55 | 45 |
| 211 | 13 | 53 | QS | 81 | P | 1.5 | C | S | 0.8 | 15.8 | 93 | 19.0 | 1.1 | 16 | 7 | 5 | 12 | 38 | 33 | 51 | 45 |
| 212 | 13 | 53 | QS | 81 | P | 1.5 | C | S | 0.8 | 15.8 | 93 | 19.0 | 1.1 | 16 | 7 | 5 | 20 | 43 | 33 | 45 | 41 |
| 213 | 13 | 53 | QS | 81 | P | 1.5 | C | S | 0.8 | 15.8 | 93 | 19.0 | 1.1 | 16 | 7 | 5 | 24 | 45 | 36 | 51 | 41 |
| 214 | 14 | 54 | CS | 98 | P | 0.6 | C | H | 0.8 | 11.1 | 53 | 12.7 | 1.8 | 18 | 9 | 4 | 2 | 35 | 28 | 41 | 31 |
| 215 | 14 | 54 | CS | 98 | P | 0.6 | C | H | 0.8 | 11.1 | 53 | 12.7 | 1.8 | 18 | 9 | 4 | 9 | 44 | 30 | 46 | 41 |
| 216 | 14 | 54 | CS | 98 | P | 0.6 | C | H | 0.8 | 11.1 | 53 | 12.7 | 1.8 | 18 | 9 | 4 | 12 | 45 | 35 | 44 | 38 |
| 217 | 14 | 54 | CS | 98 | P | 0.6 | C | H | 0.8 | 11.1 | 53 | 12.7 | 1.8 | 18 | 9 | 4 | 20 | 47 | 36 | 49 | 37 |
| 218 | 14 | 54 | CS | 98 | P | 0.6 | C | H | 0.8 | 11.1 | 53 | 12.7 | 1.8 | 18 | 9 | 4 | 24 | 48 | 36 | 47 | 35 |
| 219 | 15 | 55 | MF | 54 | L | 0.5 | C | S | 0.9 | 20.6 | 40 | 22.9 | 1.2 | 16 | 8 | 3 | 2 | 37 | 29 | 34 | 28 |
| 220 | 15 | 55 | MF | 54 | L | 0.5 | C | S | 0.9 | 20.6 | 40 | 22.9 | 1.2 | 16 | 8 | 3 | 9 | 27 | 23 | 47 | 37 |
| 221 | 15 | 55 | MF | 54 | L | 0.5 | C | S | 0.9 | 20.6 | 40 | 22.9 | 1.2 | 16 | 8 | 3 | 12 | 27 | 17 | 48 | 41 |
| 222 | 15 | 55 | MF | 54 | L | 0.5 | C | S | 0.9 | 20.6 | 40 | 22.9 | 1.2 | 16 | 8 | 3 | 20 | 24 | 15 | 43 | 31 |
| 223 | 15 | 55 | MF | 54 | L | 0.5 | C | S | 0.9 | 20.6 | 40 | 22.9 | 1.2 | 16 | 8 | 3 | 24 | 23 | 15 | 49 | 37 |
| 224 | 16 | 56 | MC | 54 | L | 0.7 | C | S | 0.7 | 14.2 | 58 | 23.1 | 0.8 | 15 | 10 | 2 | 2 | 45 | 37 | 46 | 36 |
| 225 | 16 | 56 | MC | 54 | L | 0.7 | C | S | 0.7 | 14.2 | 58 | 23.1 | 0.8 | 15 | 10 | 2 | 9 | 44 | 38 | 56 | 46 |
| 226 | 16 | 56 | MC | 54 | L | 0.7 | C | S | 0.7 | 14.2 | 58 | 23.1 | 0.8 | 15 | 10 | 2 | 12 | 41 | 42 | 54 | 46 |
| 227 | 16 | 56 | MC | 54 | L | 0.7 | C | S | 0.7 | 14.2 | 58 | 23.1 | 0.8 | 15 | 10 | 2 | 20 | 38 | 30 | 52 | 37 |
| 228 | 16 | 56 | MC | 54 | L | 0.7 | C | S | 0.7 | 14.2 | 58 | 23.1 | 0.8 | 15 | 10 | 2 | 24 | 41 | 31 | 53 | 46 |
| 229 | 17 | 57 | DA | 48 | L | 0.5 | C | S | 0.9 | 20.4 | 28 | 40.2 | 1.9 | 15 | 8 | 4 | 2 | 37 | 29 | 34 | 27 |
| 230 | 17 | 57 | DA | 48 | L | 0.5 | C | S | 0.9 | 20.4 | 28 | 40.2 | 1.9 | 15 | 8 | 4 | 9 | 29 | 19 | 50 | 40 |
| 231 | 17 | 57 | DA | 48 | L | 0.5 | C | S | 0.9 | 20.4 | 28 | 40.2 | 1.9 | 15 | 8 | 4 | 12 | 26 | 19 | 48 | 37 |
| 232 | 17 | 57 | DA | 48 | L | 0.5 | C | S | 0.9 | 20.4 | 28 | 40.2 | 1.9 | 15 | 8 | 4 | 20 | 27 | 18 | 44 | 36 |
| 233 | 17 | 57 | DA | 48 | L | 0.5 | C | S | 0.9 | 20.4 | 28 | 40.2 | 1.9 | 15 | 8 | 4 | 24 | 25 | 19 | 46 | 34 |
| 234 | 18 | 58 | DI | 74 | L | 0.4 | C | S | 1.1 | 19.9 | 7 | 28.5 | 1.6 | 16 | 6 | 4 | 2 | 40 | 21 | 43 | 25 |
| 235 | 18 | 58 | DI | 74 | L | 0.4 | C | S | 1.1 | 19.9 | 7 | 28.5 | 1.6 | 16 | 6 | 4 | 9 | 24 | 20 | 42 | 34 |
| 236 | 18 | 58 | DI | 74 | L | 0.4 | C | S | 1.1 | 19.9 | 7 | 28.5 | 1.6 | 16 | 6 | 4 | 12 | 29 | 19 | 43 | 34 |
| 237 | 18 | 58 | DI | 74 | L | 0.4 | C | S | 1.1 | 19.9 | 7 | 28.5 | 1.6 | 16 | 6 | 4 | 20 | 31 | 22 | 37 | 29 |
| 238 | 18 | 58 | DI | 74 | L | 0.4 | C | S | 1.1 | 19.9 | 7 | 28.5 | 1.6 | 16 | 6 | 4 | 24 | 28 | 19 | 40 | 29 |
| 239 | 19 | 59 | LW | 87 | P | 1.3 | C | H | 0.8 | 21.8 | 361 | 27.2 | 2.2 | 18 | 8 | 4 | 2 | 49 | 44 | 43 | 37 |
| 240 | 19 | 59 | LW | 87 | P | 1.3 | C | H | 0.8 | 21.8 | 361 | 27.2 | 2.2 | 18 | 8 | 4 | 9 | 51 | 45 | 64 | 52 |
| 241 | 19 | 59 | LW | 87 | P | 1.3 | C | H | 0.8 | 21.8 | 361 | 27.2 | 2.2 | 18 | 8 | 4 | 12 | 58 | 40 | 63 | 54 |
| 242 | 19 | 59 | LW | 87 | P | 1.3 | C | H | 0.8 | 21.8 | 361 | 27.2 | 2.2 | 18 | 8 | 4 | 20 | 45 | 39 | 58 | 33 |
| 243 | 19 | 59 | LW | 87 | P | 1.3 | C | H | 0.8 | 21.8 | 361 | 27.2 | 2.2 | 18 | 8 | 4 | 24 | 51 | 32 | 61 | 52 |
| 244 | 20 | 60 | LW | 87 | L | 0.5 | C | H | 0.8 | 22.4 | 404 | 27.7 | 3.5 | 18 | 9 | 0 | 2 | 49 | 41 | 44 | 37 |
| 245 | 20 | 60 | LW | 87 | L | 0.5 | C | H | 0.8 | 22.4 | 404 | 27.7 | 3.5 | 18 | 9 | 0 | 9 | 52 | 41 | 64 | 52 |

| OBS | SECTION | REP | AGG_TYPE | SE | FILLER | P_FILLER | EMULTYPE | BASE_AC | P_THEO | P_EMUL | WTAT | LWT | CMC | C_TIME | COHESION | FLOW | AGE | FN40A | FN55A | FN40B | FN55B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 246 | 20 | 60 | LW | 87 | L | 0.5 | C | H | 0.8 | 22.4 | 404 | 27.7 | 3.5 | 18 | 9 | 0 | 12 | 55 | 39 | 62 | 52 |
| 247 | 20 | 60 | LW | 87 | L | 0.5 | C | H | 0.8 | 22.4 | 404 | 27.7 | 3.5 | 18 | 9 | 0 | 20 | 51 | 32 | 58 | 47 |
| 248 | 20 | 60 | LW | 87 | L | 0.5 | C | H | 0.8 | 22.4 | 404 | 27.7 | 3.5 | 18 | 9 | 0 | 24 | 46 | 31 | 55 | 42 |
| 249 | 21 | 61 | FC | 53 | P | 0.6 | C | H | 0.6 | 13.4 | 33 | 12.7 | 4.0 | 18 | 7 | 2 | 2 | 48 | 38 | 50 | 41 |
| 250 | 21 | 61 | FC | 53 | P | 0.6 | C | H | 0.6 | 13.4 | 33 | 12.7 | 4.0 | 18 | 7 | 2 | 9 | 37 | 35 | 60 | 47 |
| 251 | 21 | 61 | FC | 53 | P | 0.6 | C | H | 0.6 | 13.4 | 33 | 12.7 | 4.0 | 18 | 7 | 2 | 12 | 33 | 27 | 59 | 46 |
| 252 | 21 | 61 | FC | 53 | P | 0.6 | C | H | 0.6 | 13.4 | 33 | 12.7 | 4.0 | 18 | 7 | 2 | 20 | 29 | 22 | 58 | 43 |
| 253 | 21 | 61 | FC | 53 | P | 0.6 | C | H | 0.6 | 13.4 | 33 | 12.7 | 4.0 | 18 | 7 | 2 | 24 | 31 | 22 | 61 | 49 |
| 254 | 22 | 62 | FC | 53 | P | 1.1 | C | H | 1.1 | 23.3 | 14 | 22.0 | 1.7 | 19 | 10 | 3 | 2 | 40 | 31 | 49 | 38 |
| 255 | 22 | 62 | FC | 53 | P | 1.1 | C | H | 1.1 | 23.3 | 14 | 22.0 | 1.7 | 19 | 10 | 3 | 9 | 26 | 22 | 44 | 37 |
| 256 | 22 | 62 | FC | 53 | P | 1.1 | C | H | 1.1 | 23.3 | 14 | 22.0 | 1.7 | 19 | 10 | 3 | 12 | 23 | 26 | 39 | 29 |
| 257 | 22 | 62 | FC | 53 | P | 1.1 | C | H | 1.1 | 23.3 | 14 | 22.0 | 1.7 | 19 | 10 | 3 | 20 | 25 | 15 | 36 | 32 |
| 258 | 22 | 62 | FC | 53 | P | 1.1 | C | H | 1.1 | 23.3 | 14 | 22.0 | 1.7 | 19 | 10 | 3 | 24 | 23 | 18 | 39 | 37 |
| 259 | 23 | 63 | FC | 53 | P | 1.7 | C | H | 1.4 | 31.3 | 11 | 74.0 | 2.1 | 18 | 5 | 4 | 2 | 37 | 30 | 32 | 24 |
| 260 | 23 | 63 | FC | 53 | P | 1.7 | C | H | 1.4 | 31.3 | 11 | 74.0 | 2.1 | 18 | 5 | 4 | 9 | 26 | 15 | 44 | 34 |
| 261 | 23 | 63 | FC | 53 | P | 1.7 | C | H | 1.4 | 31.3 | 11 | 74.0 | 2.1 | 18 | 5 | 4 | 12 | 23 | 16 | 39 | 29 |
| 262 | 23 | 63 | FC | 53 | P | 1.7 | C | H | 1.4 | 31.3 | 11 | 74.0 | 2.1 | 18 | 5 | 4 | 20 | 21 | 14 | 35 | 21 |
| 263 | 23 | 63 | FC | 53 | P | 1.7 | C | H | 1.4 | 31.3 | 11 | 74.0 | 2.1 | 18 | 5 | 4 | 24 | 17 | 15 | 36 | 20 |
| 264 | 24 | 64 | QS | 81 | P | 1.0 | C | H | 1.0 | 18.1 | 208 | 12.7 | 1.0 | 20 | 6 | 1 | 2 | 44 | 37 | 46 | 37 |
| 265 | 24 | 64 | QS | 81 | P | 1.0 | C | H | 1.0 | 18.1 | 208 | 12.7 | 1.0 | 20 | 6 | 1 | 9 | 44 | 34 | 54 | 43 |
| 266 | 24 | 64 | QS | 81 | P | 1.0 | C | H | 1.0 | 18.1 | 208 | 12.7 | 1.0 | 20 | 6 | 1 | 12 | 43 | 37 | 53 | 46 |
| 267 | 24 | 64 | QS | 81 | P | 1.0 | C | H | 1.0 | 18.1 | 208 | 12.7 | 1.0 | 20 | 6 | 1 | 20 | 45 | 36 | 49 | 37 |
| 268 | 24 | 64 | QS | 81 | P | 1.0 | C | H | 1.0 | 18.1 | 208 | 12.7 | 1.0 | 20 | 6 | 1 | 24 | 40 | 33 | 53 | 41 |
| 269 | 25 | 65 | FC | 53 | P | 1.0 | S | S | 0.8 | 16.7 | 18 | 16.0 | 1.6 | 14 | 9 | 1 | 2 | 43 | 34 | 42 | 37 |
| 270 | 25 | 65 | FC | 53 | P | 1.0 | S | S | 0.8 | 16.7 | 18 | 16.0 | 1.6 | 14 | 9 | 1 | 9 | 43 | 35 | 54 | 45 |
| 271 | 25 | 65 | FC | 53 | P | 1.0 | S | S | 0.8 | 16.7 | 18 | 16.0 | 1.6 | 14 | 9 | 1 | 12 | 40 | 32 | 54 | 48 |
| 272 | 25 | 65 | FC | 53 | P | 1.0 | S | S | 0.8 | 16.7 | 18 | 16.0 | 1.6 | 14 | 9 | 1 | 20 | 33 | 26 | 48 | 35 |
| 273 | 25 | 65 | FC | 53 | P | 1.0 | S | S | 0.8 | 16.7 | 18 | 16.0 | 1.6 | 14 | 9 | 1 | 24 | 29 | 28 | 52 | 40 |
| 274 | 26 | 66 | FC | 53 | P | 1.1 | S | S | 0.9 | 18.9 | 13 | 20.8 | 1.4 | 16 | 7 | 0 | 2 | 41 | 36 | 38 | 32 |
| 275 | 26 | 66 | FC | 53 | P | 1.1 | S | S | 0.9 | 18.9 | 13 | 20.8 | 1.4 | 16 | 7 | 0 | 9 | 41 | 34 | 53 | 41 |
| 276 | 26 | 66 | FC | 53 | P | 1.1 | S | S | 0.9 | 18.9 | 13 | 20.8 | 1.4 | 16 | 7 | 0 | 12 | 37 | 30 | 51 | 42 |
| 277 | 26 | 66 | FC | 53 | P | 1.1 | S | S | 0.9 | 18.9 | 13 | 20.8 | 1.4 | 16 | 7 | 0 | 20 | 30 | 22 | 46 | 34 |
| 278 | 26 | 66 | FC | 53 | P | 1.1 | S | S | 0.9 | 18.9 | 13 | 20.8 | 1.4 | 16 | 7 | 0 | 24 | 32 | 24 | 48 | 35 |
| 279 | 27 | 67 | FC | 53 | P | 1.2 | S | S | 1.1 | 24.4 | 11 | 45.4 | 1.9 | 14 | 7 | 0 | 2 | 36 | 32 | 31 | 27 |
| 280 | 27 | 67 | FC | 53 | P | 1.2 | S | S | 1.1 | 24.4 | 11 | 45.4 | 1.9 | 14 | 7 | 0 | 9 | 30 | 23 | 44 | 33 |
| 281 | 27 | 67 | FC | 53 | P | 1.2 | S | S | 1.1 | 24.4 | 11 | 45.4 | 1.9 | 14 | 7 | 0 | 12 | 22 | 18 | 44 | 32 |
| 282 | 27 | 67 | FC | 53 | P | 1.2 | S | S | 1.1 | 24.4 | 11 | 45.4 | 1.9 | 14 | 7 | 0 | 20 | 22 | 10 | 33 | 20 |
| 283 | 27 | 67 | FC | 53 | P | 1.2 | S | S | 1.1 | 24.4 | 11 | 45.4 | 1.9 | 14 | 7 | 0 | 24 | 17 | 13 | 45 | 29 |
| 284 | 28 | 68 | MC | 54 | P | 0.8 | S | S | 0.8 | 16.1 | 40 | 9.0 | 2.5 | 15 | 10 | 0 | 2 | 45 | 35 | 46 | 41 |
| 285 | 28 | 68 | MC | 54 | P | 0.8 | S | S | 0.8 | 16.1 | 40 | 9.0 | 2.5 | 15 | 10 | 0 | 9 | 43 | 41 | 56 | 46 |
| 286 | 28 | 68 | MC | 54 | P | 0.8 | S | S | 0.8 | 16.1 | 40 | 9.0 | 2.5 | 15 | 10 | 0 | 12 | 48 | 37 | 56 | 49 |
| 287 | 28 | 68 | MC | 54 | P | 0.8 | S | S | 0.8 | 16.1 | 40 | 9.0 | 2.5 | 15 | 10 | 0 | 20 | 45 | 38 | 47 | 38 |
| 288 | 28 | 68 | MC | 54 | P | 0.8 | S | S | 0.8 | 16.1 | 40 | 9.0 | 2.5 | 15 | 10 | 0 | 24 | 49 | 39 | 55 | 46 |
| 289 | 29 | 69 | DI | 74 | P | 0.4 | S | S | 1.0 | 17.0 | 115 | 17.5 | 3.7 | 16 | 9 | 3 | 2 | 36 | 31 | 35 | 34 |
| 290 | 29 | 69 | DI | 74 | P | 0.4 | S | S | 1.0 | 17.0 | 115 | 17.5 | 3.7 | 16 | 9 | 3 | 9 | 40 | 38 | 53 | 48 |
| 291 | 29 | 69 | DI | 74 | P | 0.4 | S | S | 1.0 | 17.0 | 115 | 17.5 | 3.7 | 16 | 9 | 3 | 12 | 44 | 39 | 46 | 48 |
| 292 | 29 | 69 | DI | 74 | P | 0.4 | S | S | 1.0 | 17.0 | 115 | 17.5 | 3.7 | 16 | 9 | 3 | 20 | 42 | 38 | 43 | 43 |
| 293 | 29 | 69 | DI | 74 | P | 0.4 | S | S | 1.0 | 17.0 | 115 | 17.5 | 3.7 | 16 | 9 | 3 | 24 | 50 | 37 | 55 | 44 |
| 294 | 30 | 70 | LW | 87 | P | 3.2 | S | S | 0.8 | 21.2 | 156 | 10.6 | 0.6 | 24 | 9 | 0 | 2 | 47 | 38 | 60 | 56 |

| OBS | SECTION | REP | AGG_TYPE | SE | FILLER | P_FILLER | EMULTYPE | BASE_AC | P_THEO | P_EMUL | WTAT | LWT | CMC | C_TIME | COHESION | FLOW | AGE | FN40A | FN55A | FN40B | FN55B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 295 | 30 | 70 | LW | 87 | P | 3.2 | S | S | 0.8 | 21.2 | 156 | 10.6 | 0.6 | 24 | 9 | 0 | 9 | 51 | 30 | 55 | 46 |
| 296 | 30 | 70 | LW | 87 | P | 3.2 | S | S | 0.8 | 21.2 | 156 | 10.6 | 0.6 | 24 | 9 | 0 | 12 | 50 | 35 | 49 | 46 |
| 297 | 30 | 70 | LW | 87 | P | 3.2 | S | S | 0.8 | 21.2 | 156 | 10.6 | 0.6 | 24 | 9 | 0 | 20 | 43 | 31 | 49 | 39 |
| 298 | 30 | 70 | LW | 87 | P | 3.2 | S | S | 0.8 | 21.2 | 156 | 10.6 | 0.6 | 24 | 9 | 0 | 24 | 43 | 29 | 52 | 44 |
| 299 | 31 | 71 | LW | 87 | L | 0.5 | S | S | 1.2 | 32.9 | 77 | 34.0 | 1.5 | 25 | 7 | 2 | 2 | 49 | . | 51 | . |
| 300 | 31 | 71 | LW | 87 | L | 0.5 | S | S | 1.2 | 32.9 | 77 | 34.0 | 1.5 | 25 | 7 | 2 | 9 | 47 | 35 | 58 | 45 |
| 301 | 31 | 71 | LW | 87 | L | 0.5 | S | S | 1.2 | 32.9 | 77 | 34.0 | 1.5 | 25 | 7 | 2 | 12 | 50 | 45 | 48 | 57 |
| 302 | 31 | 71 | LW | 87 | L | 0.5 | S | S | 1.2 | 32.9 | 77 | 34.0 | 1.5 | 25 | 7 | 2 | 20 | 50 | 29 | 50 | 40 |
| 303 | 31 | 71 | LW | 87 | L | 0.5 | S | S | 1.2 | 32.9 | 77 | 34.0 | 1.5 | 25 | 7 | 2 | 24 | 47 | 30 | 61 | 46 |

[a]Rep = replications; Rep 41-71 = Sections 1A-31A.

[b]Agg Type = aggregate type.
FC = Ferguson coarse; GC = Garner coarse.
FF = Ferguson fine; QS = Quartzite.
CS = 90% concrete sand plus 10% fly ash.
MC = Moscow dolomite coarse; MF = Moscow dolomite fine.
DA = Dallas crushed gravel; DI = Dickinson crushed gravel.
LW = Lightweight aggregate (Haydite).

[c]SE = Sand equivalent.

[d]Filler type: P = Type 1 Portland cement.
F = hydrated lime.

[e]P Filler = percent filler by weight of aggregate.

[f]Emu Type = emulsion type; c = cationic emulsion;
s = anionic emulsion.

[g]Base AC = Base asphalt; S = soft (85-100 pen).
H = hard (60-70 pen).

[h]P Theo = percent theoretical emulsion (1.0 = 100% theoretical).

[i]P Emul = percent emulsion content by weight of aggregate (based on emulsion tank measurement).

[j]WTAT = wet track abrasion test on laboratory sample, weight loss in grams per square foot.

[k]LWT = loaded wheel test on laboratory sample, weight of sand adhesion in grams per square foot.

[l]CMC = cured moisture content, percent by weight of slurry, on laboratory sample.

[m]C Time = cured time, hours, of laboratory sample, determined by cohesion test.

[n]Cohesion = maximum torque, in in.-lbs, developed in cured laboratory sample.

[o]Flow = cone consistency test on field sample, cm.

[p]Age = ages of test sections, in months, when friction tests were conducted.

[q]FN40A = friction number at 40 mph in wheel track.
FN55A = friction number at 55 mph in wheel track.
FN40B = friction number at 40 mph in 1/4-point.
FN55B = friction number at 55 mph at 1/4-point.

# 4. CONSTRUCTION

## 4.1. Materials

The aggregate used in the slurry came from eight sources. Quartzite is not available in Iowa, consequently that came from New Ulm, Minnesota. The expanded shale was not available in Iowa with the proper gradation, so it came from New Market, Missouri. The mineral filler, Type I Portland cement and hydrated lime, was available locally.

The aggregate sources, identification codes, and specific requirements are given in Table 2.

Three types of emulsion were used on the project. They were CSS-1h, 85-100 penetration (pen), CSS-1h, 60-70 pen, and SS-1h, 85 pen.

The CSS-1h came from Bitucote Products Company in Des Moines, Iowa, and the SS-1h came from Union Asphalt Company, Kansas City, Kansas.

## 4.2. Equipment and Calibration

The slurry machine was custom-built for the contractor, Missouri Petroleum Products Company of Clayton, Missouri. The truck-mounted continuous slurry machine was powered by a diesel engine; and the dual shaft pugmill, feed chain and emulsion pump were powered by a four-cylinder 60 HP gasoline engine.

The machine had an eight cubic yard aggregate bin, an eight cubic foot mineral filler bin, a 600-gallon water tank, two emulsion tanks, a 1,000-gallon tank, and a 600-gallon tank connected by a three-inch pipe.

The aggregate was fed into the dual shaft pugmill where the mineral filler was added; the water and the emulsion were added last.

Other equipment necessary for construction included a self-propelled rotary broom, a distributor truck, a self-propelled pneumatic roller, a water truck, and a tanker for emulsion storage.

The slurry machine was calibrated at the Iowa DOT maintenance shop, where the aggregates were stockpiled. The machine was calibrated for each slurry mix design used on the project with respect to design emulsion content. Calibration was carried out by keeping the aggregate bin gate constant and by changing gears to vary the emulsion delivery rate of the Roper pump. Calibration was under the direction of Highway Division District Materials personnel.

## 4.3. Procedures and Controls

Before placement of the slurry seal began, the road was burned and bladed by Highway Division maintenance personnel to reduce the depth of the wheel path ruts. The depth of the original ruts was about one-half inch. By burning and blading, the depth was reduced to about two-tenths inch. Transverse cracks (at 15-25 ft intervals) and centerline cracks were sealed with RS-2.

In the two weeks prior to construction, most of the aggregates were delivered to the Highway Division maintenance shop on University Avenue west of Des Moines. They were stockpiled on the ground. The area was well-compacted and generally covered with aggregate.

During construction, an Iowa DOT maintenance employee was in charge of seeing that the correct aggregate was loaded onto the trucks and transported to the job site as needed.

On September 11, 1978, the eastbound lane was tack-coated with diluted (1:3) cationic emulsion at an average rate of 0.05 gallons per square yard. The slurry seal was placed on the test sections between September 12 and October 4, 1978. The control section, the westbound lane, was tack-coated on October 6; the west one-half of the lane was slurry sealed between October 10 and October 18, 1978, when operations were suspended for the winter. The rest of the control section and the reapplication of test sections that had failed because of excessive emulsion and that had been burned by Iowa DOT maintenance personnel were completed between June 21 and June 29, 1979.

Placement of the slurry seal did not begin at one end and progress continuously. Instead, test sections were placed to minimize the number of gear changes on the emulsion pump and/or changes of aggregate. In general, the slurry machine travelled with the traffic.

The amount of emulsion used for each test section was determined by tank measurement before and after each test section was placed. The aggregate was weighed when delivered to the slurry machine, and the amount of aggregate wasted at the end of each section was estimated by the inspector to determine the amount of aggregate used.

Although pre-wet moisture content was determined in the laboratory for each material combination (section), there was no attempt to control or adjust the moisture content of the aggregate.

During placement of each test section, a sample was obtained from the pugmill discharge chutes and a cone flow test was made. Another sample was obtained and delivered to the District Materials Laboratory for extraction.

The slurry was allowed to cure, with the length of time depending on emulsion content, and was proof-rolled before traffic was allowed over the area. Due to the short sections of slurries with varying cure times, the time between placement and resumption of traffic varied from 2 to 6 hours.

## 4.4. Construction Problems

The slurry machine used on this project was built for high production, thus control was difficult on short sections. Tanks and plumbing were also in need of cleaning, as the emulsion would not flow freely between the two tanks, making it difficult to determine emulsion quantities. At times, the emulsion lines would become clogged and external heat would be applied to open them. The lack of augers may have been the reason for segregation and nonuniform slurry in the spreader box, especially at the rear outside corners. Many times, the slurry would have to be forced to the ends of the spreader box with a shovel. Bags of cement were placed on top of the spreader box to maintain a uniform slurry depth.

It was not possible to determine the exact amount of aggregate used for each test section. There was always some aggregate wasted at the end of each section, so that a straight joint with the next section could be acquired. Sometimes there would be some aggregate left in the bin when a section was completed. In both cases, the amount had to be estimated to determine the amount of aggregate used per square yard on a test section (e.g., Sections 4, 21-24, and 21A-24A). Another problem was oversize aggregates that would not go under the squeegee and consequently left streaks in the finished slurry seal (e.g., Sections 4, 20A-22A).

An additional problem was the accurate control and determination of emulsion content in the slurry. Of 62 test sections, only 23 sections were on target (± 1%) with respect to intended emulsion content. In 15 sections, the actual emulsion contents missed target values by more than 5%.

Emulsion content determined by tank stick measurements provided reasonable results of emulsion contents in the slurries, except in sections on a slope (e.g., Section 4). However, emulsion contents based on extraction tests were erratic or erroneous in most cases. Only 13 of 62 extraction results came close to tank stick measurements. This could be attributed to nonrepresentative sampling either from the slurry machine or in the laboratory. The fact that extraction tests could not be performed immediately was another source of error; consequently, the slurries were broken and segregated by the time extraction tests were run. In any case, slurry sampling and extraction test procedures should be reevaluated.

The results of the cone flow test were questionable. An acceptable test could be made with a homogeneous slurry, but sometimes the aggregate would not stay in suspension. It would fall in a pile and the liquid would run to the base plate and spread out. This may have been caused by the operator adding water to make the slurry spread easier, and/or possibly too high an emulsion content for the aggregate. Sometimes a stiff slurry would stand with little or no flow. By the time the cone flow test was completed, it would be too late to make corrections for that test section. Accurate control of water and mineral filler was very difficult to obtain. These problems arose, perhaps due to lack of stringent control on the moisture content present in the aggregate, pre-wet aggregate water content, and filler content.

Although the road was burned and bladed, the wheel paths were slightly rutted. The squeegee was so stiff that it could not conform to the wheel path. This resulted in a deeper slurry surface, sometimes with excess emulsion. The time required to cure, proof-roll, and open the road to traffic was determined by the deeper slurry.

Section 10 was completed at 1:19 p.m. and Section 11 at 2:21 p.m. on September 19, a cloudy, humid day. At 3:15 p.m., it started to rain lightly and then rained hard between 4 and 5 p.m. The rain washed considerable emulsion from Section 10, leaving the aggregate exposed. Section 11 did not break, and as it was getting late in the day, the contractor was required to remove it with the rotary broom.

Section 10 had cured to the point that the rotary broom could not remove the slurry. The rain continued that night and by morning, traffic had loosened aggregate from Sections 7, 8, 9 and 10. The remaining slurry was bladed from those sections and replaced later.

## 4.5. Reapplications

Several test sections had to be reapplied, either because of failure caused by excessive emulsion or loss of aggregate because of rain before the slurry seal had completely cured.

Section 1, as originally placed, was deemed a failure and removed with a motor patrol 10 days after placement. Cause of failure was excessive emulsion, which caused a very slippery appearance.

Sections 7, 8, 9 and 10 were rained on before they were completely cured, and traffic removed some of the aggregate. These sections were bladed to remove the rest of the slurry and a new slurry was applied.

The test sections placed during the fall of 1978 were tested for friction in November 1978. Sections 1A, 2A, 3, 6, 12, 12A and 17 were deemed failures because of low friction values. The surface of these sections was burned by the Highway Division maintenance personnel and bladed from the road. These sections were reapplied in the summer of 1979 when the slurry seal was completed on the remainder of the westbound lane, which was used as a control section. Aggregates corresponding to the original designs were used in Sections 1A (FCLS) and 3 (GCLS). However, Moscow dolomite (MC) was used on Section 2A, and lightweight aggregate (LW) was used on Sections 12, 12A and 17.

## 5. POST-CONSTRUCTION PERFORMANCE EVALUATION OF COMPLETED WORK

One of the most important features of any research project is the performance of the work on the roadway under normal environmental conditions.

From the time this project was completed until this report was written, more than four special field evaluations were made between October 1979 and December 1980. Most of the post-construction evaluation consisted of a review of friction tests and surveys concerning the appearance of the various sections. In reviewing and discussing this information, two of the important features, friction number and surface appearance, often were not concurrent, i.e., sections with good friction numbers were poor in appearance, and some sections where appearance was very good had low friction numbers.

To bring this information together into a usable form, a review team was appointed to establish numerical criteria, to make a final field performance evaluation, and to assemble the information in table form.

Criteria established for use in making this comparison table was based on a range of 1 through 5 for both appearance rating and friction number measurements.

Although friction tests were performed at 2, 9, 12, 20 and 24 months for the majority of the test sections and at both 40 and 55 mph, for the purpose of overall evaluation, only friction numbers (FN) at 40 mph in wheel track at approximately 12 and 24 months were used. The rating criteria for both surface appearance and friction number are given in Table 6. The composite post-construction performance evaluation ratings are given in Table 7.

From an examination of the appearance evaluation and the friction tests in Table 7, the following conclusions can be made.

1. The coarse limestones from Ferguson, Garner, and Moscow have all produced a surface appearance that exhibits good macro-texture. The Ferguson and Moscow coarse limestones, however, are the only limestones that exhibit good frictional characteristics. The frictional characteristics, however, were not satisfactory with these two aggregates when the asphalt content appeared excessive.

   Elsewhere in the report (Table 5) there is a reference to the sand equivalency of the aggregates. Examination of this data would indicate that sand equivalent may be a factor contributing to the difference, since all aggregates except those from Garner exhibit a factor above 45 [6,7].

2. Quartzite produced good results consistently with regard to both appearance and frictional characteristics. One section did appear as though it might be a little over-asphalted; however, the frictional characteristics were still very good.

3. Concrete sand and fly ash exhibited very good frictional characteristics. There was, however, a considerable loss of material from the 1/4-point and near the centerline. The wet track abrasion losses for these two sections showed 36 and 53 grams per square foot for Section 14 (at 12.3% emulsion) and Section 14A (at 11.1% emulsion), respectively, quite acceptable,

Table 6. Performance Evaluation Criteria.

Appearance Evaluation

| Rating | Criteria |
| --- | --- |
| 1 | Good macrotexture and no evidence of significant loss of texture in wheel track area. |
| 2 | Fair macrotexture over most of the area; evidence of some loss of macrotexture in wheel track; no shine. |
| 3 | Smooth, tight surface with no shine. |
| 4 | Flushed with some shine in wheel tracks and/or evidence of thinness and areas exhibiting loss of slurry surface. |
| 5 | Badly flushed and/or considerable loss of slurry surface. |

Friction Evaluation

| Rating | FN at 40 mph |
| --- | --- |
| 1 | 50 and above |
| 2 | 41 to 49 inclusive |
| 3 | 35 to 40 inclusive |
| 4 | 26 to 34 inclusive |
| 5 | 25 and less |

Table 7. Composite Post-Construction Performance Evaluation Ratings.

| Section Number | Aggregate[a] | Appearance Factor | FN40 October 1979 | FN40 September 1980 |
|---|---|---|---|---|
| 1 | FC | 3 | 5 | 5 |
| 1-A | FC | 4 | 5 | 5 |
| 2 | FC | 2 | 3 | 2 |
| 2-A | MC | 3 | 5 | 5 |
| 3 | GC | 4 | 5 | 5 |
| 3-A | GC | 2 | 4 | 4 |
| 4 | GC | 3 | 5 | 5 |
| 4-A | GC | 2 | 4 | 4 |
| 5 | FF | 4 | 5 | 5 |
| 5-A | FF | 2 | 4 | 4 |
| 6 | GC | 4 | 5 | 5 |
| 6-A | FF | 3 | 5 | 4 |
| 7 | FC | 2 | 3 | 3 |
| 7-A | FC | 1 | 1 | 1 |
| 8 | FC | 2 | 3 | 3 |
| 8-A | FC | 3 | 3 | 3 |
| 9 | FC | 3 | 4 | 4 |
| 9-A | FC | 1 | 3 | 3 |
| 10 | FC | 3 | 5 | 5 |
| 10-A | FC | 3 | 5 | 5 |
| 11 | FC | 3 | 5 | 5 |
| 11-A | FC | 3 | 5 | 4 |
| 12 | LW | 3 | 3 | 2 |
| 12-A | LW | 3 | 2 | 2 |
| 13 | QS | 2 | 3 | 2 |
| 13-A | QS | 2 | 3 | 2 |
| 14 | CS | 4 | 2 | 2 |
| 14-A | CS | 5 | 2 | 2 |
| 15 | MF | 4 | 5 | 5 |
| 15-A | MF | 3 | 4 | 5 |
| 16 | MC | 3 | 5 | 4 |
| 16-A | MC | 1 | 2 | 2 |
| 17 | LW | 4 | 3 | 4 |
| 17-A | DA | 4 | 4 | 5 |
| 18 | DI | 4 | 5 | 4 |
| 18-A | DI | 3 | 4 | 4 |
| 19 | LW | 4 | 1 | 3 |
| 19-A | LW | 4 | 1 | 1 |
| 20 | LW | 5 | 1 | 2 |
| 20-A | LW | 4 | 1 | 2 |
| 21 | FC | 2 | 4 | 4 |
| 21-A | FC | 2 | 4 | 4 |
| 22 | FC | 3 | 4 | 4 |
| 22-A | FC | 2 | 5 | 5 |

Table 7. Continued.

| Section Number | Aggregate[a] | Appearance Factor | FN40 October 1979 | FN40 September 1980 |
|---|---|---|---|---|
| 23 | FC | 4 | 5 | 5 |
| 23-A | FC | 4 | 5 | 5 |
| 24 | QS | 2 | 2 | 2 |
| 24-A | QS | 3 | 2 | 3 |
| 25 | FC | 1 | 2 | 2 |
| 25-A | FC | 3 | 3 | 4 |
| 26 | FC | 3 | 5 | 5 |
| 26-A | FC | 3 | 3 | 4 |
| 27 | FC | 4 | 4 | 5 |
| 27-A | FC | 4 | 5 | 5 |
| 28 | MC | 3 | 2 | 2 |
| 28-A | MC | 1 | 2 | 2 |
| 29 | DI | 5 | 3 | 4 |
| 29-A | DI | 5 | 2 | 1 |
| 30 | LW | 5 | 2 | 2 |
| 30-A | LW | 5 | 1 | 2 |
| 31 | LW | 5 | 1 | 1 |
| 31-A | LW | 5 | 1 | 2 |

[a]FC = Ferguson coarse.
FF = Ferguson fine.
GC = Garner coarse.
MC = Moscow coarse.
MF = Moscow fine.
QS = quartzite.
LW = lightweight.
DI = Dickinson crushed gravel.
DA = Dallas crushed gravel.
CS = concrete sand.

based on currently held design criterion of 75 grams per square foot [8]. It appears that this material went down very thin, except in the wheel paths, and that snowplow abrasion had stripped the material from the high spots.

4. Lightweight aggregate resulted in very good frictional characteristics in all sections where it was used. The eight sections of lightweight aggregate slurry seals had an average friction number at 40 mph of 47 (ranging from 40 to 53) after 24 months or about 1.4 million vehicles. Except for two sections, the surface appearance is much like that of the concrete sand and fly ash with considerable loss from the high spots. This was reflected in the very high wet track abrasion test losses exhibited by these mixes in the laboratory (from 77 to 404 grams per square foot, with an average of 247 grams per square foot).

   On the two sections that do exhibit a satisfactory surface appearance, the surface is lacking somewhat in macrotexture and gives an appearance of being over-asphalted. It appears that the lightweight aggregate, because of its high absorption, can tolerate a relatively high asphalt content.

5. None of the fine-graded materials or crushed gravels produced any sections with combinations of satisfactory appearance and frictional characteristics.

6. Although most of the test sections were laid with the slurry machine travelling with traffic, there were 10 sections (15, 18, 30, 31, 2A, 7A, 8A, 14A, 19A and 20A) laid with the

laying machine travelling against traffic. This afforded the opportunity to study the effect of the direction of slurry machine travel on the slurry surface performance. Comparison of paired sections (i.e., 15 vs 15A, 18 vs 18A, 30 vs 30A, etc.) indicated that, in general, sections laid with the slurry machine travelling against traffic gave higher friction numbers, while sections laid with the slurry machine travelling with traffic gave better appearance under traffic.

7. From a review of the appearance rating, the friction tests, and the emulsion contents of the test sections, it can be seen that the coarse-graded sections producing the best results (Sections 2, 7A, 16A, 25, 28 and 28A) had emulsion contents ranging from about 10.3% to about 18.5%, with an average of 15.2%. The emulsion contents in terms of the theoretical emulsion content for each aggregate based on 8 μm film, Et, ranged from 0.5 to 0.9 Et, with an average of 0.73 Et. The friction numbers of these sections after 24 months or a traffic of 1.4 million vehicles ranged from 41 to 51, with an average of 45. The four sections containing quartzite seem to retain good frictional characteristics (an average friction number after 24 months of 44), with emulsion content ranging from 15.8% to 18.8% (residue asphalt content 10 to 12%).

8. During the process of developing emulsion requirements for this project and up to the time of actual construction, it was suggested that the break time for anionic emulsion would

be sufficiently long to severely restrict the amount of slurry seal that could be completed and opened to traffic in a given day. This did not prove to be the case. In fact, there were instances when the sections where anionic emulsion was used could be opened to traffic quicker than those where cationic emulsion was used. Nor was there any notable difference in the appearance or performance factors of the two different emulsions.

9. From the standpoint of appearance and friction testing, it is very difficult to determine the differences between sections containing emulsions meeting standard specification CSS-1h (40-90 pen) and sections containing emulsions meeting Iowa specification (85-100 pen) because of the additional variables in filler and emulsion content. It is possible that there could be some difference in the durability factor, but the sections have not been in service for a sufficient time to permit a durability evaluation.

10. Also due to the inability to produce slurry mixes exactly as designed, there was insufficient data to evaluate slurry performance based on differences in filler type (Portland cement vs hydrated lime) and cone flow (4-5 cm vs 2-3 cm).

## 6. LABORATORY AND FIELD CORRELATIONS

Sixty-two slurry seal mixes corresponding to filler and emulsion contents actually used in the field test sections were prepared in the laboratory using field-stockpiled materials and tested for WTAT, LWT, cure time and cohesion [1,4]. Slurry mats 8 in. in diameter and 1/4-in. thick were made for each mix and cured at room temperature (72-78° F) and at 55% to 70% relative humidity. Cohesion (torque) tests were performed at 1 to 8 hour intervals. The tests were repeated until no particle was dislodged while a torque was applied to the slurry through a rubber foot (under 21 psi pressure). The time, in hours elapsed, was considered to be the cure time. The torque, in in.-lbs, when the slurry mat was cured was defined as cohesion. The moisture content when the slurry was cured as determined by the cohesion test was termed cured moisture content. All laboratory test results are given in Table 5.

As indicated in Table 5, the cure time varied from 12 to 25 hours. The cure time is significantly correlated with sand equivalent of aggregate ($r = 0.3217$) and emulsion content ($r = 0.2047$), but not with emulsion type, as one might have postulated. The cohesion (torque) data were not as useful as originally anticipated due to the lack of repeatability and the low capacity of the torque tester used. Cohesion values of cured slurry mixes ranged from 5 to 12 or more in.-lbs. Nevertheless, it was found that cohesion was significantly correlated with sand equivalent ($r = 0.2644$), with LWT ($r = 0.4366$), and with percent of theoretical emulsion content ($r = 0.4658$). The cured moisture content varied from 0.6 to 4.4% by weight of dry slurry. It also appeared that slurries made with cationic emulsions had lower cured moisture contents than equivalent slurries made with anionic emulsion. Cured moisture content was also significantly correlated with percent filler (r = -0.2362), but seemed to be independent of pre-wet water and emulsion contents.

The cure time and cured slurry moisture content determined by the cohesion test were intended to be used as a guide for determining the timings for rolling and opening to traffic. However, since field slurry compositions including emulsion and filler content were often different from the preconstruction mix designs and since there was virtually no pre-wet moisture content control, the data on cure times determined from the designed mixes were useless. In order to correlate laboratory-determined and field curing characteristics, the cure time tests of the slurries using field compositions were repeated after completion of the construction. Again, due to the lack of information on field moisture content and variation in field temperature and humidity conditions, the correlation was poor. The usefulness of the laboratory curing test is, therefore, doubtful. However, at least based on the experience from this project, the curing of slurries, including those with anionic emulsions, did not present problems. Almost all sections were cured between 4 and 6 hours.

The results of WTAT and LWT on slurries prepared based on field materials and test section compositions are given in Table 5. The effects of emulsion content on WTAT and LWT for Garner coarse (GCLS) and CSS-1h(Iowa) are shown in Fig. 3. The effects of emulsion content

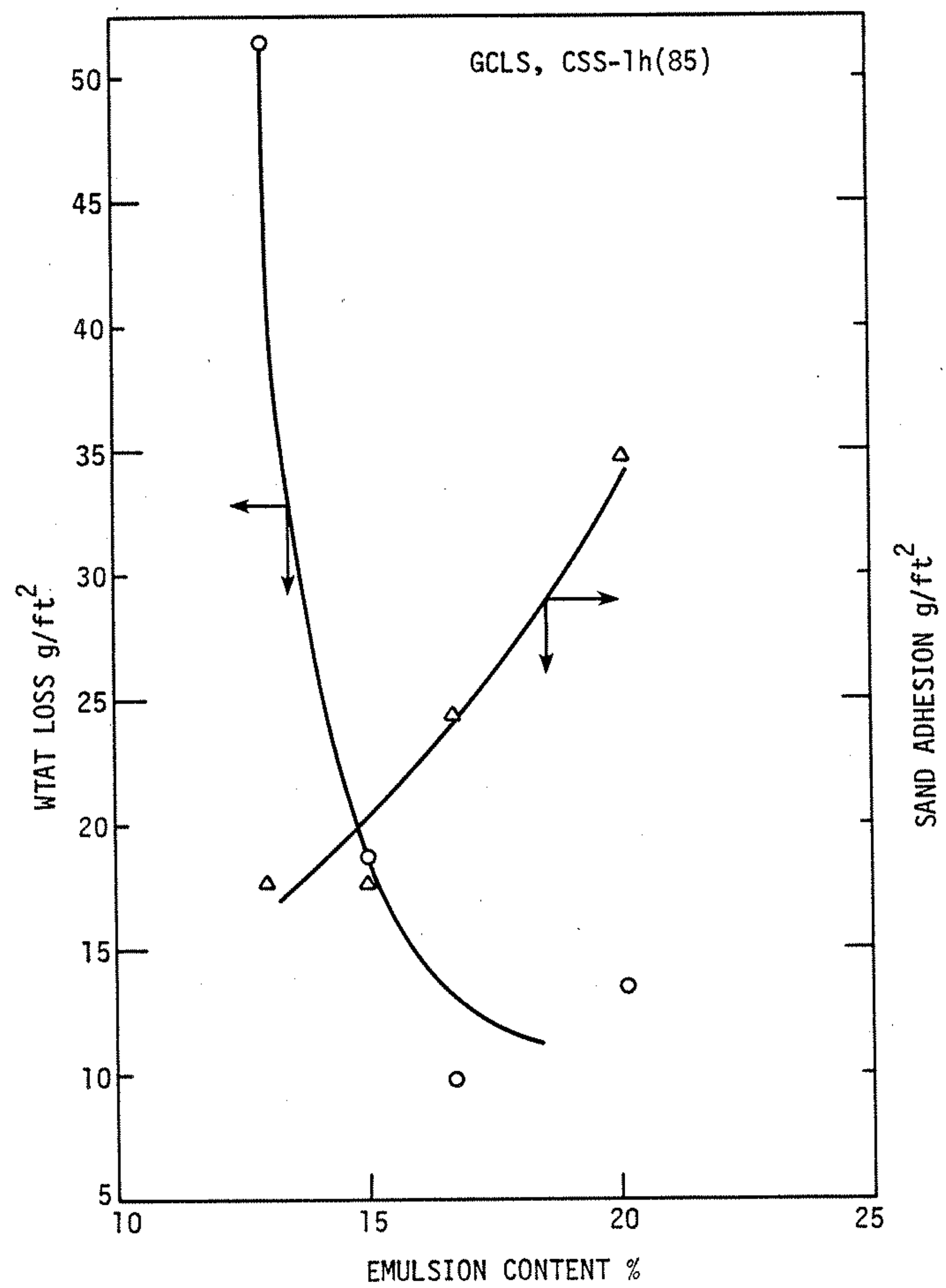


Fig. 3. WTAT loss and LWT sand adhesion vs emulsion content, Garner coarse/CSS-1h (Iowa).

on WTAT and LWT for Ferguson coarse (FCLS) are shown in Figs. 4-6 for the three emulsions used in the test sections. Figures 7 and 8 compare the three types of emulsion on WTAT and LWT. Figure 9 shows the effect of emulsion content on WTAT and LWT for Ferguson fine (FFLS), while Figs. 10 and 11 show the effects of emulsion content on the WTAT and LWT results for lightweight aggregate. All figures showed the general relationships found in Phase 1 of this study, i.e., the WTAT wear loss decreases and the LWT sand adhesion increases with increasing emulsion content. For both Ferguson coarse and lightweight aggregate at the same emulsion contents, slurry seals with anionic emulsion had lower WTAT values than those with cationic emulsion. However, there was no difference in the LWT results. At the same emulsion contents, coarse-graded slurry seal mixes had lower WTAT and LWT values than did the fine-graded slurry mixes.

Figure 12 shows WTAT wear loss of Ferguson coarse-graded slurries in the test sections as affected by the emulsion content as percent of theoretical emulsion content. The figure shows the decrease in WTAT wear loss with increasing percent of theoretical emulsion content. It also suggests that there is a slightly lower wear loss for slurries with standard CSS-1h than for those with CSS-1h(Iowa). For Ferguson coarse-graded slurries, the WTAT requirement of 75 grams per square foot was met even for slurries containing as low as 0.5 to 0.6 of theoretical emulsion content.

Figure 13 is a plot of LWT sand adhesion versus percent of theoretical emulsion content. It shows the increase in sand adhesion with increasing emulsion contents, as observed previously.

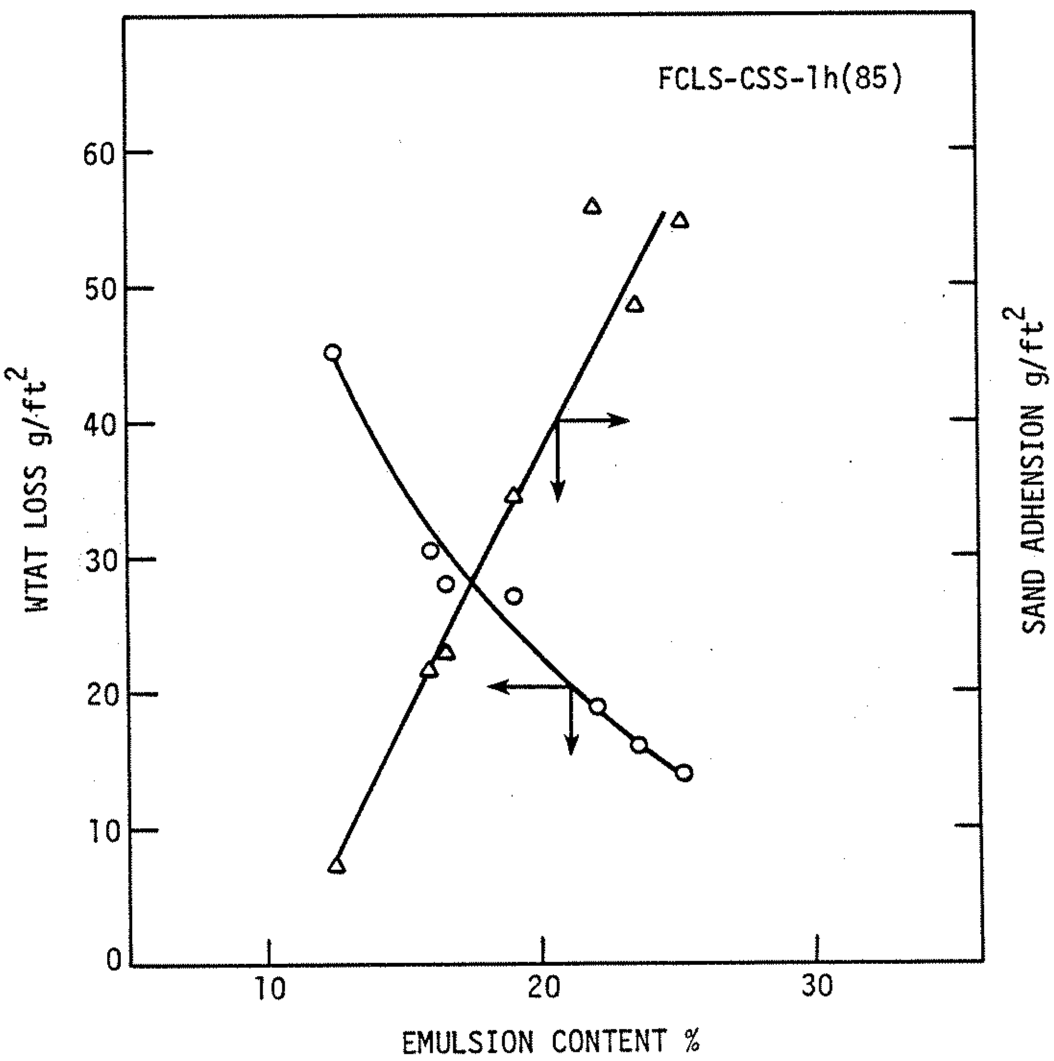


Fig. 4. WTAT loss and LWT sand adhesion vs emulsion content, Ferguson coarse/CSS-1h (Iowa).

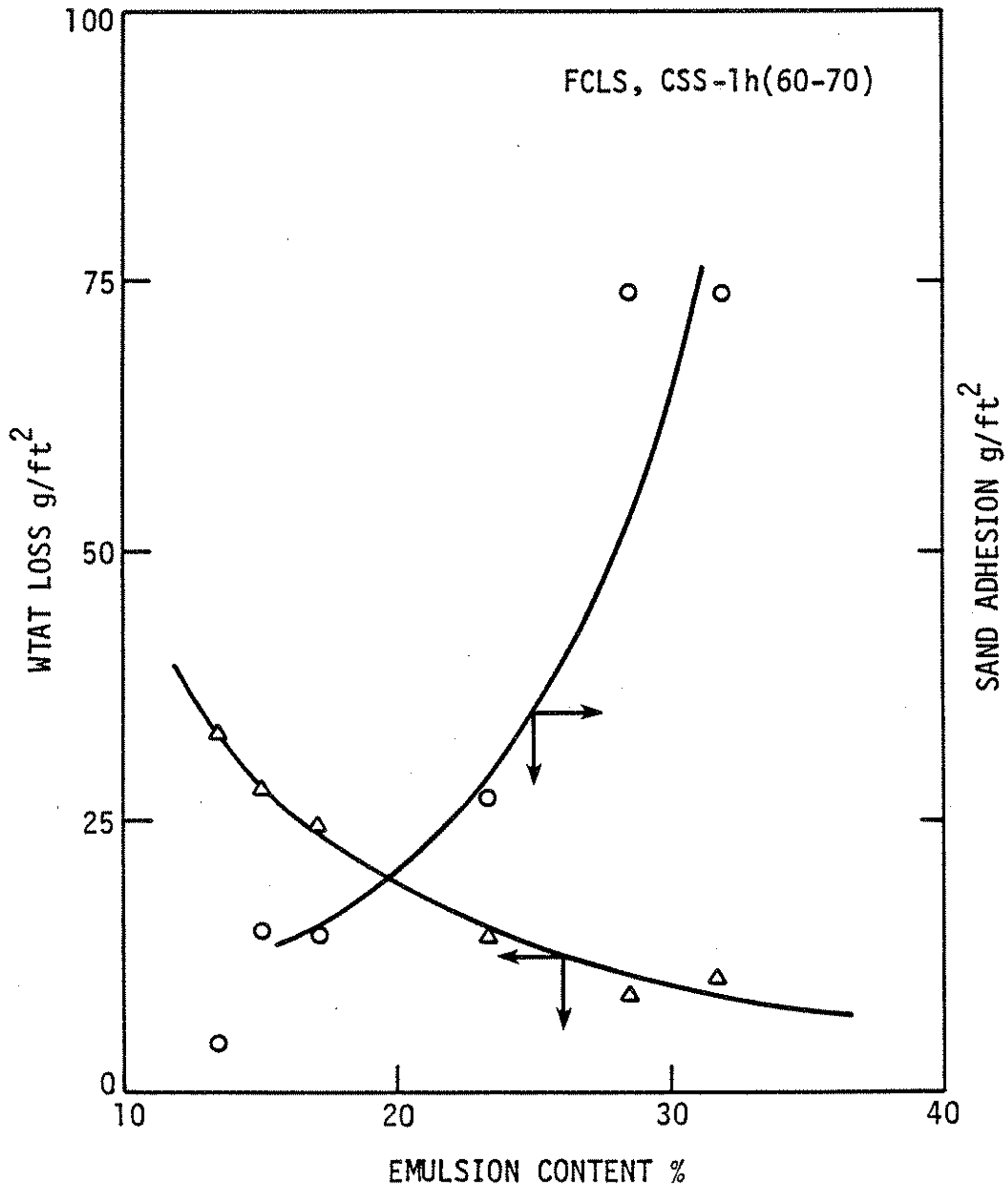


Fig. 5. WTAT loss and LWT sand adhesion vs emulsion content, Ferguson coarse/CSS-1h (60-70).

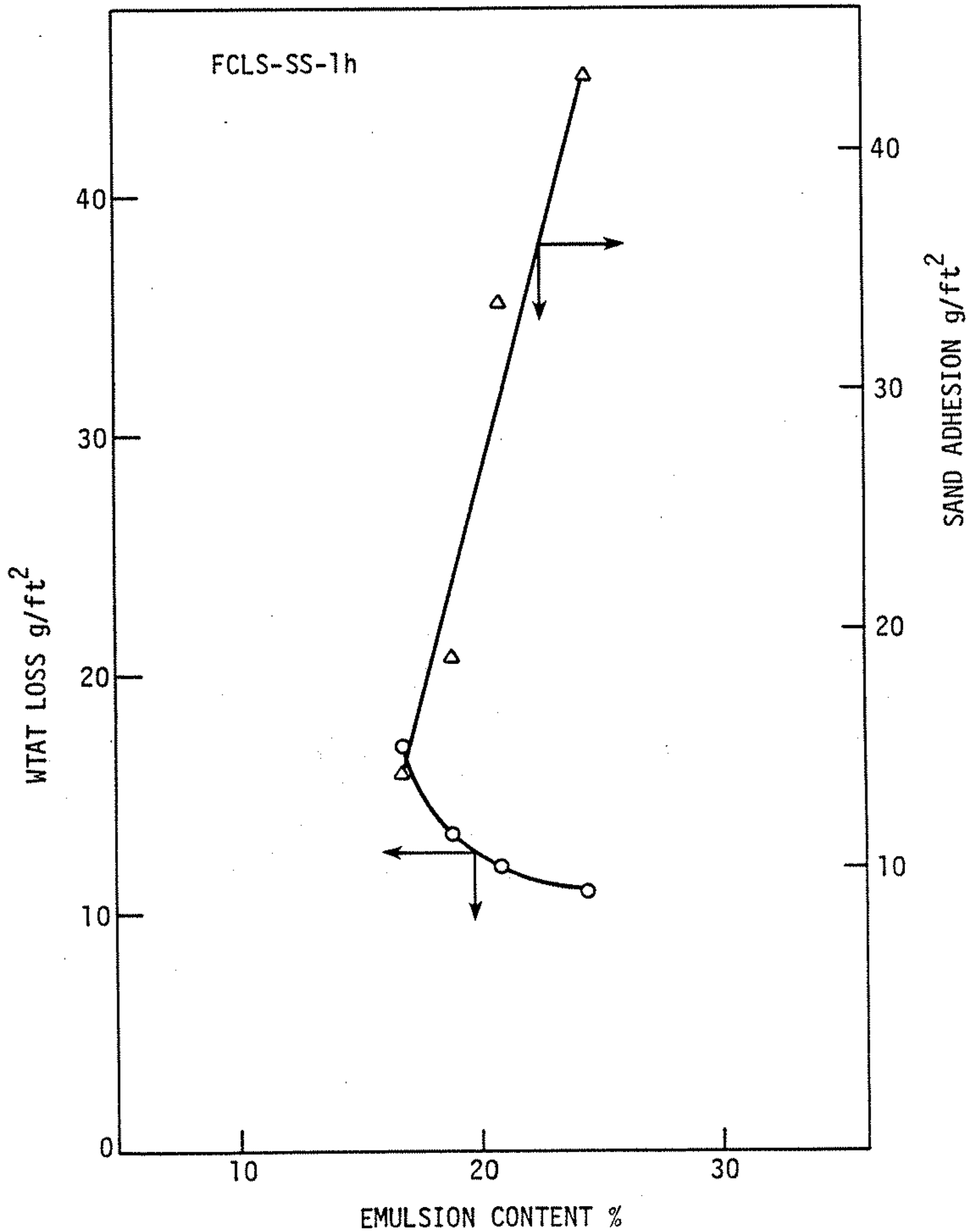


Fig. 6. WTAT loss and LWT sand adhesion vs emulsion content, Ferguson coarse/SS-1h.

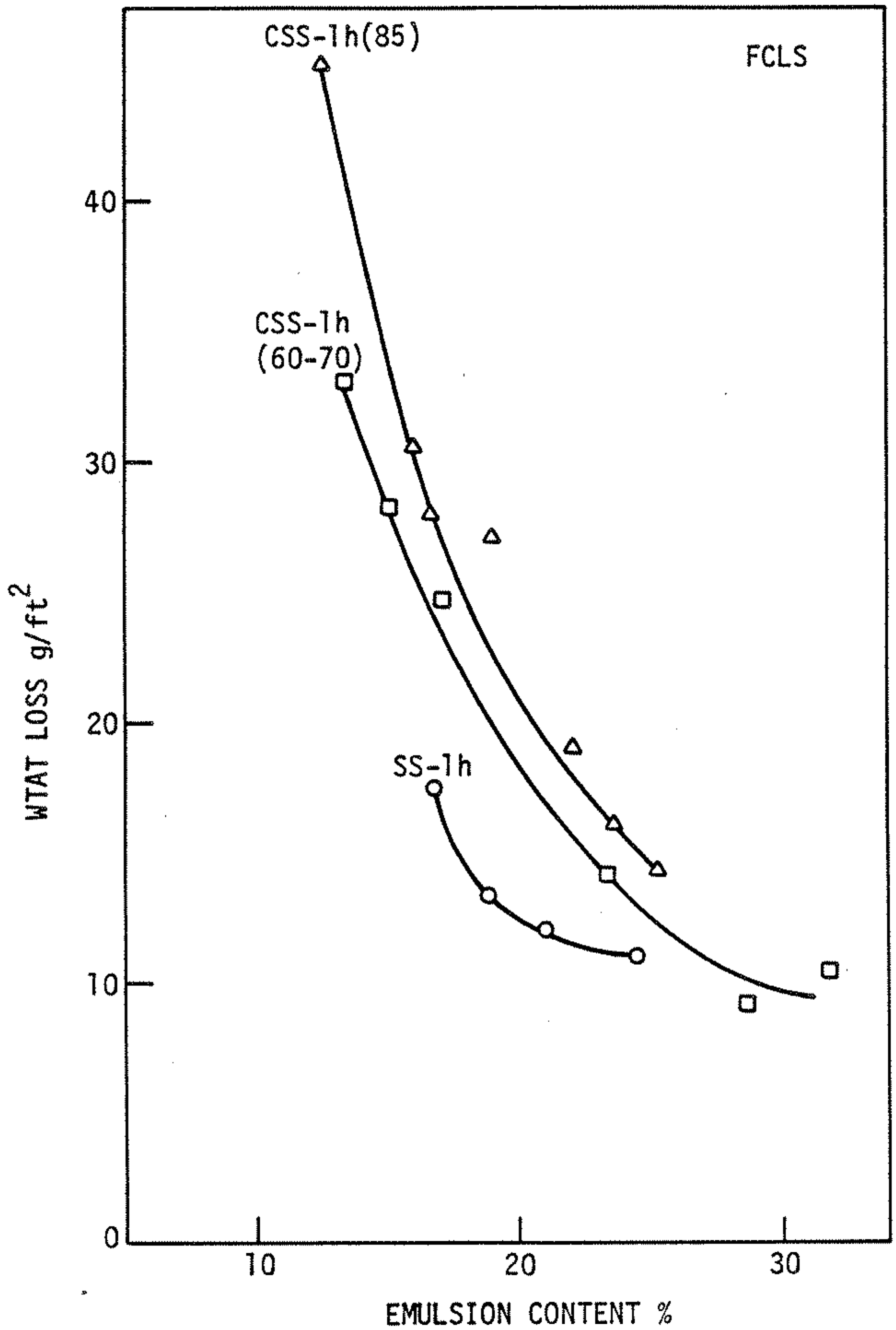


Fig. 7. WTAT loss vs emulsion content, Ferguson coarse.

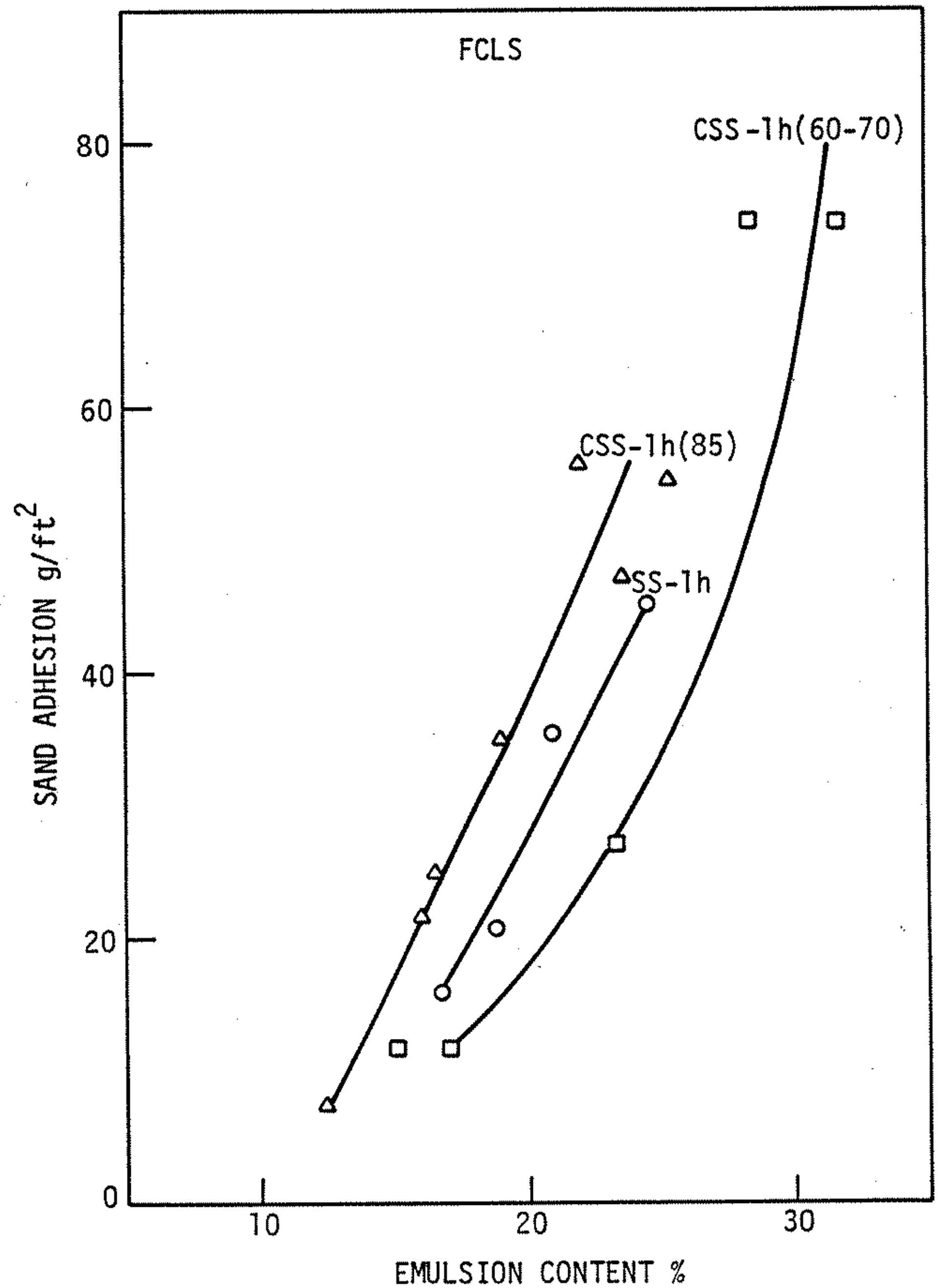


Fig. 8. LWT sand adhesion vs emulsion content, Ferguson coarse.

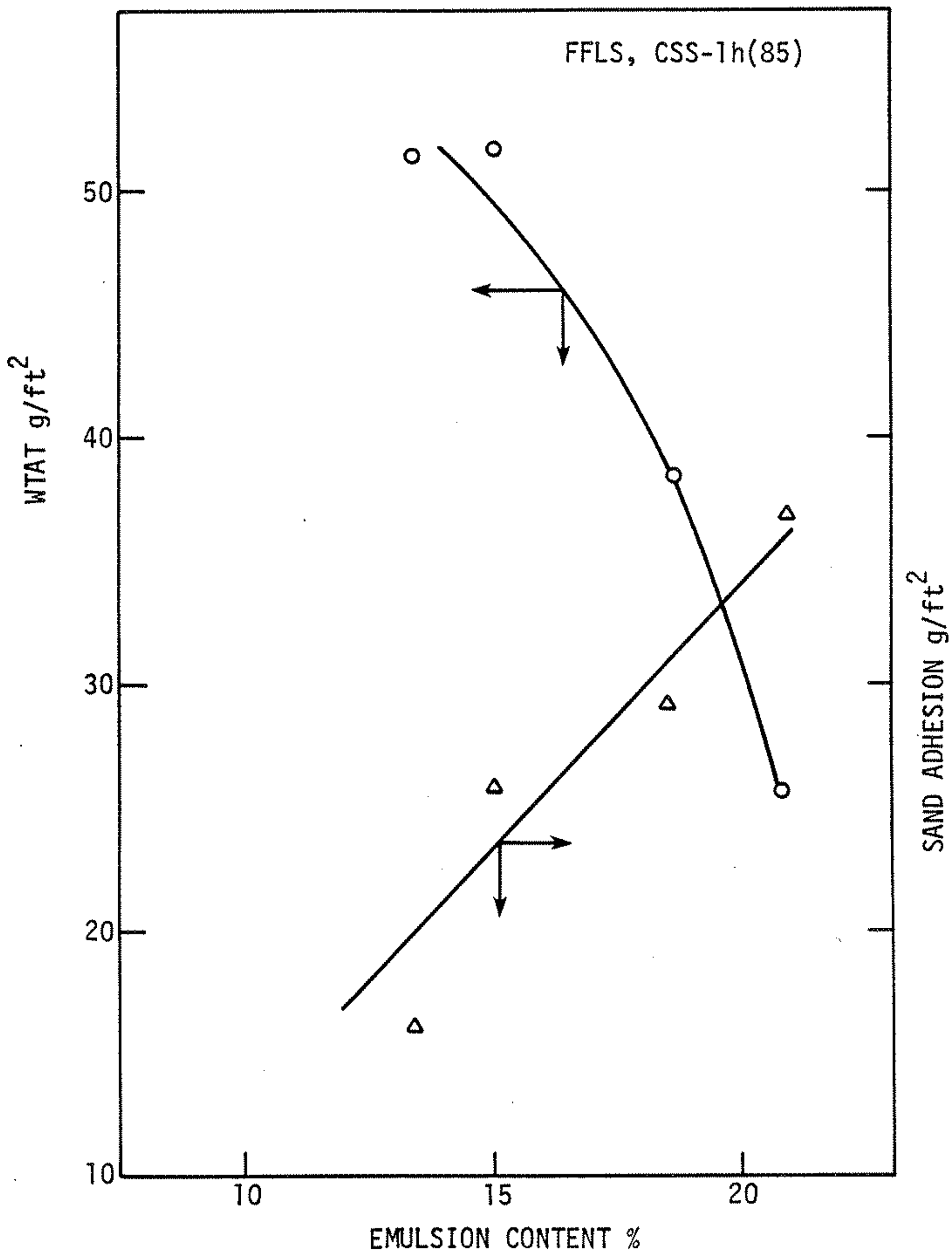


Fig. 9. WTAT and LWT vs emulsion content, Ferguson fine/CSS-1h (Iowa).

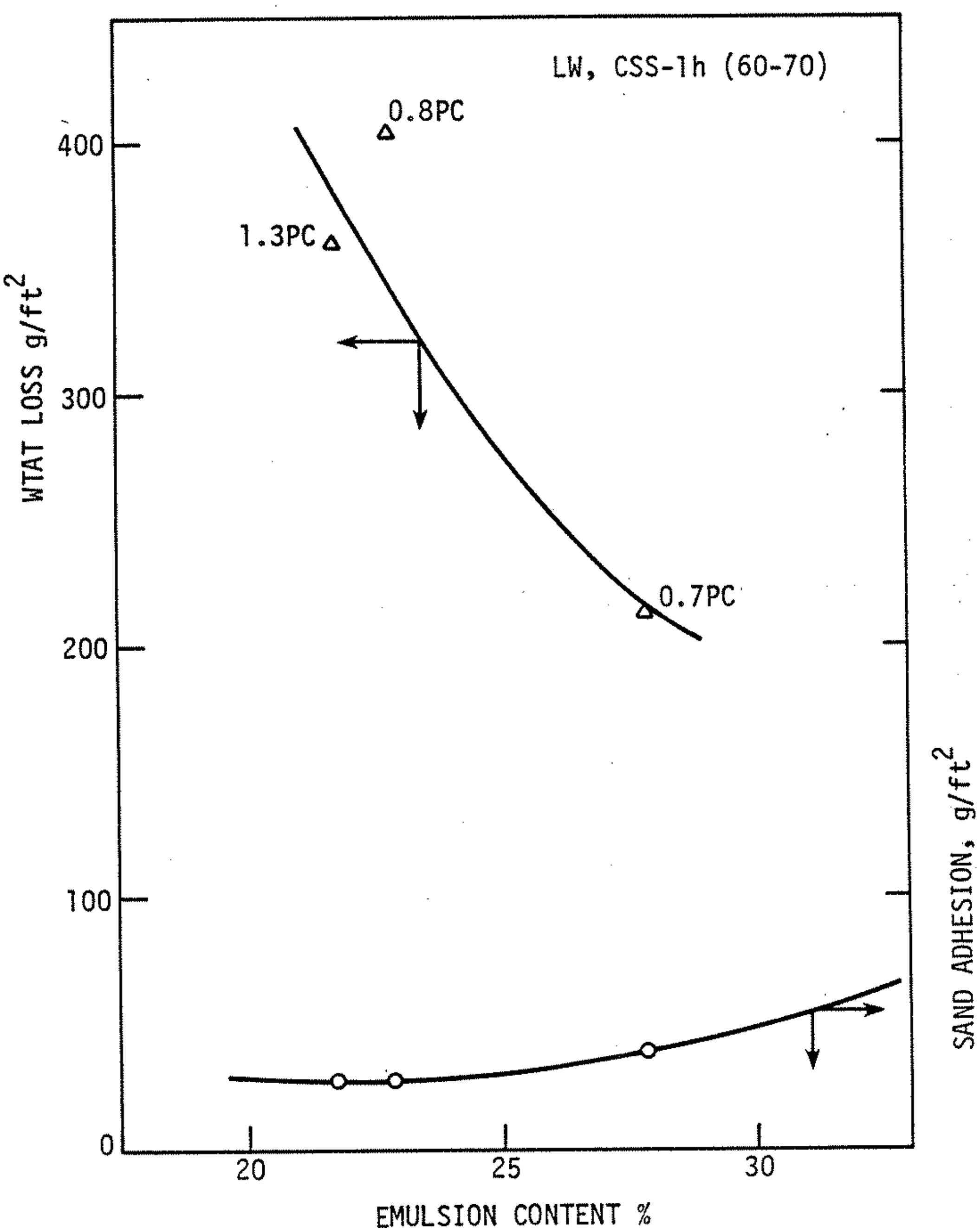


Fig. 10. WTAT and LWT vs emulsion content, LW/CSS-1h (60-70).

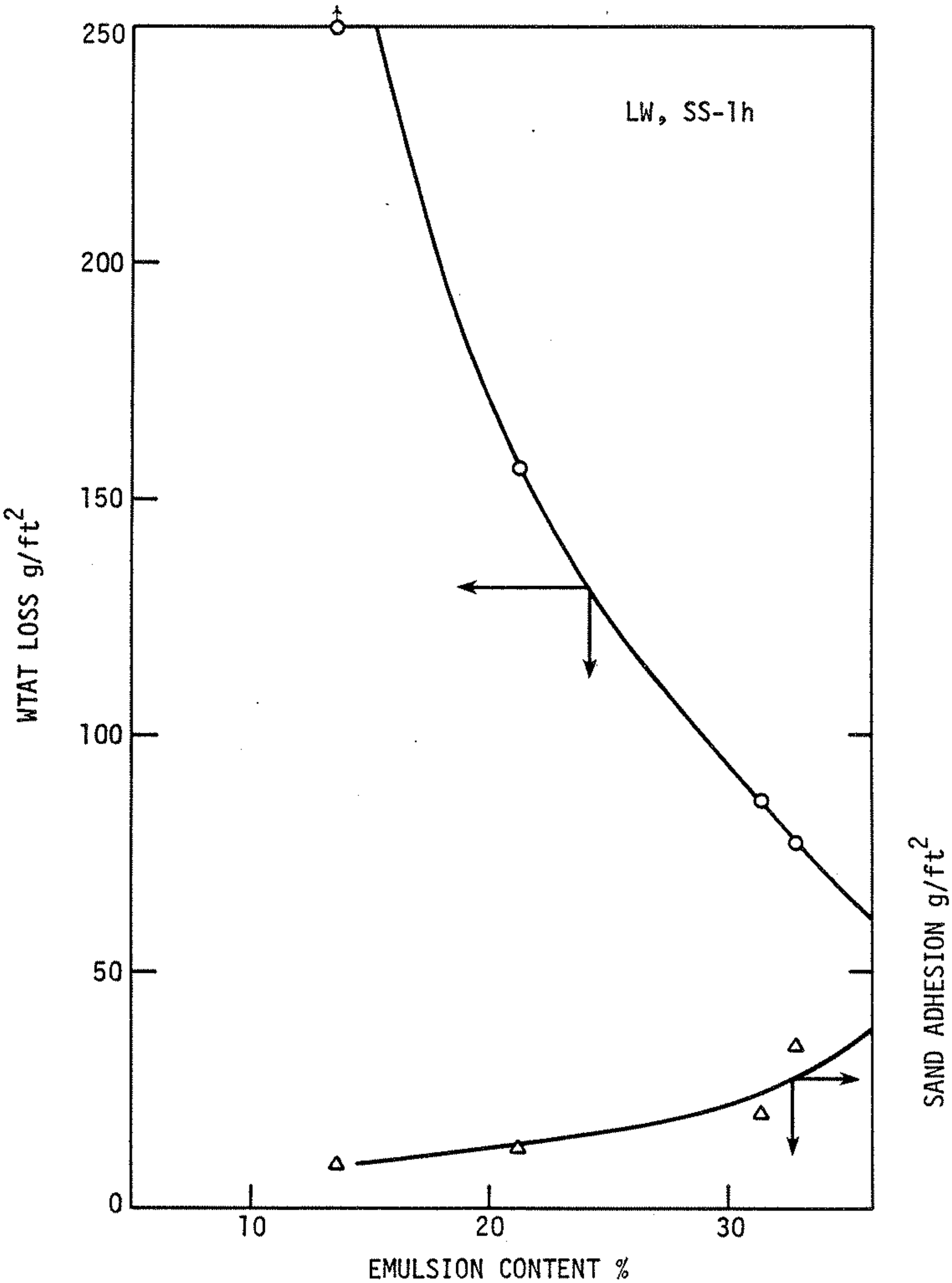


Fig. 11. WTAT and LWT vs emulsion content, LW/SS-1h.

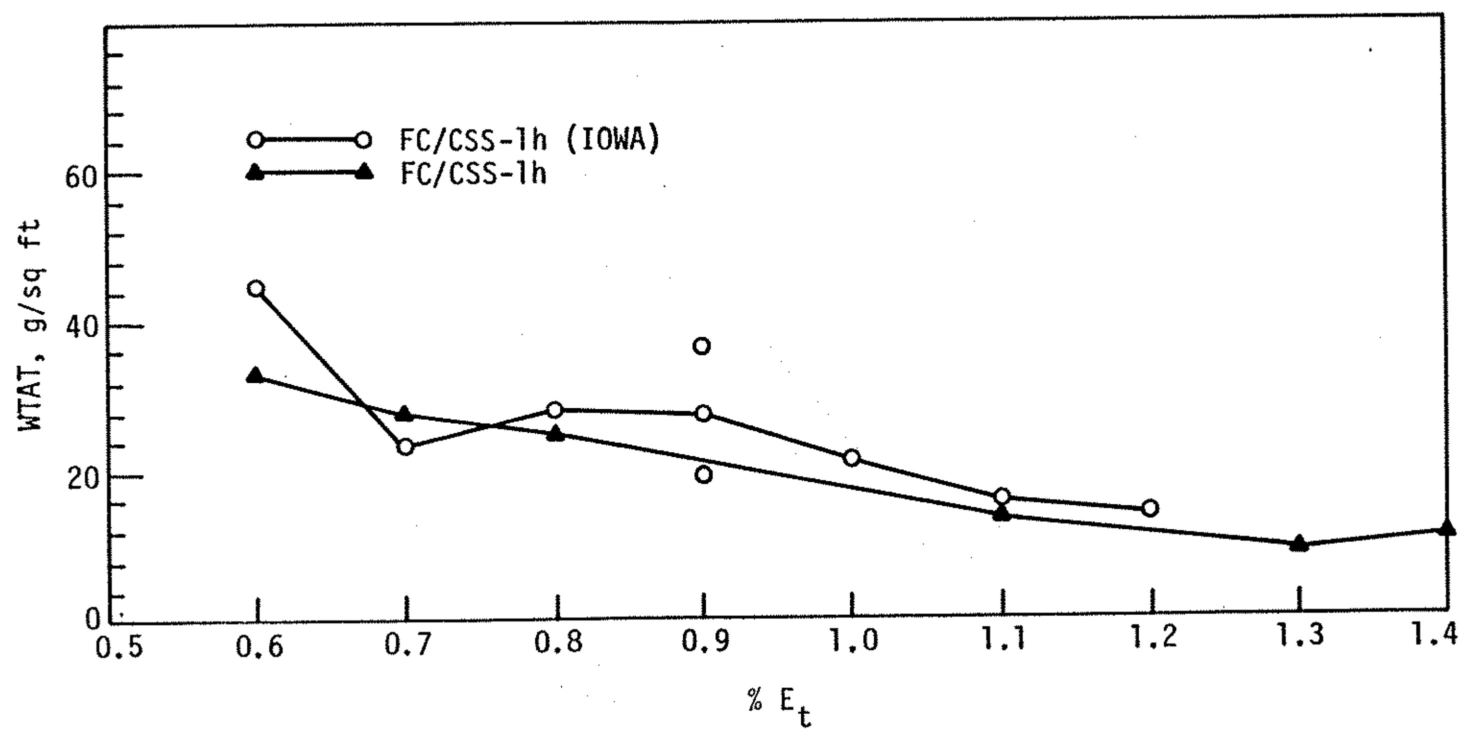


Fig. 12. WTAT vs theoretical emulsion content, Ferguson coarse.

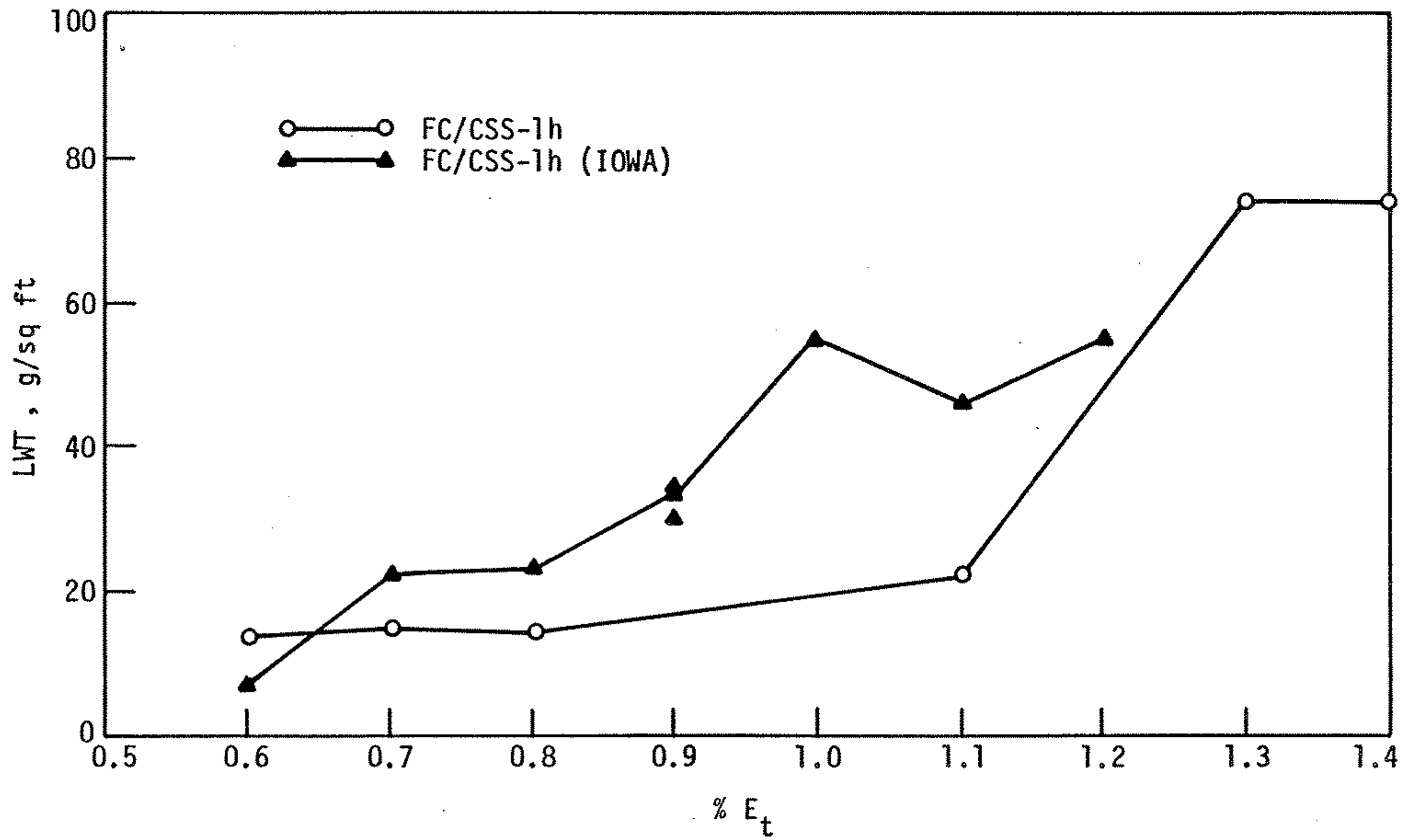


Fig. 13. LWT vs theoretical emulsion content, Ferguson coarse.

Friction numbers (FN) at 40 and 55 mph, both in wheel track (IWT) and at 1/4-point, were determined by the locked-wheel trailer method following ASTM E274. The numbers were determined at various time intervals of from 2-3 months following construction up to 24 months for most test sections. The results are given in Table 5. The friction numbers at 40 mph (IWT) for CSS-1h(Iowa) are plotted against age in months for coarse-graded sections in Fig. 14 and for coarse-graded sections using anionic emulsion in Fig. 15. For most aggregates, there was a gradual decrease in FN over time. Concrete sand (CS) (Section 14A) gained 13 points over 24 months (from 35 to 48). Quartzite (QS) (Sections 13 and 13A) gained almost 8 points in 24 months. Dickinson gravel (DI) gained 14 points in 24 months. At cationic emulsion content of about 80% of theoretical value (Et), lightweight aggregate, quartzite and concrete sand had an FN at 40 mph above 40 after 2 years, performing better than Moscow dolomite, Garner, Dallas gravel and Ferguson limestone. For anionic emulsion sections with coarse-graded aggregates, only Ferguson dropped below an FN of 30 after 2 years, while lightweight aggregate, Moscow dolomite and Dickinson gravel sections had an FN of above 40. In all cases, lightweight aggregate sections had superior performance as far as friction number is concerned.

Comparisons between coarse and fine gradings at approximately the same percent of theoretical emulsion content are shown in Figs. 16 and 17. Coarse-graded slurry mixes consistently had 5 to 15 points higher FN than fine-graded mixes at the same emulsion contents. From Fig. 16,

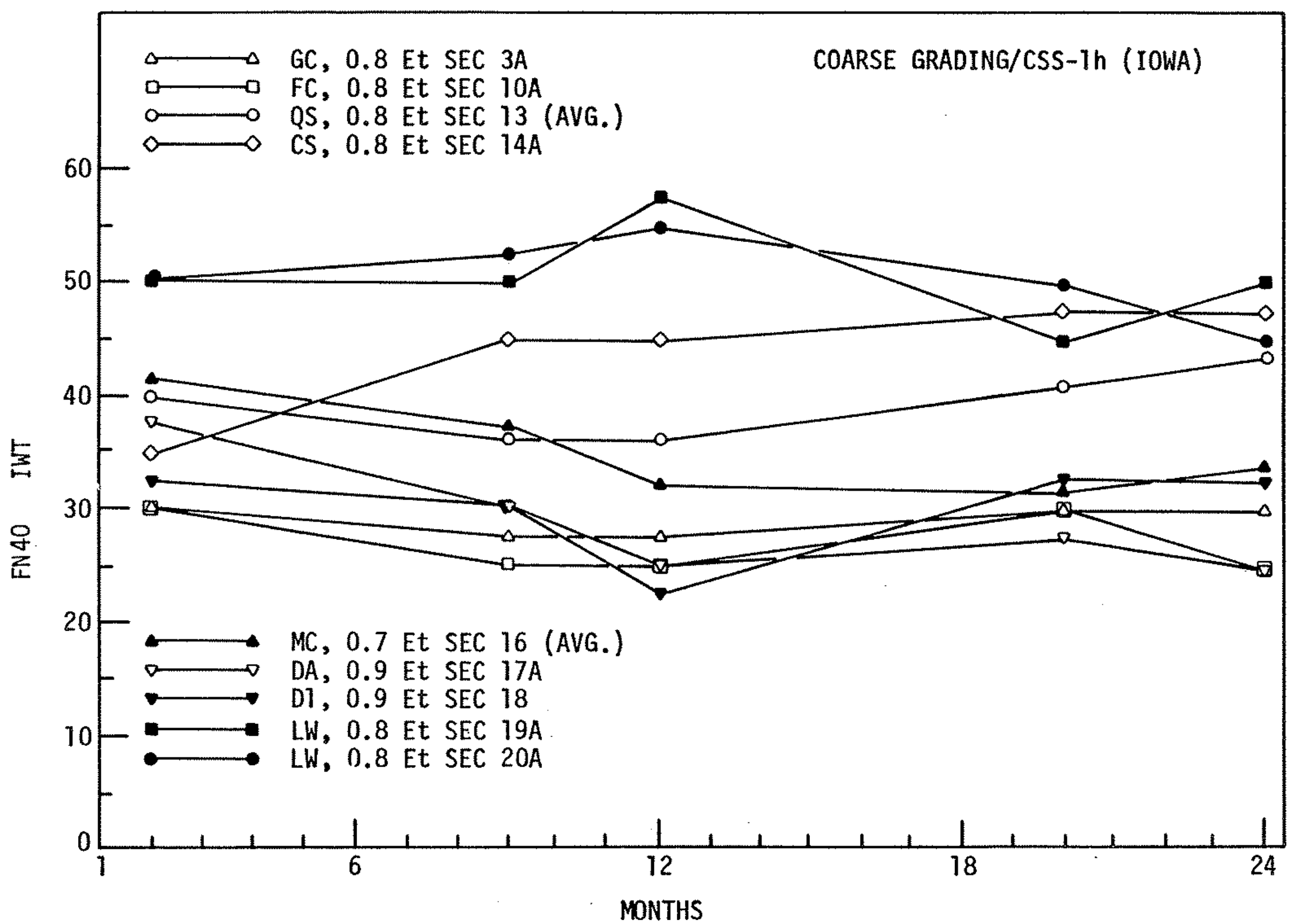


Fig. 14. Friction number at 40 mph (IWT) vs age, coarse grading/CSS-1h (Iowa).

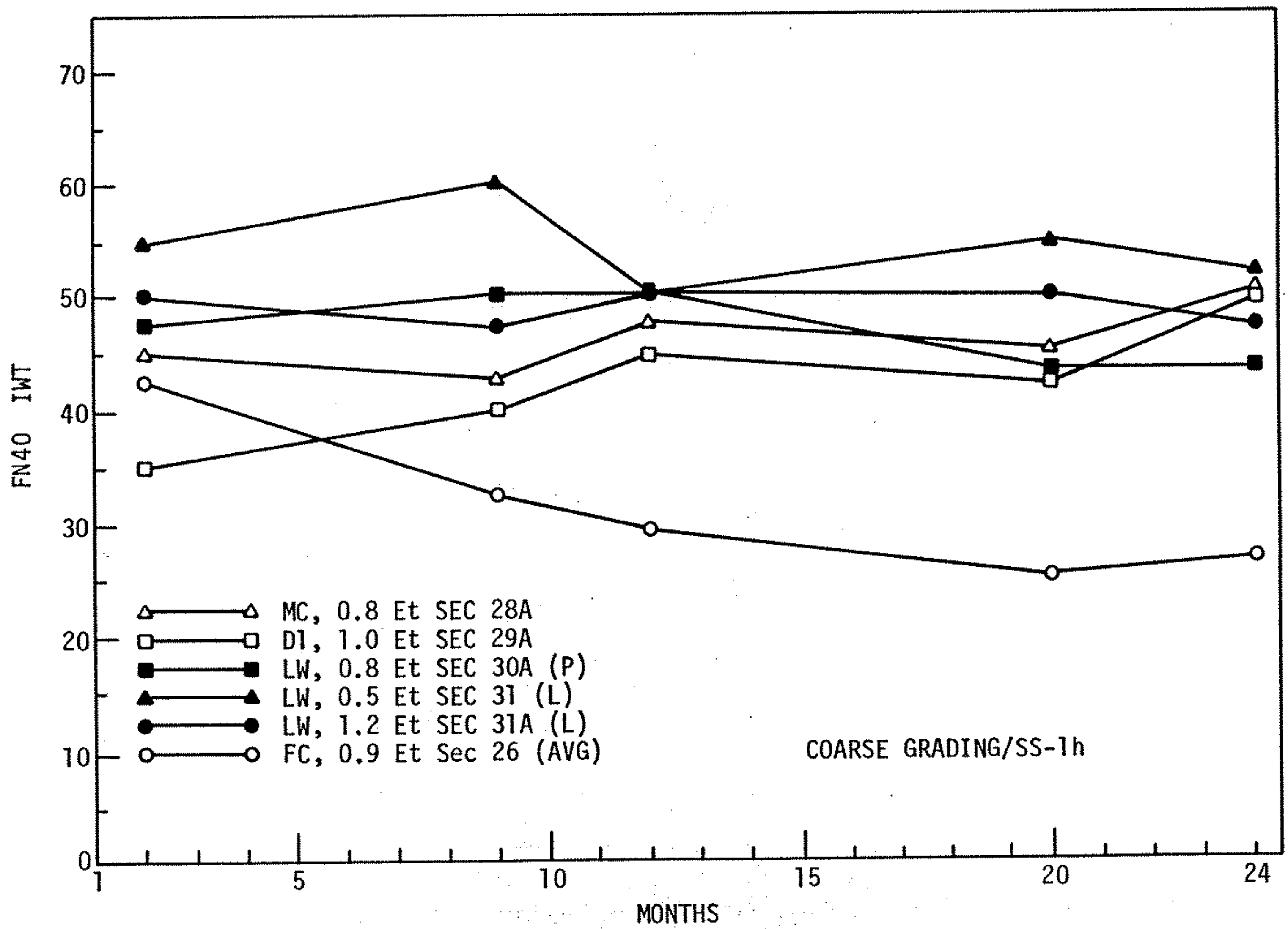


Fig. 15. Friction number at 40 mph (IWT) vs age, coarse grading/SS-1h.

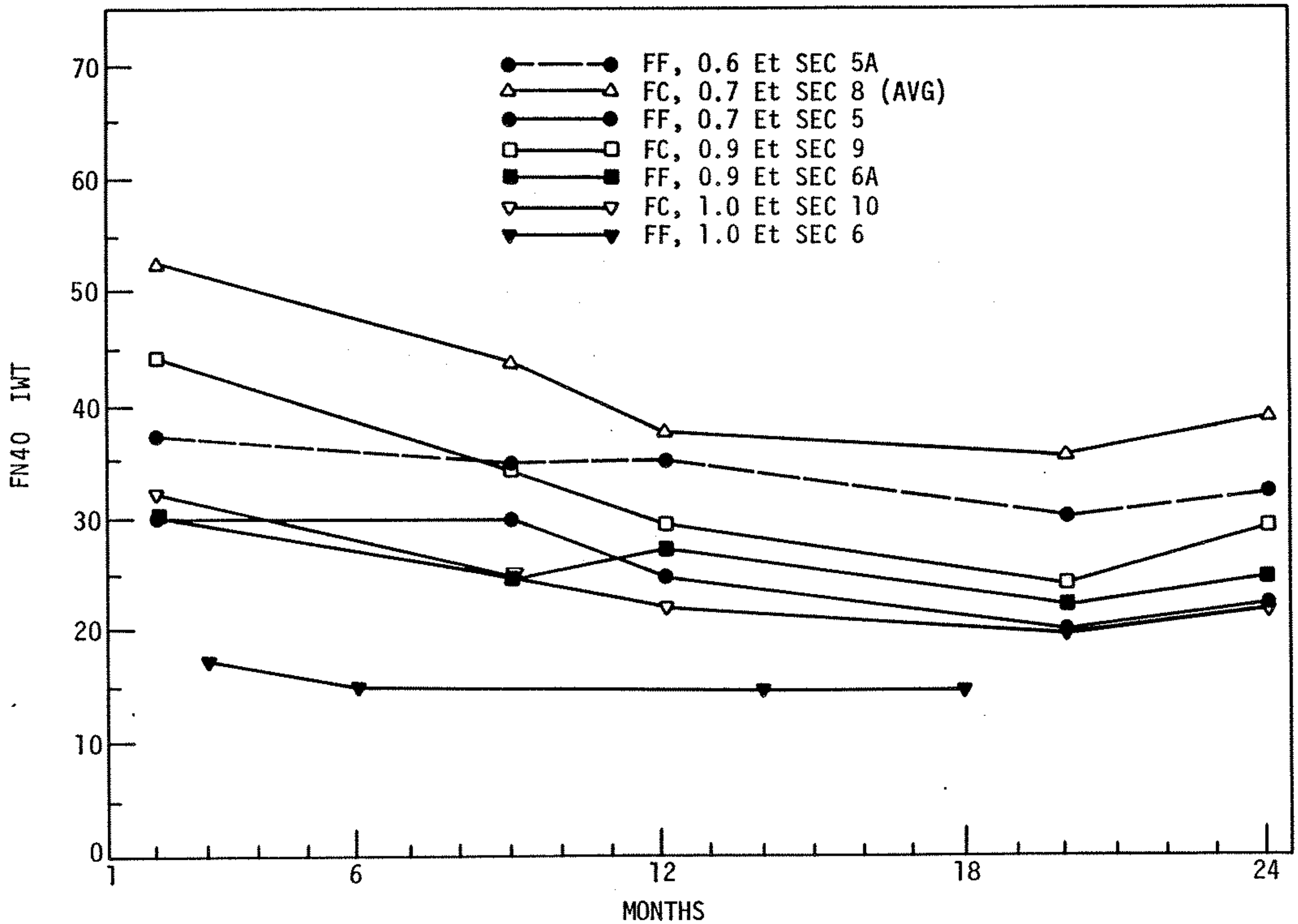


Fig. 16. Friction number at 40 mph (IWT) vs age, coarse vs fine gradings, Ferguson limestone.

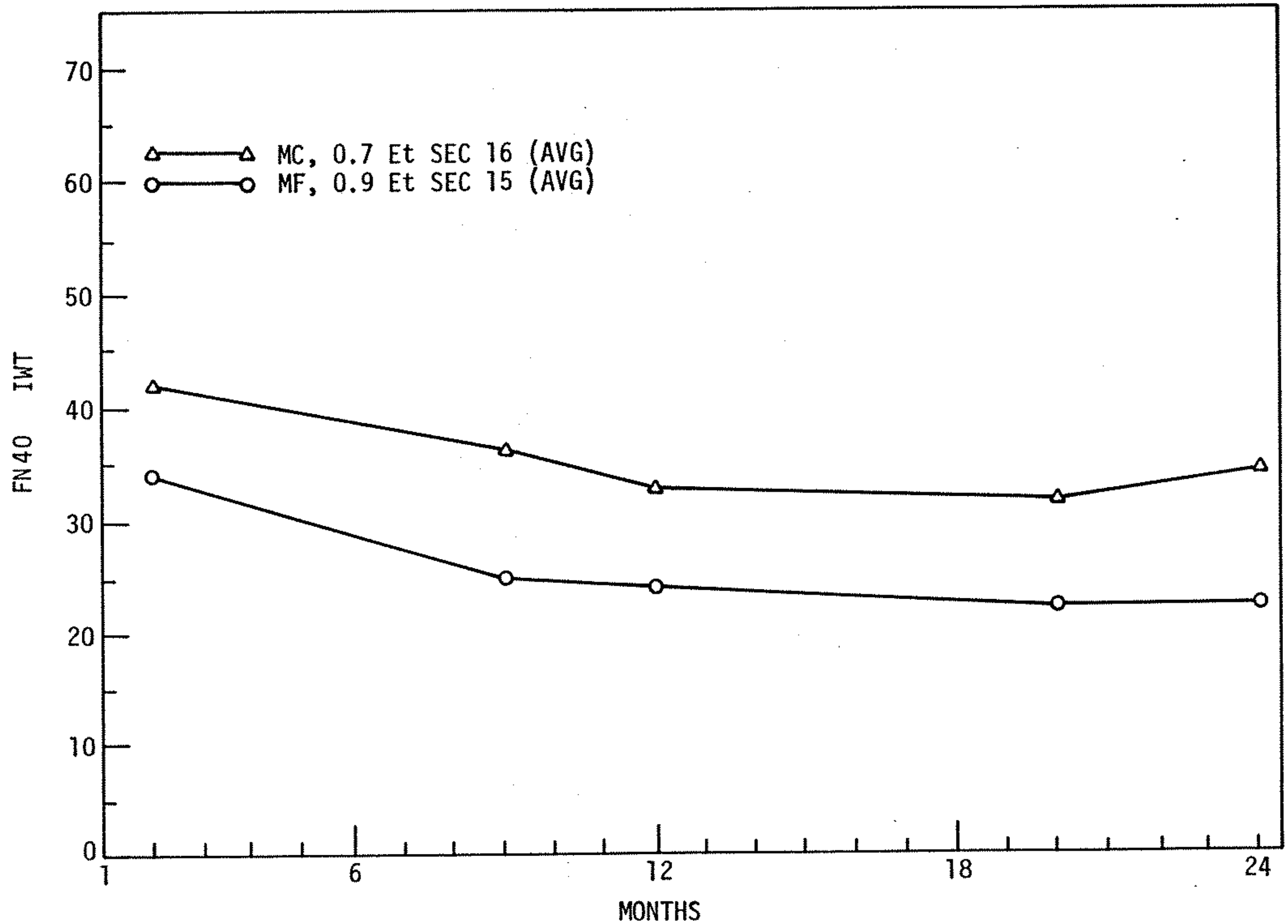


Fig. 17. Friction number at 40 mph (IWT) vs age, coarse vs fine gradings, Moscow dolomite.

it can also be seen that as emulsion content increases, the friction number decreases.

The effects of emulsion content (as percent of theoretical) and aggregate type are shown in Figs. 18 and 19. As emulsion content increases, the friction number decreases; the differences become more obvious after 12 months. Figure 19 again shows the distinctly high friction number of lightweight aggregate compared to Ferguson and Garner limestones.

Figure 20 shows the comparisons between standard and Iowa specification cationic emulsions (hard versus soft base asphalt). At least for Ferguson aggregate at about 70% of theoretical emulsion content, no differences could be observed.

In Fig. 21, the comparisons in friction number versus age plots between cationic and anionic slurry sections for four aggregates at about the same emulsion content are shown. No differences could be noted that could be attributed to the difference in emulsion type.

Figure 22 shows two paired sections where the only difference was filler type (Portland cement versus hydrated lime). Sections containing Portland cement as filler appeared to give somewhat higher friction numbers than did equivalent sections containing lime as filler.

Correlation and regression analyses were conducted between a number of aggregate characteristics such as aggregate type, grading (coarse versus fine), slurry characteristics determined on laboratory-prepared mixes such as WTAT wear, LWT sand adhesion, cured moisture content, cure time, cohesion, etc., field-measured slurry characteristics (flow), slurry seal performance in terms of friction numbers (40 mph

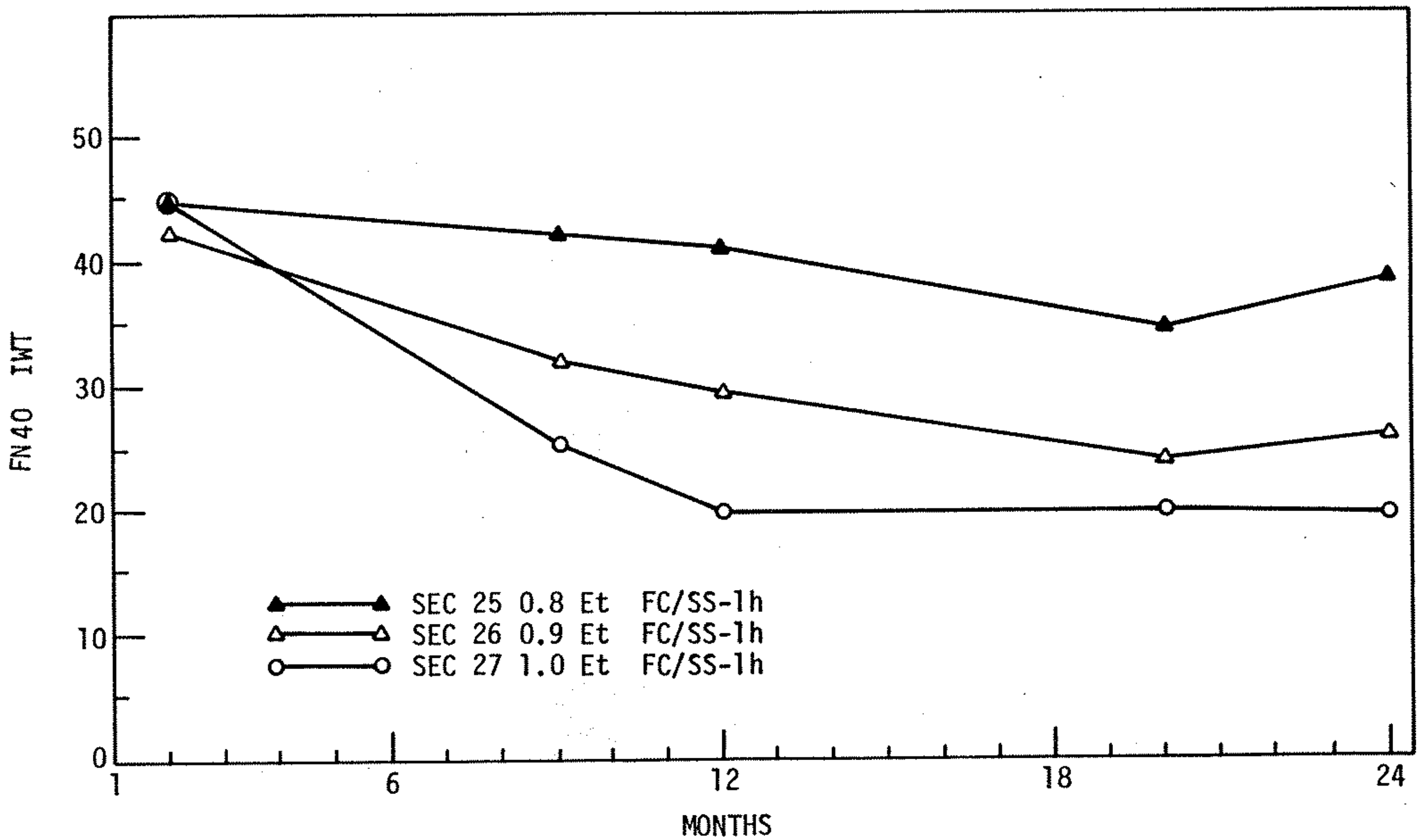


Fig. 18. Effect of emulsion content as percent of theoretical on friction number at 40 mph, Ferguson.

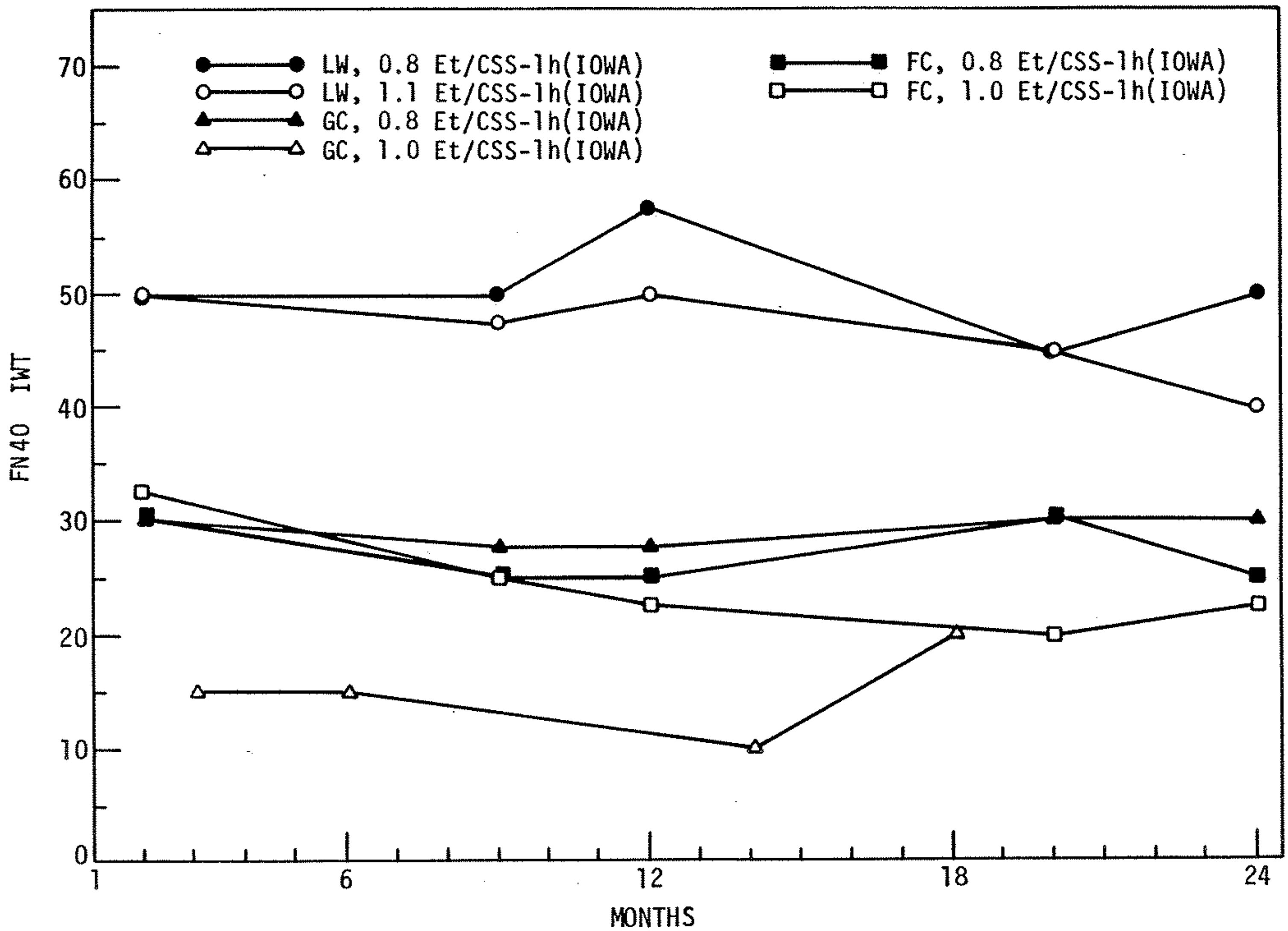


Fig. 19. Effect of emulsion content as percent of theoretical and aggregate type on friction number at 40 mph.

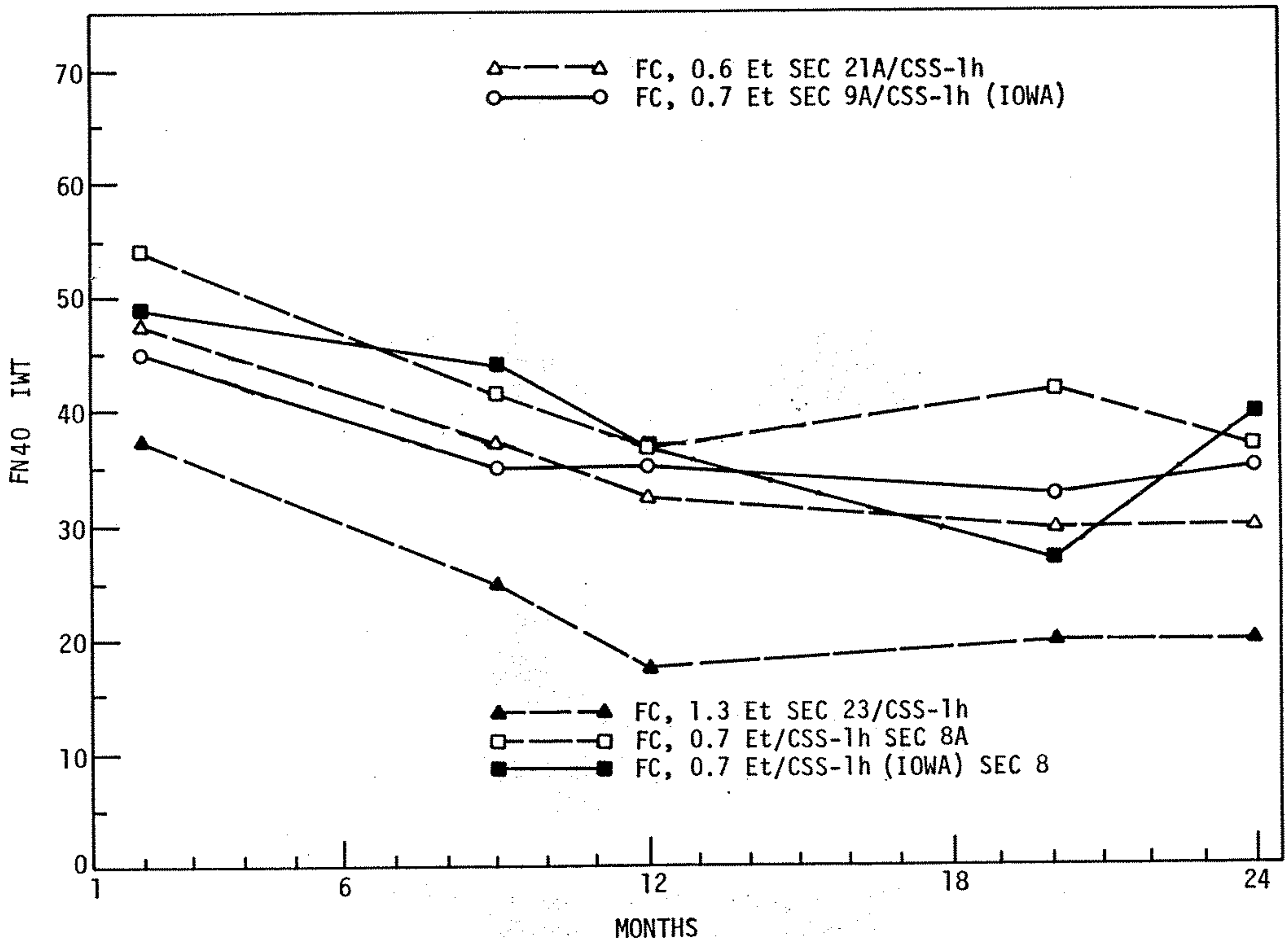


Fig. 20. Effect of base asphalt on FN40(IWT), hard (standard CSS-1h) vs soft (Iowa CSS-1h), Ferguson.

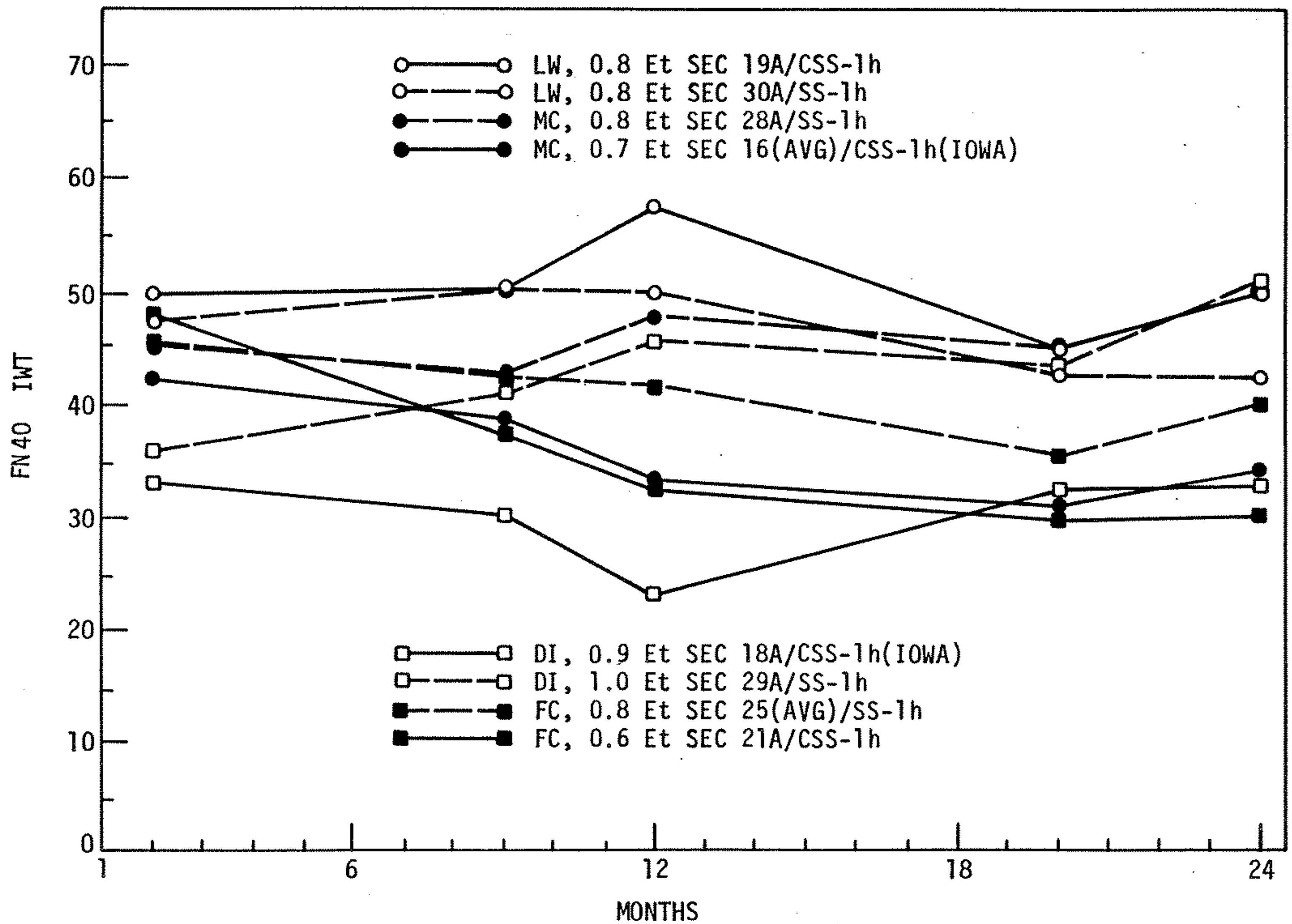


Fig. 21. Friction number at 40 mph (IWT), cationic vs anionic emulsion.

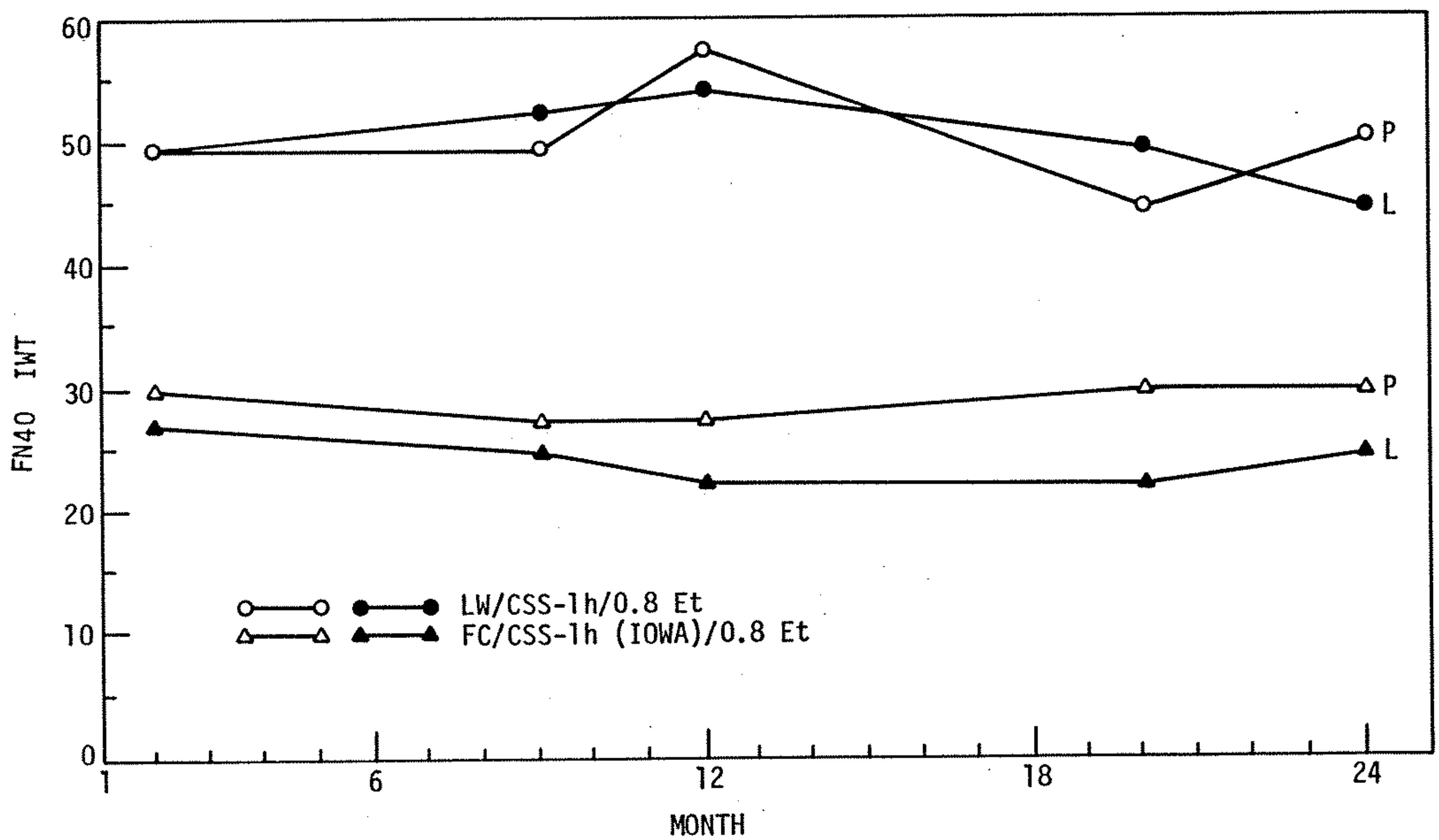


Fig. 22. Effect of filler type on friction number at 40 mph.

and 55 mph both in wheel track and at 1/4 point) at various ages, and slurry compositions (emulsion type and content, emulsion base asphalt grade, filler type and content, and percent theoretical content, Et). Significant correlation coefficients (at 0.01% level) are given in Table 8. The following can be stated:

- Friction number (FN) at both 40 and 55 mph is negatively correlated with percent theoretical emulsion content. The higher the emulsion content as percent theoretical content Et, the lower the friction number at all ages, at both 40 and 55 mph and measured both in wheel track and at 1/4 point.
- Laboratory-determined LWT (sand adhesion) is highly correlated with emulsion content as percent of theoretical content. The higher the emulsion content, the higher the LWT sand adhesion value.
- Laboratory-measured LWT sand adhesion is negatively correlated with field-measured friction numbers.
- Laboratory-determined WTAT is positively correlated with field-determined friction number.
- Sand equivalent of aggregate is positively correlated with WTAT and friction number.
- Field-measured slurry flow is negatively correlated with friction number and positively correlated with LWT sand adhesion value.
- Laboratory-determined cured moisture content is correlated with friction number.

Table 8. Correlation Coefficients of Test Section Characteristics.[a]

| | FN40 IWT | FN55 IWT | FN40 ¼-Point | FN55 ¼-Point | WTAT | LWT |
|---|---|---|---|---|---|---|
| $E_t$ | --- | -0.2644 | -0.2627 | -0.2561 | --- | 0.7132 |
| WTAT | 0.5332 | 0.4690 | 0.3659 | 0.3474 | 1.0000 | --- |
| LWT | -0.3397 | -0.3809 | -0.3412 | -0.3625 | --- | 1.0000 |
| SE | 0.5546 | 0.4865 | 0.2960 | 0.2791 | 0.6397 | --- |
| Flow | -0.3264 | -0.3076 | -0.2290 | --- | --- | 0.2505 |
| CMC | 0.2634 | 0.2568 | 0.3101 | 0.2908 | --- | --- |

[a]P at 0.0001.

Based on correlation data, a number of linear regression analyses were run. The equations of linear regression of more significant relationships are given in Table 9. While friction number at 40 mph can be predicted by age and theoretical emulsion content (Eq. 1) and by age and LWT (Eq. 2), the best predictive equation appears to be Eq. 5, where friction number at 40 mph in wheel track is linearly related to theoretical emulsion content (Et), age in months, WTAT, LWT and sand equivalent. Although friction number at 40 mph is significantly related to log LWT (Eq. 3), the relationship is greatly improved if lightweight aggregate is excluded (Eq. 4). Also, undoubtedly, friction number is significantly affected by aggregate type and grading (Eq. 6).

Effect of emulsion content (as percent of theoretical) of field test sections on FN40 (IWT) at 12 months for 19 test sections containing Ferguson aggregate is shown in Fig. 23. There is a definite decrease in FN with increasing emulsion content. To keep FN above 30 at 40 mph, the maximum emulsion content appears to be 80% of theoretical emulsion content calculated, based on 8 μm film thickness.

The relationship between FN40 (IWT) at 12 months and LWT sand adhesion is shown in Fig. 24. To maintain FN40 (IWT) above 35, LWT sand adhesion value must be below 17 grams per square foot. The maximum sand adhesion value from LWT corresponding to FN40 (IWT) of 30 is 27 grams per square foot.

Table 9. Equations of Linear Regression.

| Number | Equation | $R^2$ | P > F |
|---|---|---|---|
| 1 | FN40(IWT) = 49.43 - 0.30(age) - 11.71(Et) | 0.0883 | 0.0001 |
| 2 | FN40(IWT) = 46.15 - 0.31(age) - 0.27(LWT) | 0.1677 | 0.0001 |
| 3 | FN40(IWT) at 12 months (including LW aggregate) = 64.08 - 21.98 log(LWT) | 0.1909 | 0.0009 |
| 4 | FN40(IWT) at 12 months (excluding LW aggregate) = 68.14 - 26.78 log(LWT) | 0.3786 | 0.0001 |
| 5 | FN40(IWT) = 31.58 - 7.65(Et) - 0.33(age) + 0.03(WTAT) - 0.10(LWT) + 0.25(SE) | 0.4756 | 0.0001 |
| 6 | FN40(IWT) = f(aggregate grading, aggregate type) | 0.8621 | 0.0001 |

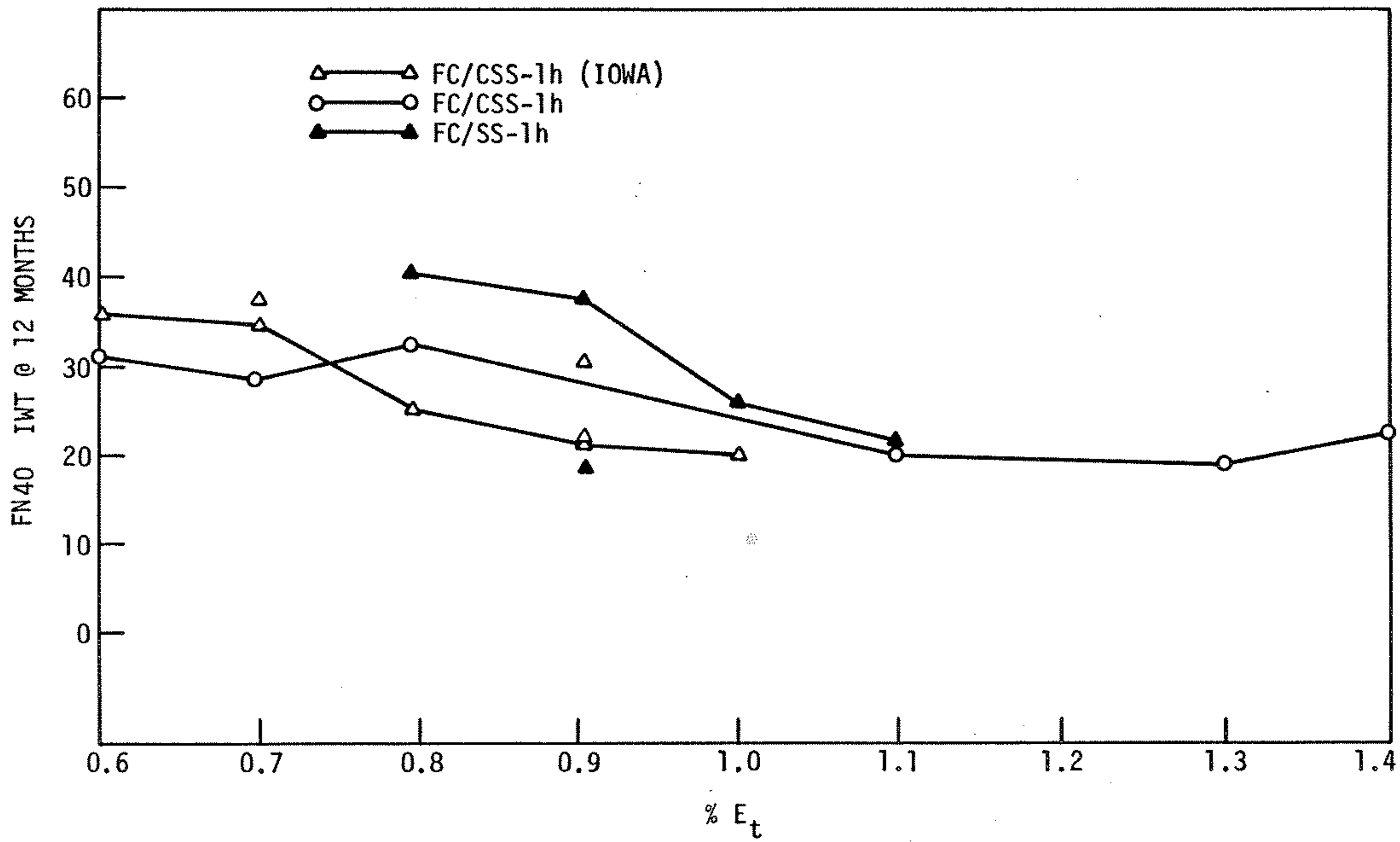


Fig. 23. Emulsion content as percent of theoretical vs FN40 at 12 months, Ferguson.

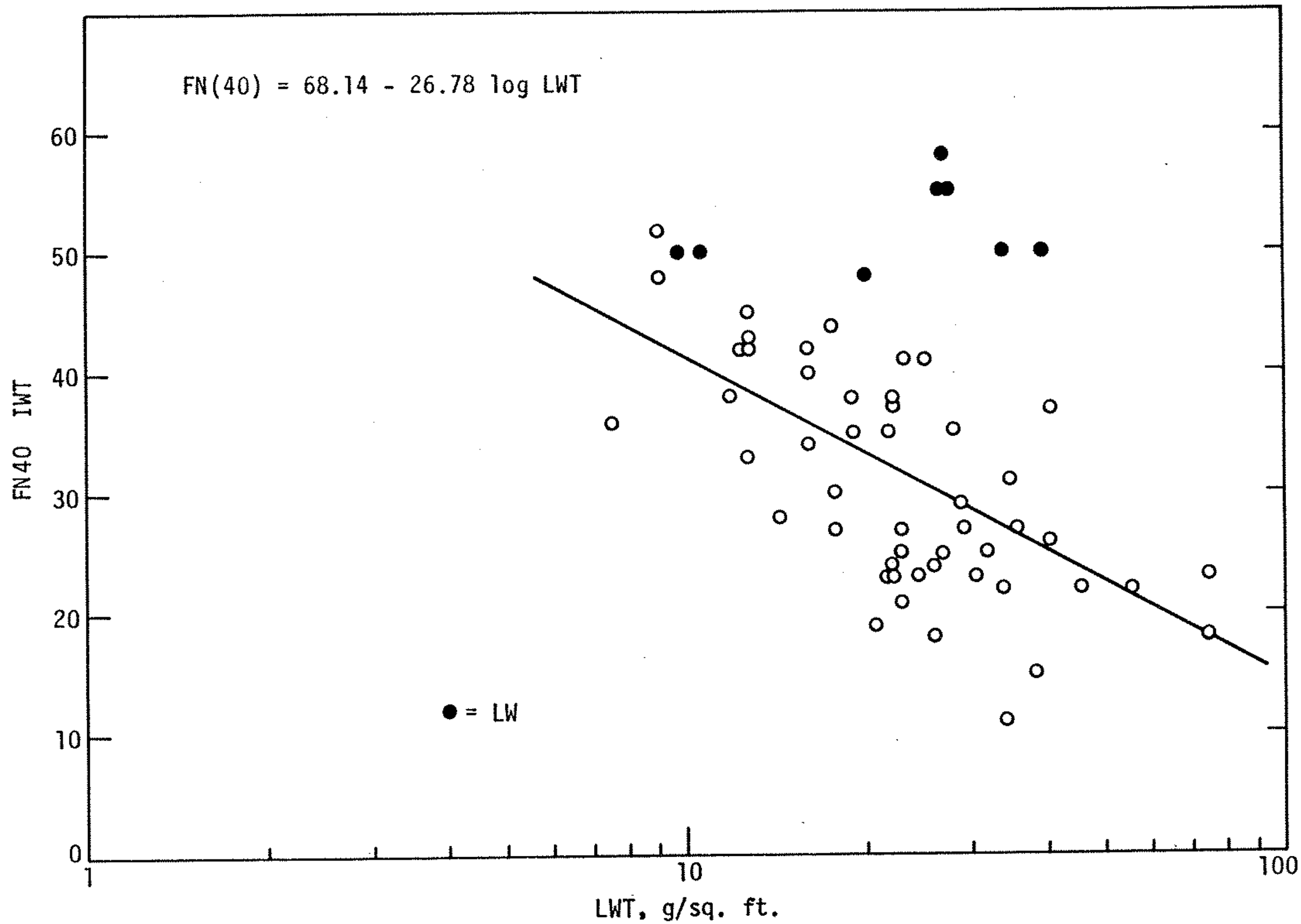


Fig. 24. Relationship between FN40(IWT) at 12 months and LWT sand adhesion (excluding LW aggregate).

# 7. SUMMARY AND CONCLUSIONS

As a part of the overall research program of evaluating asphalt emulsion slurry seal as a pavement maintenance material, 31 duplicate 500-ft test sections were constructed on U.S. 6 between Adel and Waukee in Dallas County during September and October 1978. The traffic count on this section of roadway in 1978 was 3760 vpd. These test sections included combinations of eight aggregates, two gradings, three asphalt emulsions, two mineral fillers and a range of emulsion contents determined by laboratory mix designs. The emulsion contents of the test sections varied from 10.3% (residue asphalt content of 6.5%) for Section 7A (Ferguson coarse) to 32.9% (residue asphalt content of 20.7%) for Section 31A (lightweight aggregate). In terms of theoretical emulsion content based on 8 μm film thickness, Et, the emulsion content varied from 0.5 to 1.4 Et. The post-construction performance evaluation of the test sections was primarily based on the friction numbers and surface appearances at different time intervals after construction. At the 24-month final evaluation, most of the test sections had carried a total of 1.4 million vehicles.

Inherent in any field-test program is the number of variables involved, some of which cannot be controlled. The more serious uncontrolled variables encountered in this field-test project included the weather conditions during construction (the temperature varied from an early morning low of 38° F to a high of 96° F, the sky condition varied from cloudy, foggy, drizzle, and rain to sunny and clear), the occasional machine breakdowns, the lack of control of pre-wet aggregate moisture content, and the difficulties in getting the proper emulsion contents based on designs and accurate determination of emulsion contents actually used in the slurry mixes. These factors made definitive correlations and conclusions difficult. Therefore, the conclusions that follow are general and tentative, and must be viewed as such. Further research and field tests are needed to verify and refine these conclusions.

1. Quality slurry seals of good appearances with satisfactory wear and frictional characteristics can be produced, provided the aggregates are suitable and the mixes are properly designed, evaluated and applied.
2. Friction number decreases with increasing emulsion content. Slurry mixes based on 8 μm film thickness and wet sieve analysis of aggregate were too rich for most sections. To provide satisfactory frictional characteristics, the maximum emulsion content appears to be about 80% of the theoretical emulsion content required for 8 μm film thickness, or about 6.5 μm film.
3. Coarse-graded slurries had consistently higher friction numbers than did the fine-graded slurries of the same material combinations and at the same emulsion contents.
4. Coarse-graded limestones from Ferguson and Moscow at proper emulsion contents and quartzite produced slurries of satisfactory performance with respect to surface appearance and frictional characteristics.
5. Lightweight aggregate slurries resulted in very good frictional characteristics in all sections.

6. None of the fine-graded materials, neither limestone from Garner nor crushed gravels, produced any sections with combinations of satisfactory appearance and frictional characteristics. It is to be noted that Garner limestone was the only aggregate used in the test program with a sand equivalent of less than 45.
7. Although laboratory tests showed lower wet track abrasion loss for anionic emulsion slurries than for corresponding cationic slurries, there was no noticeable difference in the appearance or performance factors of the two types of emulsions. Nor was there a difference in field cure time. The same can be said about the difference between CSS-1h (40-90 pen) (standard specifications) and CSS-1h (85-100 pen) (Iowa specification).
8. Friction number is significantly related to loaded wheel test sand adhesion.
9. A predictive equation was derived from an analysis of the data in the test sections. The friction number at 40 mph (FN40) of a slurry surface can be estimated from theoretical emulsion content (Et), age in months (T), WTAT loss, LWT, and sand equivalent (SE) by the following equation:

$$FN40 = 31.58 - 7.65\ (Et) - 0.33\ (T) + 0.03\ (WTAT) - 0.10\ (LWT) + 0.25\ (SE)$$

10. The extraction tests performed on slurries used in the project did not produce consistent and reasonable results. The slurry sampling and extraction test procedures currently being used should be reviewed.

## 8. RECOMMENDATIONS

1. Aggregate for asphalt emulsion slurry should be limited to limestone sources that will produce surfaces with good frictional characteristics.
2. Additional research is needed to evaluate quartzite aggregate in slurry surfaces.
3. Lightweight aggregate should be further evaluated either by itself or in combination with other aggregates.
4. A sand equivalency factor of 45 or better should be established as a specification for aggregates to be used in slurry work.
5. The procedure outlined in Appendix G, HR-185 Final Report, should be used in designing slurry seal mixes. The emulsion content should be based on washed sieve analysis of job aggregate and a 6.5 μm film thickness.
6. The type of emulsion should be determined on a project by project basis, not automatically ruling out the use of anionic emulsion.
7. The slurry seal machine to be used on the project should have positive control on a) the quantity of emulsion to be incorporated based on job-mix formula, b) the proper component mixing sequence; that is, the mineral filler shall be introduced at the same point as the aggregate. The water, calculated based on the design water content and the moisture in the aggregate, shall be introduced to pre-wet the aggregate and mineral filler prior to the introduction of emulsified asphalt, and c) the continuous flow of aggregate without segregation.

8. Additional research is needed to determine the upper limit of emulsion content as a function of traffic in terms of loaded wheel test results.
9. The slurry seal sampling and extraction methods currently being used should be reviewed.
10. Only coarse-graded slurry seal should be used where friction number is a major concern.
11. Tack coat, if specified, should be applied immediately prior to the application of slurry seal.

## ACKNOWLEDGEMENTS

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The following individuals contributed to the laboratory phase of this investigation: M. S. Chang, Ken Dedecker, Bob Hendrix and K. Y. Wong.

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# APPENDIX

Specification 820
Supersedes 793

IOWA DEPARTMENT OF TRANSPORTATION

Ames, Iowa

SUPPLEMENTAL SPECIFICATION

for

BITUMINOUS SLURRY SURFACE TREATMENT

November 8, 1977

THE STANDARD SPECIFICATIONS, SERIES OF 1977, ARE AMENDED BY THE FOLLOWING ADDITIONS. THIS IS A SUPPLEMENTAL SPECIFICATION AND SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

820.01 DESCRIPTION. The bituminous slurry surface shall consist of a mixture of emulsified asphalt, mineral aggregate, and water, properly proportioned, mixed, and spread evenly on the prepared surface as specified herein and as directed by the engineer. The cured slurry shall have a homogeneous appearance, shall fill all cracks, and shall adhere firmly to the surface.

820.02 MATERIALS.
A. Asphalt Emulsion. The emulsified asphalt shall meet requirements of AASHTO M 208, Type CSS-1h, except the Saybolt Furol Viscosity at 77 degrees F shall not be less than 15 seconds or more than 50 seconds, and the Cement Mixing Test will not be required. Certified analysis of each lot of material shall be furnished at time of delivery.
B. Aggregate. The mineral aggregate shall be composed of a combination of crushed stone and mineral filler meeting the following requirements:
Crushed Stone shall be produced from sources which normally show an abrasion loss not greater than 40 (grading A or B) and a freezing-and-thawing loss not greater than 10 (Laboratory Test Method 211, Method A) when tested using aggregate crushed to 3/4-inch maximum size. It shall be free of vegetative matter and other deleterious materials. Lithographic and sublithographic limestone shall not be used.
*Mineral Filler is required to obtain the necessary gradation and the desired mixture* consistency, and the addition rate will be established by the engineer, based on laboratory or field trials. Mineral filler shall meet requirements for Type I portland cement.
When tested by means of laboratory sieves, the composite aggregate, excluding mineral filler, shall meet the following requirements:

| Sieve Size | Percent Passing Min. | Percent Passing Max. |
|---|---|---|
| 3/8 | 100 | |
| No. 4 | 80 | 100 |
| No. 8 | 55 | 80 |
| No. 30 | 24 | 43 |
| No. 50 | 14 | 30 |
| No. 200 | 8 | 15 |

C. Water. All water used with the slurry mixture shall be potable and free from harmful soluble salts.
D. Composition and Quality of Mixture. Aggregate proposed for use on the project will be sampled by representatives of the contracting authority to determine a job-mix formula. After consulting with the contractor, a job-mix formula for the mixture will be set by the engineer on the basis of gradation, asphalt content, durability, and stability. This formula shall remain in effect until modified in writing by the engineer. When noncomplying results or other unsatisfactory conditions make it necessary, the engineer will establish a new job-mix formula, after consulting with the contractor. Should a change in sources of materials be made, a job-mix formula shall be set before the new material is used. Production gradation limits for the aggregates will be furnished as a guide to the contractor such that combination of these aggregates in the designated proportions should result in a gradation within the required limits and similar to that of the job-mix formula.
E. Stockpiling of Aggregate. Precautions shall be taken to insure that stockpiles do not become contaiminated with oversized rock, clay, silt, or excessive amounts of moisture. The stockpile shall be kept in areas that drain readily. Segregation of the aggregate will not be permitted.
F. Storage. The contractor shall provide suitable storage facilities for the asphalt emulsion. The container shall be equipped to prevent water from entering the emulsion. *Suitable and adequate heat shall be provided to prevent freezing and to facilitate* handling of the asphalt emulsion.
G. Sampling. Samples of materials and the finished slurry surfaces shall be furnished by the contractor as directed by the engineer during the process of the work.
H. Asphalt Content. The estimated asphalt residue content is 9 to 12 percent of the dry aggregate.

820.03 EQUIPMENT. All equipment, tools, and machines shall be subject to approval of the engineer and shall be maintained in satisfactory working order at all times.

A. Slurry-Mixing Equipment. The slurry-mixing machine shall be a continuous-flow mixing unit, capable of delivering accurately a predetermined proportion of aggregate, water, and asphalt emulsion to a multishaft pugmill mixer and discharging the thoroughly mixed product on a continuous basis. The aggregate shall be prewetted immediately prior to mixing with the emulsion. The multiblades of the mixing unit shall be capable of thoroughly blending all ingredients together. No violent mixing shall be permitted.

The mixing machine shall be equipped with an approved fines feeder that provides an accurate metering device or method to introduce a predetermined proportion of mineral filler into the mixer at the same time and location that the aggregate is fed. The fines feeder shall be used whenever added mineral filler is a part of the aggregate blend.

The aggregate feed to the mixer shall be equipped with a revolution counter or similar device so the amount of aggregate used may be determined at any time.

The emulsion pump shall be of the positive-displacement type and shall be equipped with a revolution counter or similar device so that the amount of emulsion used may be determined at any time.

The water pump for dispensing water to the mixer shall be equipped with a meter which will read out in total gallons. The pump shall be equipped with a minimum of two valves. One valve shall establish the required water flow. The other valve shall be a quick-acting valve to start and stop the water flow.

The addition of any additive to the mixture or any component material shall require a metering device attached to the slurry machine. Such device shall have positive, quick-acting controls, shall be easily calibrated, and shall maintain accurate and uniform flow.

The mixer shall have a means of calibration, and calibration will be required. The controls for proportioning each material to be added to the mix shall be calibrated and properly marked. They shall be accessible for ready calibration and shall be so placed that the engineer may determine the amount of each material being used at any time.

The mixing machine shall be equipped with a "fifth wheel" type of odometer that will measure the total feet traveled.

The mixing machine shall be equipped with a water-pressure system and fog-type spray bar adequate for complete fogging of the surface preceding spreading equipment, controllable to an application rate of 0.05 gallon per square yard.

Sufficient machine storage capacity to mix properly and apply a minimum of five tons of the slurry shall be provided.

B. Slurry-Spreading Equipment. Attached to the mixer machine shall be a mechanical-type, squeegee distributor equipped with flexible material in contact with the surface to prevent loss of slurry from the distributor. It shall be maintained so as to prevent loss of slurry on varying grades and crown by adjustments to assure uniform spread. There shall be a steering device and a flexible strike-off. The spreader box shall be adjustable from 8 to 13 feet at any increment. The box shall be kept clean, and build-up of asphalt and aggregate on the box shall not be permitted.

C. Cleaning Equipment. Power brooms, power blowers, air compressors, water-flushing equipment, and hand brooms shall be suitable for cleaning the surface and cracks of the old surface.

D. Auxiliary Equipment. Hand squeegees, shovels, and other equipment shall be provided as necessary to perform work.

E. Compaction Equipment. A self-propelled, pneumatic-tired roller shall be furnished for rolling the slurry mixture. It shall be of the 5-ton class.

820.04 PREPARATION OF SURFACE. Immediately prior to applying the slurry, the surface shall be cleaned of all loose material, silt spots, vegetation, and other objectionable material. Any standard cleaning method used to clean pavements will be acceptable, except water flusing will not be permitted in areas where considerable cracks are present in the pavement surface. The prepared surface shall be subject to approval of the engineer.

820.05 TACK COAT. After cleaning, the surface shall be given a tack coat of diluted emulsion of the same type and grade used in the slurry mixture. The emulsion should be diluted, 3 parts water to 1 part emulsion, and applied to the surface at a rate between 0.05 and 0.10 gallon per square yard. The engineer shall give final approval to the design and rate of application used.

820.06 COMPOSITION AND RATE OF APPLICATION OF THE SLURRY MIX. The amount of asphalt emulsion to be blended with the aggregate shall be that determined by the laboratory report after final adjustment in the field. A minimum amount of water shall be added as necessary to obtain a fluid and homogeneous mixture. The estimated minimum rate of application is 15 pounds of dry aggregate per square yard. The engineer shall give final approval to the design and rate of application used.

Materials used for calibration purposes shall not be used in the slurry mixture and shall not be returned to stockpiles or storage for such use. Asphalt emulsion used for calibration purposes may be used for the tack coat or wasted, at the contractor's option. Aggregate used for calibration purposes is to be wasted.

820.07 WEATHER LIMITATIONS. Slurry mixture shall not be placed when the temperature on a shaded portion of the road is less than 50 degrees F or during periods of abnormally high relative humidity.

820.08 MAINTENANCE OF TRAFFIC. Suitable methods, such as barricades, flagmen, pilot cars, etc., shall be used to protect the public and the uncured slurry surface from all types of traffic. Any damage to the uncured slurry will be the responsibility of the contractor. The road will not be closed for construction; normal traffic shall be maintained on the project at all times, and a detour will not be provided. Traffic shall not be delayed unnecessarily. The provisions for handling traffic are to be according to 1107.09 and the following:

Traffic shall be conducted through the restricted portions of the project with pilot cars. Pilot cars shall be pickup trucks or other approved vehicles, preferably carrying the contractor's company insignia, equipped with signs reading: PILOT CAR--FOLLOW ME: Two signs shall be mounted on the vehicle so as to be clearly visible from both directions. The bottoms of the signs shall be mounted at least one foot above the top of the cab. Letter size on these signs shall be a minimum 6 inch, Series C.

The pilot car, while on duty, shall be used exclusively to lead traffic and shall be used for no other purpose. While traffic is restricted, the pilot car shall be kept in continuous operation causing no delays to traffic due to periods for refueling, lunch, etc. If the pilot car is used at any time for other purposes, the signs shall be removed or covered.

One flagman shall be stationed immediately ahead of the application of the bituminous mixture, one flagman immediately behind the bituminous mixture, and one flagman immediately behind the section being rolled. Suitable warning, speed-limit, and fresh oil signs shall be displayed, and the signs shall be moved forward with the flagman as the work progresses.

Signs will be provided by the contracting authority in accordance with 1107.09 except flagman's stop and slow signs which will be furnished by the contractor. Placement of warning signs and flagman procedure shall be in accord with Supplemental Specification for Traffic Controls, a separate specification.

These foregoing requirements for pilot car and flagmen may be modified or waived in in part by the engineer on roads or portions of roads where, in built-up areas, it is more practical to place the work in short sections and allow the traffic to use the road immediately after the work is completed or where traffic is low in density and local in nature and alternate routes are apparent.

820.09 *APPLICATION OF THE SLURRY SURFACES.*

A. General. The surface shall be fogged with water directly preceding the spreader at a rate not to exceed 0.05 gallon per square yard. The slurry mixture shall be of the desired consistency when deposited on the surface, and no additional elements shall be added. Total time of mixing shall not exceed 4 minutes. A sufficient amount of slurry shall be carried in all parts of the spreader at all times so that complete coverage is obtained. No lumping, balling, or unmixed aggregate shall be permitted. No segregation of the emulsion and aggregate fines from the coarse aggregate will be permitted. If the coarse aggregate settles to the bottom of the mix, the slurry will be removed from the pavement. No excessive breaking of the emulsion will be allowed in the spreader box. No streaks, such as caused by oversized aggregate, will be left in the finished pavement.

B. Joints. No excessive build up or unsightly appearance shall be permitted on longitudinal or transverse joints. The use of burlap drags or other types of drags shall be subject to the approval of the engineer.

C. Hand Work. Approved squeegees shall be used to spread slurry in areas nonaccessible to the slurry mixer. Care shall be exercised to leave no unsightly appearance from hand work.

D. Curing. The treated area will be allowed to cure until such time as it may be opened to traffic or rolled without pickup of the slurry mixture. The paved surface shall then be rolled by the pneumatic-tired roller. The roller should be operated at a tire pressure of 50 pounds per square inch. The paved area shall be rolled as directed by the engineer.

E. Opening to Traffic. After curing and rolling, the treated area may be opened to traffic.

820.10 *METHOD OF MEASUREMENT.* The bituminous slurry surface will be measured by the engineer as follows:

A. Aggregate for Slurry Seal. The number of tons of aggregate used in accepted portions of the work will be measured by weight of individual loads. No deduction will be made for moisture naturally occurring in the aggregate. The quantity of mineral filler will be included, and this quantity may be computed from a count of sacks of sacked cement used.

B. Asphalt Emulsion for Slurry Seal. The number of gallons of asphalt emulsion, including undiluted tack coat, used in accepted portions of the work will be measured by volume (using a tank with approved calibration) or by weight. No deduction will be made for water in approved emulsion. The gallons shall be corrected for temperature to 60 degrees F.

Materials actually wasted after being used for calibration purposes will be included in quantities measured for payment, but the amount so included shall not exceed 5 tons of aggregate and 100 gallons of asphalt emulsion.

820.11 BASIS OF PAYMENT. Bituminous Slurry Surface treatment will be paid for as follows:

A. Aggregate for Slurry Seal. For the number of tons of aggregate, measured as provided above, the contractor will be paid the contract unit price per ton. Such amount shall be full payment for furnishing all materials except asphalt emulsion, all equipment and labor necessary to prepare the surface, mix, and apply the slurry, and control traffic.

B. Asphalt Emulsion for Slurry Seal. For the number of gallons of asphalt emulsion, measured as provided above, the contractor will be paid the contract unit price per gallon. Such amount shall be full payment for furnishing the asphalt emulsion. Article 1109.03 shall not apply to this item of asphalt emulsion.