EVALUATION OF FLEXURAL STRENGTH TESTING APPARATUS USED BY VERMONT DEPARTMENT OF HIGHWAYS

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ABSTRACT

A study comparing the flexural strength results of concrete test beam specimens as measured by various testing apparatus used by the Vermont Department of Highways.

INTRODUCTION

The purpose of this investigation is to compare the flexural strength results obtained from several machines available in the Vermont Highway Laboratory for testing concrete beam specimens. Currently, AASHO and ASTM recognize only center-point and third-point loading as acceptable methods of testing for modulus of rupture, with the latter to be used for specimens having a cross-section of six inches square or larger. Also, third-point loading is almost universally accepted as being the superior method for determining flexural strength.

The Vermont Highway Department's Laboratory has, for over 40 years, used a homemade cantilever type breaker for determining modulus of rupture. This device has become antiquated with respect to AASHO specifications and could be hazardous to the operator.

This testing program was developed to compare flexural strength results of concrete test beams when broken with various devices. It was conducted in two parts. Part 1 utilized test specimens molded from a single load of transit mixed concrete with normal field conditions being duplicated relative to handling and curing. Part 2 differed from the former through the controlled curing and handling conditions of the laboratory as well as by utilizing an additional testing device loaned to the Materials Division.

TESTING APPARATUS

Cantilever Device

This machine is a manually operated device capable of applying a bending moment to a test specimen by use of an extension arm loaded through a spring operated gauge. Due to the gear ratio of the loading mechanism, the rate of load application cannot be applied to conform with AASHO Designation: T 97-64.

Manual Third-Point Loading Device

With this portable machine loads are applied by use of a gear box type loading jack and measured by a set of hardened tool-steel bars and micrometer dial calibrated to read in modulus of rupture. As with most manually operated mechanical devices, the application of a uniform rate of loading is difficult.

Motorized Third-Point Loading Device

This machine is a standard third-point loading device purchased from Hogentogler and utilizes a motorized jack and an infinitely variable speed control. This allows a wide range of adjustments according to need and specifications. Measurement of load is accomplished through the use of a calibrated proving ring and dial gauge.

Recording Third-Point Loading Device

The Rainhart Beam Tester utilizes a manually operated hydraulic pump which allows the application of a smooth, steady load. A chart recorder (Figure I) provides a permanent record of both the rate of loading and the total load at failure.

MATERIALS

The Vermont Highway Department Class A concrete used to mold the specimens for Part 1 of this investigation was supplied by Calkins Redimix, Coventry, Vermont. All specimens were cast from a single batch of concrete having a 3½" slump and an air content of 6%.

Materials used in Part 2 of this investigation were obtained from several sources. They were considered incidental to the objectives of the test which was to compare the testing apparatus.

PROCEDURES

Part 1

A total of thirty-two 6"x6"x36" test beams were cast and moist cured in the field for seven days. Half of the test beams were broken in flexure at that time and the remaining beams were transported to the laboratory where standard moist curing was continued until the age of 28 days.

Three machines were used to test the concrete in flexure. The Motorized Third-Point Loading Device served as a reference machine in which each beam was broken once. The remaining portions of the beams were then tested on either of the manually loaded devices.

Various rates of load application were applied to ascertain the affect on the modulus of rupture as is indicated in ASTM Designation C 78. This standard specifies that the load may be applied rapidly up to approximately 50% of the breaking load, after which it shall be applied at such a rate that the increase in extreme fiber stress does not exceed 150 psi per minute. Generally, the Motorized Third-Point Loading Device was controlled in this manner. However, when the manually operated devices were used, the load was applied as uniformly as possible but did not meet ASTM requirements.

Part 2

In this phase of the program, ten 6"x6"x36" test beams were cast and tested. Casting, handling, and curing of the various concrete mixes followed standard laboratory procedures. The Rainhart Device was used as the reference machine to which the other devices were compared. The beams were measured to the nearest 1/16" and results were corrected to a 6"x6" cross-section using the chart illustrated in Figure II.

As in Part 1, the manually operated Cantilever Device was too crude to meet AASHO or ASTM requirements relative to rate of loading.

RESULTS

Part 1

The results of all tests performed in Part 1 are exhibited in Figure III.

Although consideration must be given to the nature of the material (the normal within batching variations of concrete), it may be noted that sizeable variations in test results occur between the testing devices used. Furthermore, the specimens made from the same batch, while being cured and handled similarly, produce variable results when tested in the same machine.

The Motorized Third-Point Loading Device was the most consistent for the 7 day breaks. The Cantilever Device was most consistent for the 28 day breaks. Nevertheless, the coefficient of variation indicates that the motorized device gives better overall consistency at both ages of testing.

With few exceptions, the manual devices consistently gave higher breaks than did the motorized device. Although no trend was established that could be attributed to the rate of load application, higher strengths were generally obtained when faster loading was applied.

Part 2

The results of all tests performed in Part 2 are exhibited in Figure IV. No attempt should be made to compare the modulus of rupture from one specimen to another as varying types of concrete were used. Therefore, no average has been determined for any of the testing devices. The object of the test is to compare testing apparatus only.

The cantilever method of testing gave consistently higher results which were erratic when compared with the Rainhart machine.

The motorized third-point device produced slightly higher results compared with the Rainhart machine but the results were much more consistent than those of the cantilever.

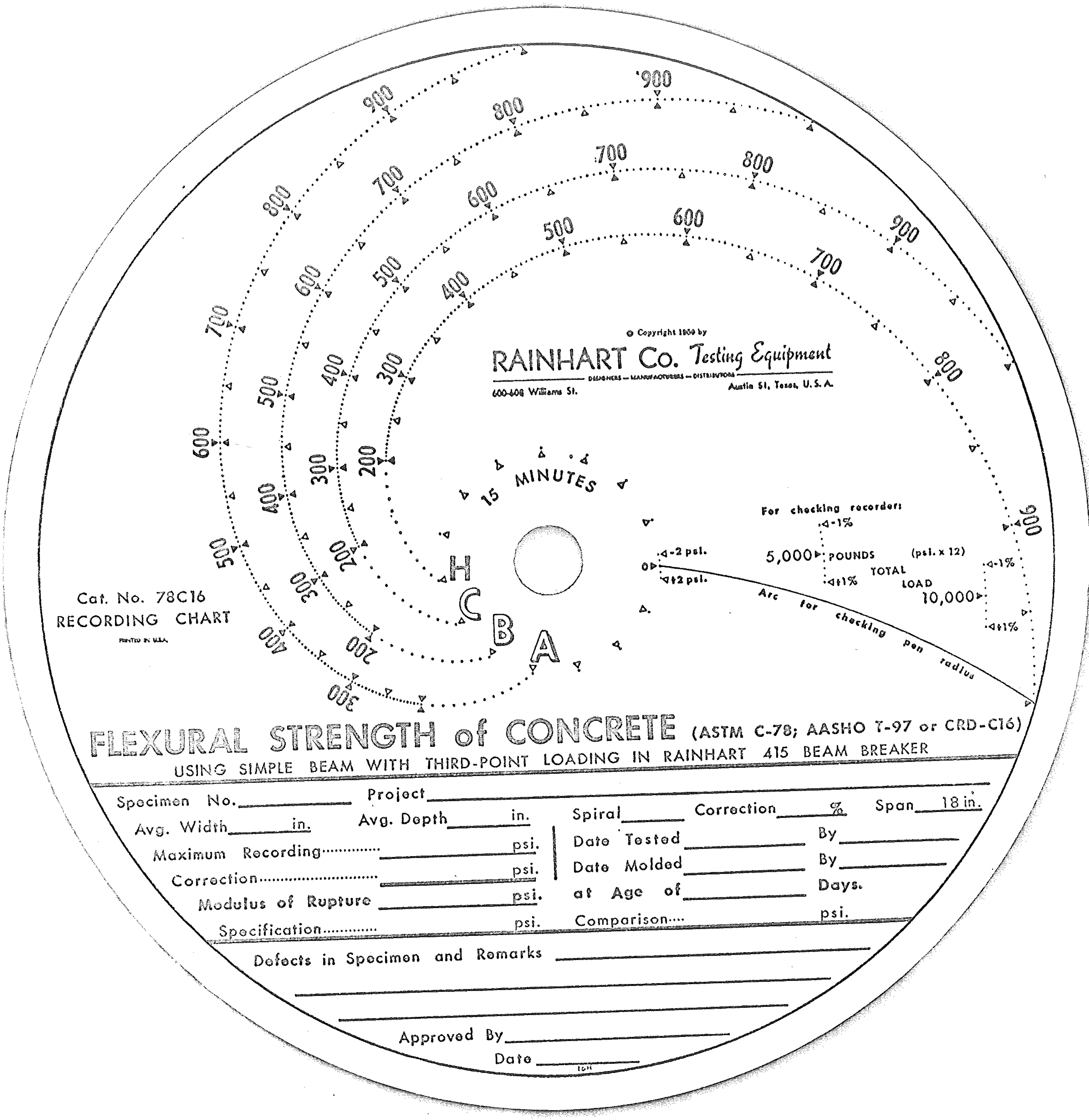
SUMMARY

1. Test beams, in most cases, reached generally higher strength values when broken on the cantilever device than when broken on any of the third-point loading devices.
2. The manually operated third-point loading device produced higher strength results than were obtained when using the motorized third-point loading device.
3. The strength results obtained using the manually operated devices were generally erratic when compared with either the motorized or hydraulically operated devices.

DISCUSSION

The lower values in modulus of rupture that result from third-point loading apparatus as compared with other testing equipment may be attributed to the nature of concrete. Since it is not homogeneous, the test specimen tends to break at its weakest section. With third-point loading, the maximum moment is distributed over a greater length of the beam.

The modulus of rupture is also sensitive to the rate of loading. A standardized application of load should give more consistent results.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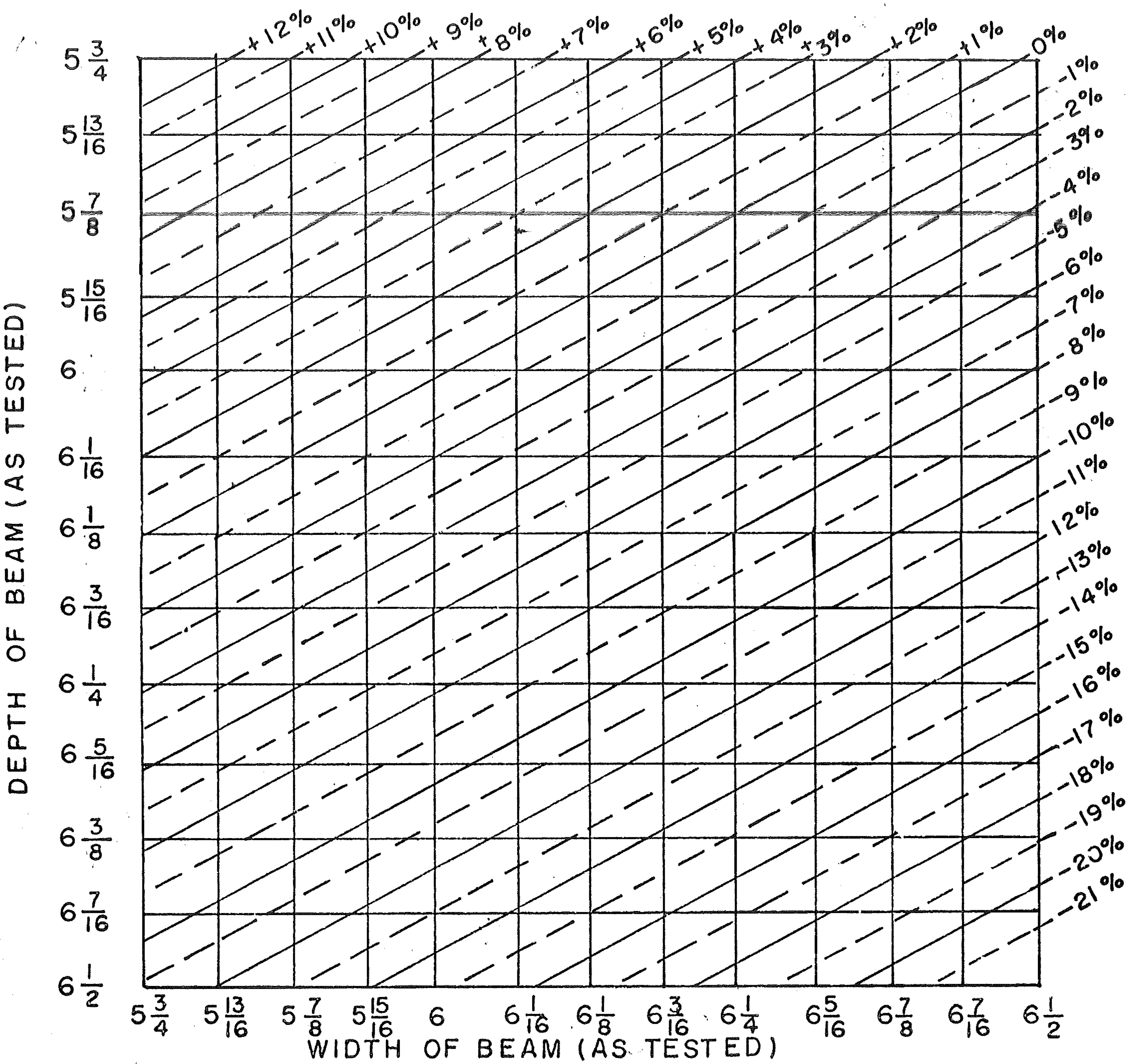
RAINHART Co. Testing Equipment
DESIGNERS — MANUFACTURERS — DISTRIBUTORS
600-608 Williams St.
Austin 51, Texas, U. S. A.
15 MINUTES
H
C
B
A
For checking recorder:
-2 psi.
+2 psi.
-1%
+1%
5,000
POUNDS
TOTAL
LOAD
(psi. x 12)
10,000
Arc for checking pen radius
Cat. No. 78C16
RECORDING CHART
PRINTED IN U.S.A.
FLEXURAL STRENGTH of CONCRETE (ASTM C-78; AASHO T-97 or CRD-C16)
USING SIMPLE BEAM WITH THIRD-POINT LOADING IN RAINHART 415 BEAM BREAKER
Specimen No.
Project
Avg. Width in.
Avg. Depth in.
Spiral
Correction %
Span 18 in.
Maximum Recording psi.
Correction psi.
Modulus of Rupture psi.
Specification psi.
Date Tested
By
Date Molded
By
at Age of
Days.
Comparison psi.
Defects in Specimen and Remarks
Approved By
Date

FIGURE I

DIMENSIONAL CORRECTION CHART



FLEXURAL STRENGTH OF CONCRETE BEAM

FIGURE II

7 DAY BREAKS							28 DAY BREAKS						
	Manual Cantilever		Manual Third-Point		Motorized Third-Point			Manual Cantilever		Manual Third-Point		Motorized Third-Point	
Beam	M of R (psi)	Time (Min.)	M of R (psi)	Time (Min.)	M of R (psi)	Time (Min.)	Beam	M of R (psi)	Time (Min.)	M of R (psi)	Time (Min.)	M of R (psi)	Time (Min.)
1	418	0:48			420	2:06	17	628	0:22			530	1:19
2	366	0:07			415	0:14	18	663	0:38			545	1:35
3	523	0:09			445	3:25	19	646	0:26			550	1:39
4	646	0:08			545	0:42	20	663	0:25			505	1:10
5	488	0:07			475	1:25	21	663	0:22			545	1:28
6	488	0:08			430	1:40	22	628	0:26			510	1:15
7	488	0:05			430	1:08	23	646	0:25			565	1:42
8	453	0:52			470	1:36	24	698	0:27			570	1:37
9			415	2:02	350	0:58	25			590	2:00	585	1:46
10			370	0:16	360	1:03	26			760	1:55	535	1:26
11			650	0:25	490	0:25	27			570	1:36	555	1:28
12			600	1:15	510	1:14	28			540	1:36	485	1:04
13			490	1:07	500	1:43	29			600	2:12	575	1:41
14			440	1:32	440	1:35	30			660	2:25	565	1:40
15			500	1:50	485	1:23	31			510	2:45	540	2:20
16			490	2:04	470	1:30	32			570	1:45	515	1:30
Aver.	484		494		452			654		600		542	
V*	15.8%		17.6%		11.1%			3.3%		12.2%		5.0%	

*Coefficient of Variation

FLEXURAL STRENGTH OF BEAMS - PART 1

FIGURE III

Beam	Cantilever Manual	Third Point Motorized	Third Point Rainhart	Difference
	M of R (psi)	M of R (psi)	M of R (psi)	%
1	462		367	26
2	491		344	42
3	581		466	25
4	558		510	10
5		597	551	9
6		590	570	3
7		595	575	3
8		780	710	10
9		480	436	10
10		619	603	3

FLEXURAL STRENGTH OF BEAMS - PART 2

FIGURE IV