PRELIMINARY EVALUATION OF THE KEMPSTER VOIDMETER

Report 85-7

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Reporting on Work Plan 82-C-28

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

SUSAN C. CRAMPTON, SECRETARY
FRANK E. ALDRICH, P.E., CHIEF ENGINEER
R. F. NICHOLSON, P.E., MATERIALS & RESEARCH ENGINEER
C. C. BENDA, P.E., STRUCTURAL CONCRETE ENGINEER

Prepared By:
Structural Concrete Subdivision

Reviewed By:

R. F. Nicholson

R. F. Nicholson, P.E.
Materials & Research Engineer

Date: 05-08-'85

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ABSTRACT

An apparatus for measuring percent of voids and specific gravity of aggregates and percent of voids of dry concrete mixtures was purchased by the Materials and Research Division in 1982. The device was developed by E. Kempster and is known as the Kempster Voidmeter.

This report documents the results of tests performed with the voidmeter and compares them with results obtained using conventional AASHTO test methods. Part of the evaluation included development of an operating manual outlined in VT AOT-MRD-36-85, "Method of Test For Void Content And Specific Gravity of Aggregates And Cement/Aggregate Combinations By The Voidmeter Method.

Tests indicate the voidmeter has value primarily in determining the voids in various cement/aggregate combinations. This application may be significant when concrete is to be pumped as the absence of voids in the solid particle system reduces the chances of concrete dewatering.

INTRODUCTION

A Kempster Voidmeter was purchased by the Materials and Research Division from Jencons (Scientific)Limited, Leighton Buzzard, England in the fall of 1982. Information previously obtained indicated the voidmeter would quickly and simply determine void contents of fine and coarse aggregates, aggregate mixtures and aggregate/cement mixtures [1].

Research has demonstrated that the void content of combined aggregates in a concrete mix is related to the pumpability of the concrete. Study has also shown that when void content is minimized, finishes of increased quality are obtained and mixes are said to have increased workability and cohesion under heavy vibration, without segregation or bleeding [2,3].

The apparatus studied in this investigation was developed by E. Kempster [1]. It is based on determining percent voids by measuring the head of water which can be supported by a partial vacuum created within an aggregate sample [4]. The apparatus can also be used to determine the specific gravity of fine and coarse aggregates.

This report represents a preliminary investigation of the operation and capabilities of the Kempster Voidmeter. Techniques and procedures for using the apparatus were developed and refined during the investigation.

Tests were performed on selected fine and coarse aggregates, aggregate mixtures and aggregate/cement mixtures. Aggregates used were chosen from the 1983 Annual Aggregate Testing Program, allowing results of voidmeter tests to be compared to test results obtained through conventional AASHTO test methods.

APPARATUS

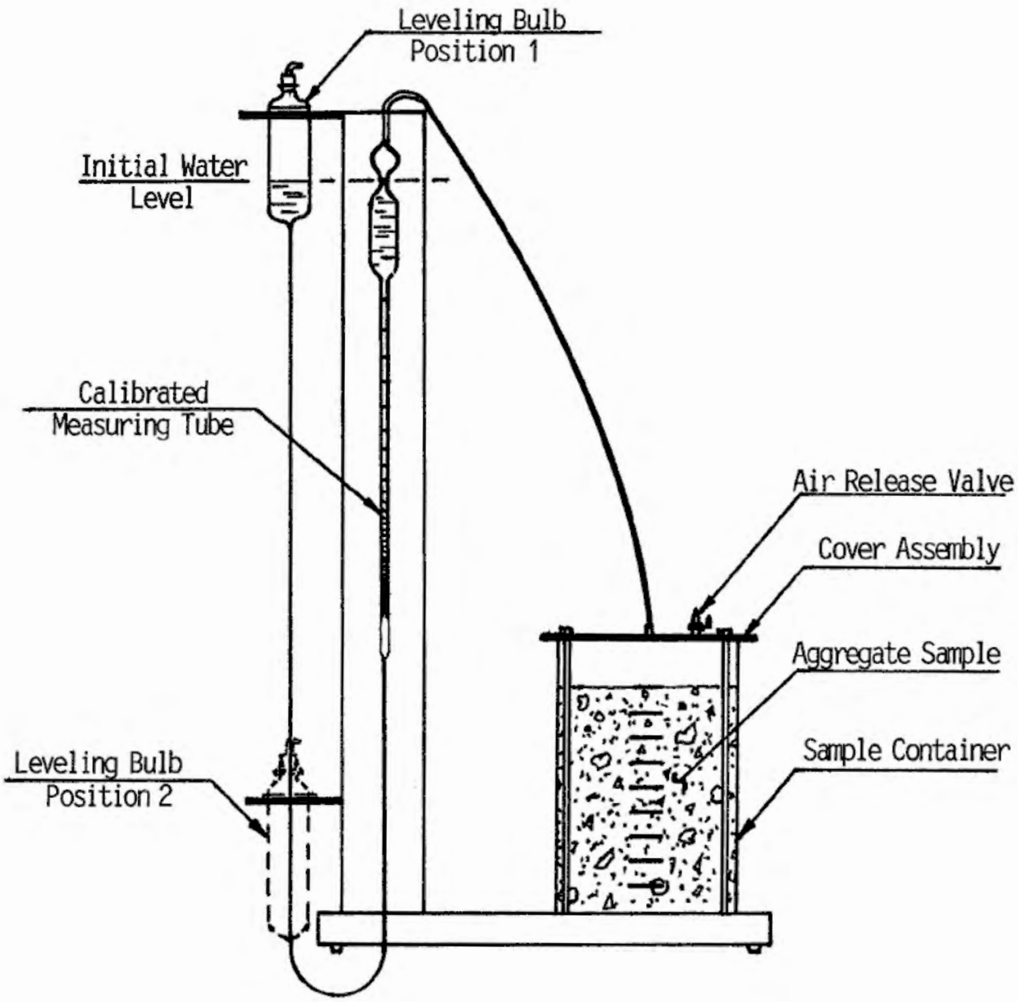
The apparatus used in this investigation consists of the following:

A. (1) Kempster Voidmeter

The voidmeter developed by E. Kempster is illustrated in Figure 1. The material to be examined is placed in the glass sample container in 25mm layers to the uppermost mark on the container which indicates 3.5 liters. Each layer is compacted with a tamper included with the apparatus. The tamper is also used as a spacer for indicating when the sample has reached the required level in the container.

Once the sample is in place, the sample container is sealed with an air tight cover. At this point, the air release valve is opened, allowing the water in the system to be adjusted to the level shown in position 1 of Figure 1.

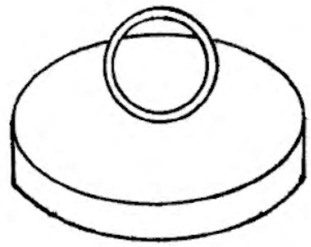
To determine the voids in a sample, the air release valve is closed and the reservoir is lowered to position 2, creating a head of water in the calibrated measuring tube. As the water in the tube tries to reach equilibrium, it causes a vacuum within the sample container. The head of water sustained in the measuring tube is inversely proportional to the volume of air in the sample. This volume of air is equal to the voids in the sample and can be read directly off the pre-calibrated measuring tube.



KEMPSTER VOID MEASURING APPARATUS
FIGURE I

A. (2) Tamping Piston (See Figure II)

The piston consists of a steel disc with rubber discs bonded to the top and the bottom, as protection against damage to the glass container. For convenience, the thickness of the piston is such that when the volume of the sample is 3.5 liters, the top of the piston is flush with the top of the container. The weight of the tamping piston is 3.15 kilograms.



5 1/4 inches diameter
1 3/8 inches depth

TAMPING PISTON
FIGURE II

B. Balance

Mettler P 11N
10 Kilogram capacity

C. Scoop

A round mouth aluminum scoop, 3 inches wide x 5 inches long.

D. Spoon

A stainless steel spoon, 11 1/2 inches long.

E. Mixing Container

A rubbermaid plastic dish, 11 inches wide x 13 inches long x 5 1/2 inches deep.

MATERIALS

The materials used in this investigation are as follows:

Graded Standard Sand

Screened Silica 20-30 meeting the requirements outlined in AASHTO T 106.

Fine Aggregate (See Table 1)

A. G. Anderson, Highgate, Vt.

Calkins Redimix, Coventry, Vt.

J. P. Carrara, E. Middlebury, Vt.

J. P. Carrara, N. Clarendon, Vt.

W. E. Dailey, Manchester, Vt.

W. E. Dailey, S. Shaftsbury, Vt.

S. T. Griswold, Williston, Vt.

Hinesburg S & G, Hinesburg, Vt.

Lawrence Sangravco, Guildhall, Vt.

Lebanon Crushed Stone, W. Lebanon, N.H.

A. S. Nadeau, Johnson, Vt.

Northfield S & G, Northfield, MA

Pike Industries, Waterford, Vt.

F. W. Whitcomb, Wallingford, Vt.

*F. W. Whitcomb, Winooski, Vt.

*Manufactured sand

Coarse Aggregate (See Table 2)

3/4 Inch Crushed Gravel

Calkins Redimix, Coventry, Vt.
J.P. Carrara, E. Middlebury, Vt.
W.E. Dailey, S. Shaftsbury, Vt.
Lawrence Sangravco, Guildhall, Vt.
Northfield S&G, Northfield, MA

3/4 Inch Crushed Stone

Lebanon Crushed Stone, W. Lebanon, N.H.
Swanton Limestone, Swanton, Vt.
F.W. Whitcomb, N. Walpole, N.H.
F.W. Whitcomb, Winooski, Vt.

3/4 Inch Crushed Igneous Stone

Cooley, Websterville, Vt.

Cement

Type II

Northeast Cement Co., St. Constant, Que.

TABLE 1

FINE AGGREGATE - GRADATION TEST DATA

	Sieve Size								
	3/8"	No.4	No.8	No.16	No.30	No.50	No.100	No.200	Fineness Modulus
	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing	
A. G. Anderson, Highgate, Vt.	100	99	86	64	40	16	4	1	2.91
Calkins Redimix, Coventry, Vt.	100	100	88	65	42	20	7	2	2.78
J.P. Carrara, E. Middlebury, Vt.	100	97	83	63	41	18	5	1	2.93
J.P. Carrara, N. Clarendon, Vt.	100	99	90	70	43	21	10	4	2.67
W.E. Dailey, Manchester, Vt.	100	99	89	62	35	19	9	4	2.87
W.E. Dailey, S. Shaftsbury, Vt.	100	95	72	47	30	17	6	2	3.33
S.T. Griswold, Williston, Vt.	100	99	91	75	49	22	9	5	2.55
Hinesburg S&G, Hinesburg, Vt.	100	98	81	68	49	24	8	2	2.72
Lawrence Sangravco, Guildhall, Vt.	100	100	87	62	37	17	5	2	2.92
Lebanon Crushed Stone, W. Lebanon, N.H.	100	100	90	73	45	15	5	2	2.72
A.S. Nadeau, Johnson, Vt.	100	97	76	55	37	19	7	2	3.09
Northfield S&G, Northfield, MA	100	100	90	70	44	20	5	1	2.71
Pike Industries, Waterford, Vt.	100	99	89	71	46	24	11	6	2.60
F.W. Whitcomb, Wallingford, Vt.	100	99	85	62	40	23	11	4	2.80
*F.W. Whitcomb, Winooski, Vt.	100	100	94	60	35	23	10	3	2.78

*Manufactured Sand

TABLE 2

COARSE AGGREGATE - GRADATION TEST DATA

	Sieve Size				
	1"	3/4"	3/8"	No.4	No.8
	% Passing	% Passing	% Passing	% Passing	% Passing
Calkins Redimix, Coventry, Vt.	100	99	31	7	1
J.P. Carrara, E. Middlebury, Vt.	100	94	26	2	1
Cooley, Websterville, Vt.	100	96	28	2	1
W.E. Dailey, S. Shaftsbury, Vt.	100	97	25	4	2
Lawrence Sangravco, Guildhall, Vt.	100	96	47	7	3
Lebanon Crushed Stone, W. Lebanon, N.H.	100	100	43	22	5
Northfield S&G, Northfield, MA	100	98	38	9	2
Swanton Limestone, Swanton, Vt.	100	100	59	2	1
F.W. Whitcomb, N. Walpole, N.H.	100	98	32	6	1
F.W. Whitcomb, Winooski, Vt.	100	99	26	4	1

PROCEDURES

Prior to commencing any physical work with the apparatus, a complete review of available literature was conducted. The manufacturer's data, received with the voidmeter, provided very little useful information regarding operation of the device. However, papers published by E. Kempster, et al, discussing voids in aggregates and techniques for improving the pumpability of concrete did supply information which allowed testing to begin.

Samples used in this investigation were first subjected to testing in the Materials and Research Division's 1983 Annual Aggregate Testing Program. The remaining portions of samples were then used to evaluate the voidmeter.

Fine and coarse aggregate samples were reduced by splitting to obtain a 10 - 15 kilogram test sample. Voidmeter tests were repeated three times to establish average results and to examine reproducability of results. Aggregates were generally examined by compacting materials in a dry condition. Only one source of fine aggregate, Northfield S & G, Northfield, MA was examined in a dry loose condition as well as in a saturated-surface-dry, compacted condition. In addition to determining the percent of voids in each aggregate, several materials were also examined for specific gravity using the voidmeter.

Aggregate mixtures and aggregate/cement mixtures were examined for percent voids using the same proportions used in Vermont Agency of Transportation Class B concrete. Materials were mixed in small quantities to minimize segregation during handling. The combinations of materials were also examined in a compacted condition.

The method of filling the container and compacting the materials was described in one of the papers published by E. Kempster [1]. Materials were placed in the sample container in 25mm layers, each layer being compacted by dropping the tamping piston ten times through 25mm.

Combinations of materials were prepared by determining the quantities necessary to equal a 25mm layer in the sample container. The materials were weighed and mixed in the correct proportions and the mixture placed in the container. The materials were compacted by tamping as noted previously. The procedure of weighing and mixing individual layers was repeated until the container was filled.

The specific gravity of aggregates was established by first obtaining the void content of the compacted material. The material was then removed from the container and the weight of the sample determined in grams. The specific gravity was then calculated as follows:

$$V_v = \frac{V \times C}{100}$$

$$V_s = C - V_v$$

$$W_w = V_s \times 1.0 \text{ gm/cm}^3$$

$$S.G. = \frac{W_s}{W_w}$$

Where:

C = Volume of container (3500 cm^3)

V = Percent voids

V_v = Volume voids

V_s = Volume of sample

W_s = Weight of sample

W_w = Weight of equal volume of water

RESULTS

The results of tests performed using fine aggregates are shown in Table 1. Coarse aggregate test results are shown in Table 2. Both Table 1 and Table 2 contain a comparison of results obtained using the Kempster Voidmeter and results obtained using AASHTO test methods.

The percent voids of aggregate combinations and aggregate/cement combinations are shown in Table 3.

TABLE 3

FINE AGGREGATE TEST RESULTS

Source	Percent Voids: Kempster Voidmeter Test #1	#2	#3	Avg.	AASHTO T19-80	Apparent Sp. Gr.: Kempster Voidmeter	AASHTO T84-81
Anderson, Highgate, Vt.	36.5	35.7	34.8	35.7	33.1	-	2.70
Calkins, Coventry, Vt.	31.2	31.2	31.0	31.1	32.6	2.77	2.72
Carrara, E. Middlebury, Vt.	29.5	29.7	29.5	29.6	35.4	2.70	2.67
Carrara, N. Clarendon, Vt.	31.5	31.2	31.2	31.3	34.1	2.69	2.69
Dailey, Manchester, Vt.	33.6	32.5	32.5	32.9	31.4	-	2.73
Dailey, So. Shaftsbury, Vt.	29.0	29.5	28.5	29.0	32.4	-	2.74
Griswold, Williston, Vt.	30.7	31.0	31.3	31.0	33.8	2.72	2.70
Hinesburg S & G, Hinesburg, Vt.	31.5	31.7	31.2	31.5	31.3	2.81	2.70
Lawrence Sangravco, Guildhall, Vt.	34.5	34.3	33.6	34.1	33.9	-	2.73
Lebanon Crushed Stone, W. Lebanon, N.H.	34.3	34.0	34.5	34.3	36.0	2.81	2.73
Nadeau, Johnson, Vt.	34.0	34.0	34.0	34.0	32.0	-	2.72
Pike, Waterford, Vt.	34.3	33.6	33.0	33.6	33.7	-	2.76
Whitcomb, N. Walpole, N.H.	33.0	33.1	33.5	33.3	35.3	2.77	2.69
Whitcomb, Wallingford, Vt.	31.2	30.3	30.5	30.7	31.8	2.78	2.71
Whitcomb, Winooski, Vt.[1]	35.0	34.2	34.0	34.4	-	2.75	2.66
Northfield S & G, Northfield, MA	34.2	34.0	34.2	34.1	34.9	2.80	2.72
Northfield S & G, (SSD)	34.8	-	-	34.8	-	2.72[2]	2.66[2]
Northfield S & G, (Dry Loose)	43.0	43.0	42.8	42.9	-	2.83	-

1. Manufactured sand

2. Bulk Saturated Surface-Dry Specific Gravity.

TABLE 4

COARSE AGGREGATE TEST RESULTS

Source	Percent Voids: Kempster Voidmeter Test #1	#2	#3	Avg.	AASHTO T19-80	Apparent Sp. Gr.: Kempster Voidmeter	AASHTO T85-81
Calkins,Coventry, Vt.	38.1	38.4	37.1	37.9	37.5	2.83	2.79
Carrara, E. Middlebury,Vt.	41.7	41.2	41.2	41.4	40.5	2.73	2.66
Dailey, So. Shaftsbury, Vt.	40.7	40.3	40.7	40.6	39.9	2.78	2.75
Lebanon Crushed Stone, W.Lebanon, N.H.	40.0	39.0	38.8	39.3	41.1	2.97	2.95
Northfield S & G, Northfield, MA	40.6	39.7	38.3	39.5	37.2	2.75	2.72
Whitcomb, N. Walpole, N.H.	44.2	44.3	43.7	44.1	42.8	2.96	2.92
Whitcomb, Winooski, Vt.	43.7	42.8	41.6	42.7	42.2	2.85	2.81

TABLE 5

AGGREGATE COMBINATION & AGGREGATE/CEMENT COMBINATION TEST RESULTS

Source	Material Used	Dry Weight lbs/yd^3	Percent Voids Kempster Voidmeter
Dailey, So. Shaftsbury, Vt.	Coarse Aggregate	1640	
Dailey, So. Shaftsbury, Vt.	Fine Aggregate	1412	25.5
Dailey, So. Shaftsbury, Vt.	Coarse Aggregate	1640	
Dailey, So. Shaftsbury, Vt.	Fine Aggregate	1412	
Northeast Cement, St. Constant, Que.	Type II Cement	611	22.0
Cooley, Websterville, Vt.	Coarse Aggregate	1550	
Nadeau, Johnson, Vt.	Fine Aggregate	1441	26.6
Cooley, Websterville, Vt.	Coarse Aggregate	1550	
Nadeau, Johnson, Vt.	Fine Aggregate	1441	
Northeast Cement, St. Constant, Que.	Type II Cement	611	24.2
Swanton Limestone, Swanton, Vt.	Coarse Aggregate	1603	
Anderson, Highgate, Vt.	Fine Aggregate	1406	25.5
Swanton Limestone, Swanton, Vt.	Coarse Aggregate	1603	
Anderson, Highgate, Vt.	Fine Aggregate	1406	
Northeast Cement, St. Constant, Que.	Type II Cement	611	23.3
Lawrence Sangravco, Guildhall, Vt.	Coarse Aggregate	1724	
Lawrence Sangravco, Guildhall, Vt.	Fine Aggregate	1361	25.9
Lawrence Sangravco, Guildhall, Vt.	Coarse Aggregate	1724	
Lawrence Sangravco, Guildhall, Vt.	Fine Aggregate	1361	
Northeast Cement, St. Constant, Que.	Type II Cement	611	21.2

SUMMARY

1. The results of tests of individual fine and coarse aggregates indicate that three repetitions using the Kempster Voidmeter provide adequate precision for establishing an average percent of voids.

2. The percent voids of both fine and coarse aggregates obtained with the Voidmeter generally were in close agreement with the percent voids calculated according to AASHTO T 19. The larger discrepancies were noted with the fine aggregates.

3. Tests of aggregate combinations and aggregate/cement combinations indicate that small differences in percent voids exist with materials from different sources, when combined to produce Class B concrete mixes. These differences, in many cases, were less than some of the differences between individual fine or coarse aggregates.

4. The apparent specific gravity of fine and coarse aggregates determined with the voidmeter were higher in all but one case than AASHTO T 84 and AASHTO T 85 values. Values ranged from no change to 0.11 higher for fine aggregates and from 0.02 to 0.07 higher for coarse aggregates.

5. The single fine aggregate sample tested in a saturated-surface-dry condition resulted in a bulk specific gravity (saturated-surface-dry basis) value 0.06 higher than that obtained with AASHTO T 84.

6. A Vermont Agency of Transportation Materials & Research Standard Test Method was developed in conjunction with this evaluation entitled VT AOT-MRD-36-85, "Method of Test for Void Content and Specific Gravity of Aggregates and Cement/Aggregate Combinations by the Voidmeter Method." This method of test will serve as an operating manual to aid the user in any future work with the Kempster Voidmeter.

CONCLUSIONS AND RECOMMENDATIONS

1. The percent of voids of individual aggregates may be obtained with relative ease and quickness by use of the Kempster Voidmeter. This information, however, is readily available for aggregates used in Vermont Agency of Transportation projects by using data gathered in the Materials & Research Division's Annual Aggregate Testing Program.

2. Most organizations involved with the design of concrete mixtures use either bulk (dry) or bulk (saturated-surface-dry) specific gravity to establish mix proportions [5,6]. The bulk (dry) value is used when mix proportions are based on aggregates in a dry condition while the bulk (SSD) specific gravity takes into account the absorbed water present in the aggregate particles. Both of these values include the permeable and impermeable voids normal to the aggregate while the apparent specific gravity, the value primarily obtained in this evaluation, considers only the mass of the impermeable portion of the material.

   Although the procedure used to obtain an apparent specific gravity with the Kempster Voidmeter is substantially less time consuming that the AASHTO test methods, the values arrived at do not match those attained with the standard AASHTO test methods and should be considered unacceptable for future use when comparisons of apparent specific gravity of various aggregate is required.

   As the use of the Kempster Voidmeter for bulk specific gravity determination results in no significant time savings, future testing to determine the validity of bulk specific gravity values obtained with this apparatus is not warranted and it is recommended that use of conventional methods for determining specific gravity be continued.

3. More work performed in conjunction with the pumping of structural concrete is needed to determine if further benefits can be obtained from the use of the Kempster Voidmeter. The ability of the voidmeter to provide percent of voids of various aggergate/cement combinations may prove to be valuable when mixes are proportioned specifically for pumping applications. In general, however, field experience has demonstrated that cement contents in Vermont Agency of Transportation mixes are rich enough to allow adequate pumping when the need arises and overall concrete mix proportions provide sufficient workability for other placement and finishing operations.

4. It is recommended that the Vermont Agency of Transportation Materials and Research Division Standard Method of Test number VT AOT-MRD-36-85 "Method of Test for Void Content and Specific Gravity of Aggregates and Cement/Aggregate Combinations by the Voidmeter Method" be adopted for all future work using the Kempster Voidmeter.

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[4] Browne, R.D. and Bamforth, P.B., "Tests To Establish Concrete Pumpability", Title No. 74-19, Journal Of The American Concrete Institute, May 1977, Pp. 193-203.

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TA 565 Rev. 4/79

Prepared By: W. Meyer
Date: 12/22/82
Sheet 1 of 1

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

RESEARCH INVESTIGATION

Work Plan No. 82-C-28

Subject: Preliminary Evaluation of Kempster Void-meter

Investigation Requested By: Structural Concrete Subdvsn Date: December 22, 1982

Date Information Required:

Purpose of Investigation: A preliminary investigation to familiarize subdivision personnel with procedures and techniques for operating the Kempster Void-meter. Another objective will be to develop a more complete operating manual than was submitted by the manufacturer.

Proposed Tests or Evaluation Procedure: Determine void contents of selected coarse and fine aggregates, aggregate combinations, and aggregate/cement combinations.

Conduct several repetitions of each test to establish, if possible, an acceptable range of results.

Determine specific gravity of selected aggregates and compare results with those obtained using conventional test methods.

Proposal Discussed With: R. Frascoia Projected Manpower Requirements: 20 Man days

Investigation To Be Conducted By: Structural Concrete Subdivision

Proposed Starting Date: December 28, 1982 Estimated Completion Date: April 1, 1983

Approval/Disapproval by Materials Engineer: R.F. Nicholson 1-7-83

Comments by Materials Engineer:

Materials & Research Division
Agency of Transportation
Date Typed: January 3, 1983