WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

DEVELOPMENT AND USE OF THE EQUATION FOR PREDICTING POTENTIAL STRENGTH OF PORTLAND CEMENT CONCRETE

1.0 PURPOSE

1.1 To set forth a procedure for development of the equation for predicting the potential strength of Portland Cement Concrete from the results of early age tests on concrete cylinders.

1.2 To establish criteria for use of the results of these early tests and the resultant predicted values as a part of the Quality Assurance process.

2.0 SCOPE

2.1 This procedure may be applicable to any Portland Cement Concrete when it is desired to estimate the potential strength of that concrete.

3.0 KEY WORDS

3.1 Maturity - A term used to describe the combinations of conditions in and around a concrete cylinder that affect the strength gain of that concrete. Maturity is expressed in degree - hours. (M or m)

3.2 Degree - Hours - The age of a concrete cylinder, in hours, multiplied by the ambient temperature of that specimen - [C(hr)].

3.3 Line of Prediction - The line which represents the relationship between the logarithm of the maturity of compressive strength specimens and the strength of those specimens.

3.4 Prediction Equation - The equation, representing the line of prediction, which is used to predict the potential strength of Portland Cement Concrete from tests on compressive strength specimens at an early age.

4.0 THE GENERAL FORM OF THE PREDICTION EQUATION IS:

$S_M = S_m + b$ (Log M-Log m) Equation A-1

Where:

S_M is the predicted potential strength at maturity M.

S_m is the measured compressive strength at maturity m.

b is the slope of the prediction line.

M is degree-hours of maturity under standard conditions.

m is degree-hours of maturity of the specimen at time of early test ±K.

K is degree-hours of maturity determined from residual temperature and other possible unmeasurable factors which would influence the strength of the concrete.

5.0 EQUATION DEVELOPMENT

The development of the prediction equation is dependent upon development of the line of prediction.

5.1 Compressive strength data, for different ages of test, and the corresponding maturity values will generally be developed in the laboratory to determine the line of prediction for each class of concrete to be used. This data should include tests at age 24 hours, 3, 7, 14, and 28 days.

5.2 Prepare a sheet of semi-log graph paper, 3 cycle by 10 divisions. Number the 25.4 mm divisions in 10 MPa increments (y axis). The Logarthmic scale will represent maturity, in degree hours, at time of test (x axis). See Attachment 1.

5.3 Plot each of the strength values, developed as per Subsection 5.1, versus the maturity for each age of test.

5.4 Ideally the line of prediction would pass through each of the points plotted as strength versus maturity to form a straight line. (The value of 15,000°C (hr) is always used for M at 28 days). Because of the inaccuracy in determining all of the factors which affect the maturity, these points may not fall in a straight line.

5.5 A best fitting straight line shall be drawn through the plotted points making sure the line passes through the point which represents the 28 day maturity versus strength. The points representing maturity at test ages less than 28 days may not fall on a straight line which passes through the 28 day point, but it may be possible to shift these points in one direction, either to the left or the right, a certain distance (K) to cause them to better fit the straight line. In this event, the distance "K" is used in the equation set forth in Section 4 and is either added to or subtracted from the value "m" depending on whether the points were shifted to the right or to the left. Since the exact maturity is an unknown value, the constant (K) will have to be determined by trial and error.

5.6 From the line of prediction, the value (b) can be determined. The slope (b) of this line is the vertical scale distance between the intercept on the 1,000 m line and the intercept on the 10,000 m line.

5.7 The constants b and k thus developed are used in the equation (See Article 4) to predict the potential 28 day strength of Portland Cement Concrete.

6.0 EQUATION USE

6.1 The equation developed as per Article 5 may be used to predict the potential 28 day strength of any class of Portland Cement Concrete.

6.2 Compressive strength test specimens shall be fabricated in accordance with the applicable specification requirements. The specimens shall be cured for at least 24 hours. An accurate record should be maintained of the temperature immediately surrounding the specimens.

6.3 The specimens shall be removed from the molds as soon as practicable after 24 hours. The specimens shall be capped and tested in accordance with governing requirements. The exact age at time of test shall be noted. The maturity (m) of the early age test specimen is the age in hours multiplied by the ambient temperature plus the constant K [(hrs.) (°C) + K = m].

6.4 The frequency with which early age specimens are made and tested may vary but in any case, the frequency will be specified for the work being done.

7.0 PREDICTION ACCURACY

7.1 With each third set of specimens made for prediction purposes, a set of specimens shall be made and tested at the age corresponding to the maturity M. The strengths thus determined will be compared to the early age test values to verify the accuracy of the prediction equation.

7.2 The early age test value (S_m) shall have a strength equal to or greater than 5.9 MPa at 24 hours and the predicted value (S_M) shall have a strength at maturity M equal to or greater than the specified minimum plus 5.5 MPa. If the early age test value (S_m) is determined at an age other than 24 hours, then the equation set forth in Section 4 shall be used to determine the strength at 24 hours.

7.3 In the event of the first occurrence of noncompliance with Subsection 7.2, the following action shall be taken.

7.3.1 An investigation shall be immediately instituted to determine if the concrete production, sampling, sample handling, and testing are in accordance with prescribed procedures.

7.3.2 The frequency of fabricating and testing early age specimens, as prescribed for the particular work, shall be increased so that the number of specimens made during the prescribed time interval shall be doubled.

7.3.3 In conjunction with the first set of specimens fabricated after the noncompliance is determined, a set of specimens shall be fabricated for tests at the age corresponding to the maturity M.

7.4 In the event of a second consecutive occurrence of noncompliance with Subsection 7.2, the following action shall be taken.

7.4.1 Appropriate personnel of the Materials Control, Soils and Testing Division shall be promptly advised of this occurrence.

7.4.2 The investigation required in Article 7.3.1 shall be repeated.

7.4.3 Notify the Contractor immediately and in writing that two consecutive strength tests have indicated that a problem may exist and that further placement of concrete will be done at his risk.

7.4.4 Continue to make specimens for early test at the rate established in Article 7.3.2. In conjunction with the first set of specimens fabricated after the second consecutive failure, a set of specimens shall be fabricated for tests at the age corresponding to the maturity M.

7.5 In the event of a third consecutive occurrence of noncompliance with Subarticle 7.2, the following action shall be taken:

7.5.1 Appropriate personnel of the Materials Control, Soils and Testing Division shall be promptly advised of this occurrence.

7.5.2 An appropriate adjustment shall be affected in the cement factor of the concrete to insure that the concrete will comply with Subsection 7.2.

7.6 If the cement factor is increased in accordance with Article 7.5.2, then the increased cement factor shall remain in effect until the particular reason for the noncompliance is isolated and appropriate action taken to insure compliance with Article 7.5.2 or until at least ten pieces of data are developed for evaluation using the criteria set forth in MP 711.03.26. Based upon this evaluation, the Division will make an appropriate adjustment to the cement factor. In no case, however, will the cement factor be less than that cement factor determined for the source production.

7.7 The slope (b) of the prediction line can be more accurately estimated with the equation:

Equation A-2

$$b = \frac{\Sigma(S - S_m)}{\Sigma(\text{Log } M - \text{Log } m)}$$

Where:

Σ Symbol indicating that the values are to be added or totaled.

S is the measured compressive strength at maturity M.

S_m is the measured compressive strength at maturity m.

8.0 REPORTING

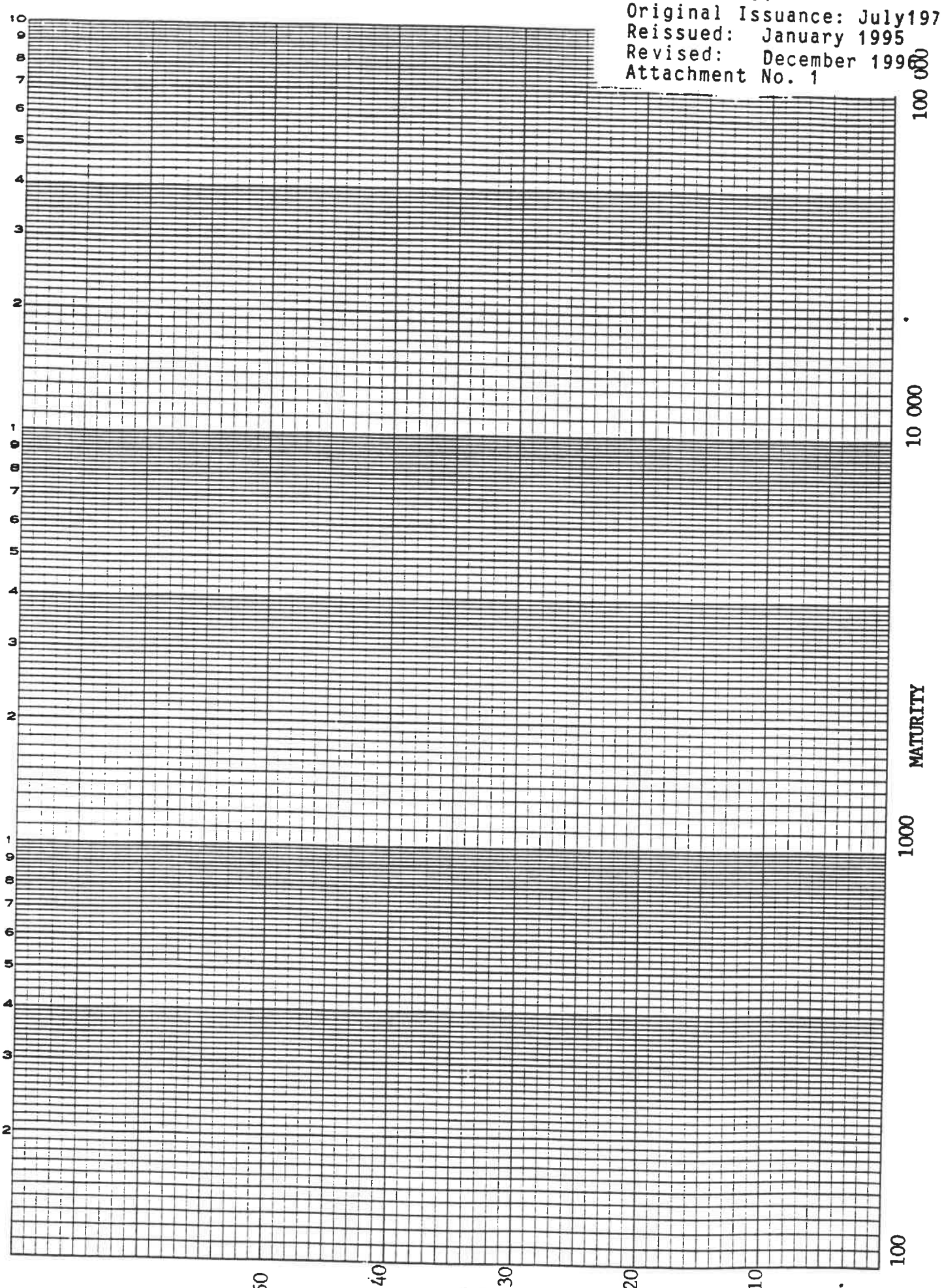
8.1 The strength values determined at maturity m and the resultant predicted value shall be reported as per Attachment Number 2.

8.2 If an investigation is warranted as per Subsection 7.2, then the investigation shall be reported using the standard Materials Inspection Report format.

Gary L. Robson, Director
Materials Control, Soils
and Testing Division

GLR:b

Attachments



FORM T7

LABORATORY NUMBER
TELETYPE OPERATOR
DATE REPORTED

WEST VIRGINIA DEPARTMENT OF HIGHWAYS

Testing Laboratories

REPORT ON SAMPLE OF

MP 711.03.31
ORIGINAL ISSUANCE: JULY [illegible]
REISSUED: JANUARY 1995
REVISED: DECEMBER 1996
ATTACHMENT NO. 2

ROAD SUBJECT: EXAMPLE FORMAT	ROUTE
COUNTY PROJECTED PCC	DISTRICT
PROJECT COMPRESSIVE STRENGTH REPORT	CONTRACT
STATION	OFFSET
TYPE OF SAMPLE	FIELD SAMPLE NUMBER
ITEM NUMBER	BRIDGE NUMBER
QUANTITY REPRESENTED BY THIS SAMPLE	QUANTITY TO DATE
TEST REQUIRED (IDENTITY GOVERNING SPECIFICATIONS)	
DATE SAMPLED	DATE SHIPPED
SAMPLED BY	NAME OF CONTRACTOR
ELEVATION	HOLE NUMBER
SOURCE	OTHER IDENTIFICATION

PSI EA CYL	001096	001132	001132
AGE HARS	000006		
AVG PSI	001122		
P AGE DAYS	000028		
P PSI	004010		
M	001820		

BASED UPON THE STRENGTH OF SPECIMENS AGED 25 HOURS AND CALCULATION OF THE EXTENSION THEREOF IT IS PREDICTED THAT SIMILAR SPECIMENS MADE FROM THE SAME CONCRETE AT THE SAME TIME AND CURED IN CONFORMANCE WITH ASTM C 31, PARAGRAPH 7.3, WOULD HAVE AN AVERAGE STRENGTH AT AGE 23 DAYS WHICH WOULD EXCEED SPECIFIED MINIMUM REQUIREMENT

Submitted by: Engineer of Materials and Tests