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RATE OF SET OF INTERNALLY
VIBRATED CONCRETE MIXES

Thesis for the Degree of B. S.
H. Wills
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THESIS

Concrete - Testing

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Rate of Set of Internally Vibrated
Concrete Mixes

A Thesis Submitted to

The Faculty of
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by

Harry
H. Wills

Candidate for the Degree of

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INTRODUCTION

The wide and rapidly increasing use of internal vibrating equipment has left a gap between the adoption and the basic information necessary for the intelligent placing of concrete by this method. It is the purpose of this treatise to investigate and answer one of the many questions arising in connection with vibrated mixes.

The question was first brought to the writer's mind by the practices of certain construction groups with respect to their vibrated concrete jobs. It was noted that on jobs where vibrators were used the forms were removed sooner than on jobs where the concrete was pooled and poked in place. This was in the case of loaded sections. On sections which were not loaded, it was the practice to start the finishing operations on vibrated mixes sooner than on sections placed by hand methods. These practices were no doubt followed from the contention that the vibrated mixes set up faster than the other mixes. The results of this study are intended to show whether this is the truth or not.

Vibration is not a cure-all and it may be the case that all vibration offers is a method of placing harsh mixes that could not be placed by hand methods.

Vibration should normally produce a concrete of greater density. In this report, the effect of this greater density with respect to strength will also be studied.

PROCEDURE

The materials to be used in the test mixes include standard portland cement, a good grade of concrete sand and a sound beach pebble type gravel.

PREPARATION OF THE AGGREGATES

The sand to be used was first dried in large pans over gas burners. The sand was only heated until the surface moisture was driven off. Care was taken not to make the fine aggregate bone dry. The reason for this was to eliminate the absorption of some water of the mixture by the sand. After drying, the sand was placed in metal drums and used as needed. The drums were placed in a dry spot so that the sand had no chance to absorb moisture from the air.

The coarse aggregates for this problem were taken from a stone pile which contained sizes up to 2". Two inches was considered too large for the purposes of this test. The maximum size was established as 1". The stones were graded over a 1" screen and the larger sizes discarded. To maintain a uniform grading, the sizes from 1" on down were further separated over the 3/8" screen. After screening the finer material out, it was found that the coarse aggregate contain approximately 20% of material that would pass the 3/8" screen. Therefore, the first grading was taken as 100% passing 1" screen and 20% passing the 3/8" screen. However, it was later found that in order to maintain a uniform slump, the material retained on the 3/8" screen had to be further separated into that passing the 1/2" and that retained on the 1/2". With this final grading, it was found that the slump for a given designed mix could be kept constant.

DESIGN OF THE MIX

The trial mix method was used in design of the test mix. The water cement ratio decided upon was 7-1/2 gallons of water to the sack of cement. This mix under ordinary conditions would give a 28 day strength of 3100#/sq. in.

The first trial batch was made up using 5# of cement and the proportionally correct amount of water to make 7-1/2 gallons ~~of~~ paste. The sand and stone were added to the paste in the approximate ratio of one part sand to two parts stone. The stone being added first to overcome the difficulty of the tendency of the sand to take considerable amounts of water. These ingredients being added until a 1" slump previously decided upon was attained. The amount of all the ingredients going into the mix had been carefully weighed before having been added. The final calculations for the first trial mix showed 1:2:7. The mix was quite harsh and very evidently undersanded. One small vibrated test cylinder and one small rodded one were made. After removing the forms the vibrated sample had a smooth even outer surface, while the rodded one was quite badly honeycombed. It was decided that the first trial mix was slightly undersanded. Several mixes were tried until the final mix of $1:2\frac{1}{2}:6\frac{1}{2}$ was decided upon.

Computations for a Five Cylinder Batch

Total Material = 1.25 cu. ft.

Weight of Batch = 150 x 1.25 = 188 lbs.

Mix = 1:2.5:6.5

Parts of Materials to 1# Cement

.67# Water

1.00# Cement

2.50# Sand

6.50# Gravel

10.67

% Water = 6.28 % Sand = 21.4

% Cement = 9.3 % Gravel = 60.9

188 x 9.3 = 17.4# Cement

188 x 6.28 = 11.80# Water

188 x 21.4 = 40.3# Sand

188 x 60.9 = 114.0# Gravel

CHOOSING A VIBRATING TIME INTERVAL

The specimens to be tested were the standard 12" test cylinders. The approximate dimensions of the vibrator were 1-1/4" by 14" in length. The problem was to find the correct method of vibrating test cylinders thoroughly with this vibrator. At first the forms were completely filled and the whole mass was vibrated in one part. This did not give satisfactory results. It was decided to vibrate the mass in parts. After several trials, the best results were obtained by vibrating the cylinders in two sections. That is, filling the form half full and vibrating and then filling the upper section and vibrating that. To find the correct vibrating time interval was the next object.

For best results in vibrated mixes, the mass should be thoroughly consolidated but the fine material in the mix should not be brought to the surface. Thirty seconds of vibration in the bottom section and the same period in the upper section consolidated the ingredients and left the mass quite uniform throughout. There was no excess of fine material on top nor any honeycomb on the outside after removing the forms. To level off the upper surface, the vibrator was laid across the top flat for 15 seconds and then struck off and leveled smooth with a trowel. This process was followed in the forming of all the rest of the samples.

The samples were made up in batches of 5 cylinders each. 5 cylinders contain approximately 1 cu. ft. of concrete. It was found that this amount was easily handled in the concrete mixing boat available in the laboratory. Also that the time required to mix and place in the forms, the concrete for 5 cylinders was not excessive. That is, there was no danger of the concrete taking an initial set before all the forms

were full.

The testing of concrete always requires more than one sample for a given test due to the inconsistency of the test results. More than one cylinder should be made and the average taken on the true answers.

The samples were made up in six batches of 5 cylinders to each batch. The batches were to be broken at three, five, seven, ten, fourteen and twenty-eight days after being poured. This many breaking periods were chosen to obtain enough data so that rate of set curves for both types of mixes might be drawn.

The ingredients were all weighed out on an accurate balance and placed in the concrete mixing boat. The boat had been previously surface moistened to remove the danger of the metal surface of the boat absorbing water from the mix and therefore making it drier than it should be. The water was weighed last and was accurately determined out to the hundredth decimal point. After the water was added, the concrete was thoroughly mixed by two men. One man standing at each end of the boat and using hose as mixing tools. The mixing time allowed for this process was 5 minutes. The concrete was then placed in the forms. The first three were vibrated as previously specified. The remaining two were rodded according to the A.S.T.M. Standards for concrete testing cylinders. These specifications require that the cylinder mold be filled one-third full and rodded 25-30 times and then filled two-thirds full and again rodded 25-30 times. The cylinder is then filled and rodded 25 times on top and struck off and leveled smooth on top.

After allowing the samples to stand for about an hour, they were placed in the moist closet. The cylinders were allowed to stand this

hour out in the air so that the top might have a chance to set. This was done to eliminate the danger of having water drip on top of the samples and make pits and holes. After one day in the moist closet, the steel forms were removed and the cylinders kept under these moist conditions until the breaking time arrived.

It was decided before any testing would be done on the samples that the hydraulic breaking press would be tested. This testing of the press was accomplished by the use of a standard hydraulic jack with a gage that had previously been tested. The jack was placed in the jaws of the press. A load was then placed on the jack and the amount of this load was recorded on the gage of both machines. Two men read the values off of each of the gages simultaneously to see if they would agree. The two machines checked perfectly.

One-eighth inch plaster board was used as a capping medium. This removed any tendency to concentrate loads on the high points of the sample being tested.

Data Sheet #1

Cylinder Number	Date Poured	Date Broken	Age Days	Process	Breaking Load Pounds	Weight Pounds
100	4-14-37	5-12-37	28	Vib.	88,000	30.69
101	"	"	"	"	94,000	30.44
102	"	"	"	"	97,000	30.31
103	"	"	"	Rodded	93,000	29.82
104	"	"	"	"	87,000	30.25
105	4-19-37	5-3-37	14	Vib.	64,000	30.69
106	"	"	"	"	67,000	30.44
107	"	"	"	"	72,500	30.56
108	"	"	"	Rodded	65,000	30.31
109	"	"	"	"	65,000	30.50
110	4-25-37	5-5-37	10	Vib.	65,000	30.82
111	"	"	"	"	70,000	30.50
112	"	"	"	"	65,500	30.75
113	"	"	"	Rodded	63,000	30.69
114	"	"	"	"	64,000	30.69
115	4-27-37	5-4-37	7	Vib.	57,500	30.63
116	"	"	"	"	60,000	30.44
117	"	"	"	"	59,000	30.56
118	"	"	"	Rodded	59,000	30.31
119	"	"	"	"	57,000	30.50

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Data Sheet #2

Cylinder Number	Date Poured	Date Broken	Age Days	Process	Breaking Load Pounds	Weight Pounds
120	5-2-37	5-7-37	5	Vib.	55,000	30.56
121	"	"	"	"	50,000	30.69
122	"	"	"	"	52,000	30.75
123	"	"	"	Rodded	62,000	30.19
124	"	"	"	"	53,000	30.44
125	5-8-37	5-11-37	3	Vib.	25,000	30.44
126	"	"	"	"	27,000	30.31
127	"	"	"	"	26,000	30.31
128	"	"	"	Rodded	28,000	30.12
129	"	"	"	"	28,500	29.69

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Method of Placement	Age Days	Strength Lbs./Sq. In.	Unit Weight Lbs./Cu. Ft.
Vib.	3	922	154.7
Rodded	3	1002	152.0
Vib.	5	1835	156.5
Rodded	5	2040	154.5
Vib.	7	2215	157.0
Rodded	7	2060	155.0
Vib.	10	2360	156.0
Rodded	10	2250	156.0
Vib.	14	2403	155.5
Rodded	14	2300	152.5
Vib.	28	3300	155.5
Rodded	28	3190	153.0

Unit strength was found by dividing the total load by the area of the cylinder which was equal to 28.2 sq. in.

To find unit weight, the weight of one cylinder was multiplied by 5.1, 5.1 being the factor to give a one cubic foot volume.

CONCLUSIONS

The conclusions to be drawn from these test results will center mainly around answering the question previously set forth in the introduction. The question was - do vibrated concrete mixes set up faster than hand placed concrete and therefore allow earlier removing of the forms. From the data obtained in this experiment, the answer is that the vibrated concrete does not set up faster but actually is a little slower setting at early periods than hand placed concrete.

Studying the smooth comparison curves on the second graph indicates that before nine days the rodded mixes gave slightly higher strength than vibrated samples. However, the comparison curves drawn by joining the points with broken straight lines indicate the point of intersection of the two curves, after which the vibrated mixes show greater strengths, is six days.

It is noted that at twenty-eight days, the vibrated mixes show strength of about 10% greater than the rodded mixes. These results compare favorably with the results published in the Bureau of Public Roads bulletin for April, which stated that vibration added 10% to the strength of concrete specimens. Their equipment was of an external nature and therefore test results are not exactly comparable with these presented here where internally operated equipment was used.

Conclusions drawn from the density curve on graph #3 are that the vibrated concrete is more dense than hand placed material, and that from the test results included in this experiment, the greater density of one mix over the other does not make it the stronger mix at early age periods.

It was noted that while density of the three day old vibrated cylinders was 154.7#/cu. ft. as compared with 152.0#/cu. ft. for the rodded samples, yet the strength of the latter specimens was 1002#/sq. in. and that of the former only 922#/sq. in.

This same state of affairs occurred again in the five day breaks, the density of the vibrated samples being 156.5#/cu. ft. and that of the rodded 154.5#/cu. ft.

The comparative strengths for these two groups were 1835# for the first and 2040# for the second.

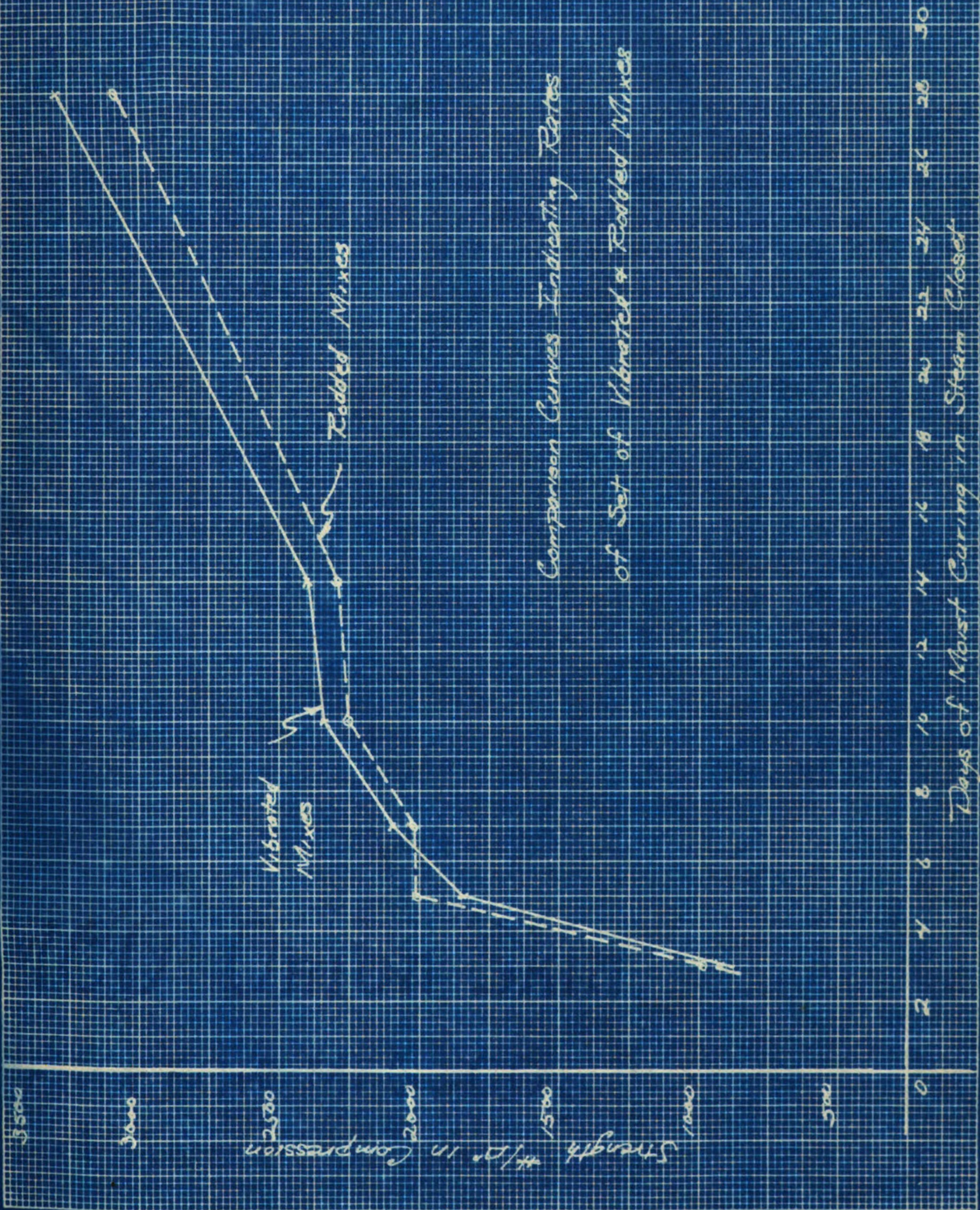
Now consider the opposite reaction of the fourteen day old specimens. The density of the vibrated cylinders for this group shows 155.5#/cu. ft. and the rodded 152.5#/cu. ft., but, however, this time the more dense vibrated cylinders are also the strongest. The two strength values being 2403 and 2300#/sq. in. with the small value equal to the strength of the rodded samples. What was true for the fourteen day batch is also true of the twenty-eight day mix. That is, the vibrated mix leading in both density and strength.

The ten day old group was the only one of the six batches in which the density of the two mixes compared closely. In every other case, the vibrated concrete was the more dense. The explanation for this probably lies in the fact that the rodded forms of this group were overfilled or the vibrated forms underfilled.

The final conclusion to be drawn from all these observations is, that while the effect of the greater density in the vibrated concrete is not felt when the mixes are yet green, it is noticeably felt as the curing goes on. Apparently the greater consolidation does not add to

the strength until after the ninth day is past. The ninth was chosen, using the smooth curve graph #2.

It is the author's opinion that several points could be further cleared up if the vibrating time were varied. In this thesis, the time of vibration was a constant. Perhaps by varying this time, a point could be reached where the rate of set curves would rise much more rapidly during the first ten days of curing. However, within the limits covered in this test, it is very poor practice to expect vibration to develop high early strength in portland cement mixes.



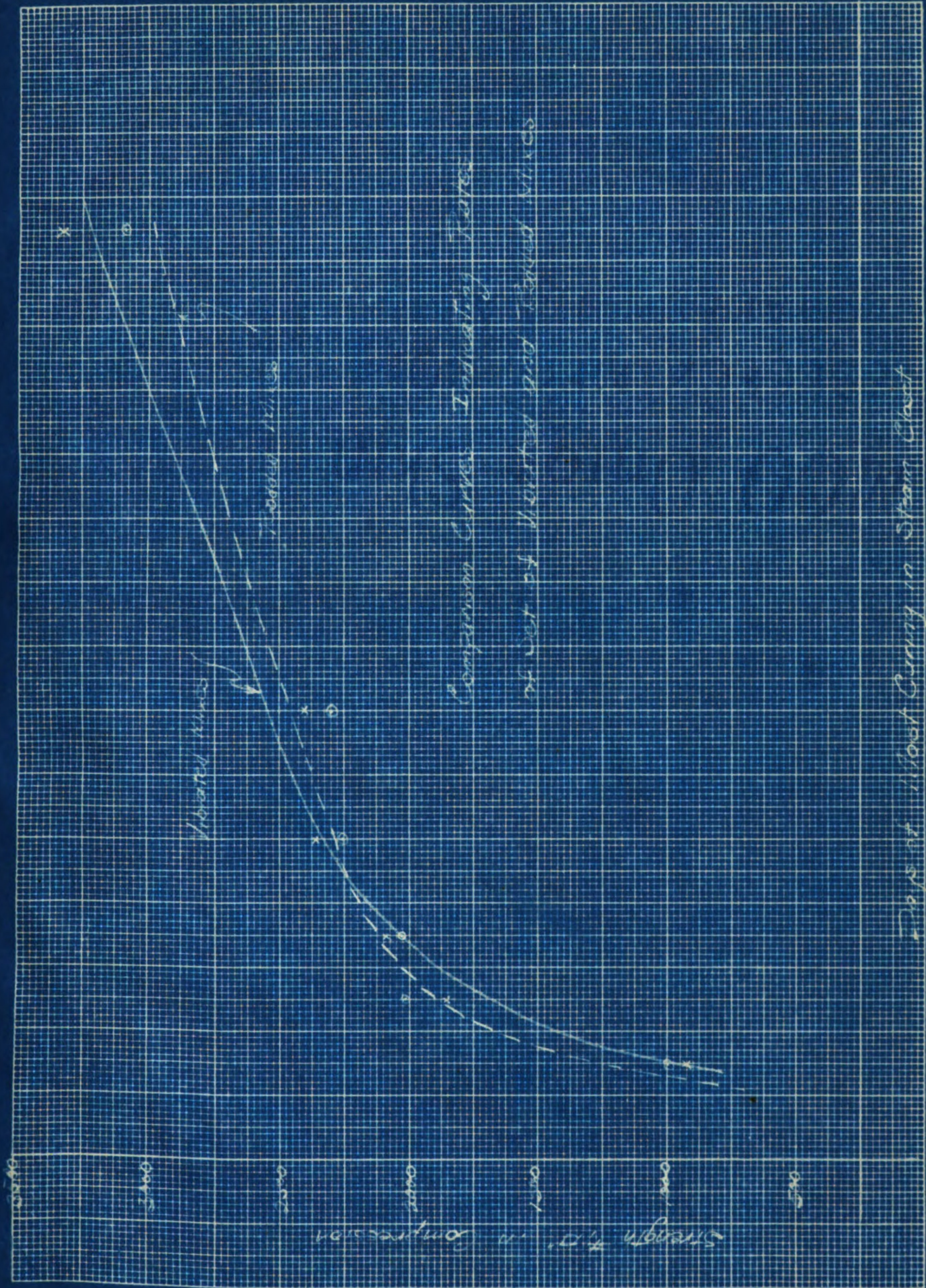
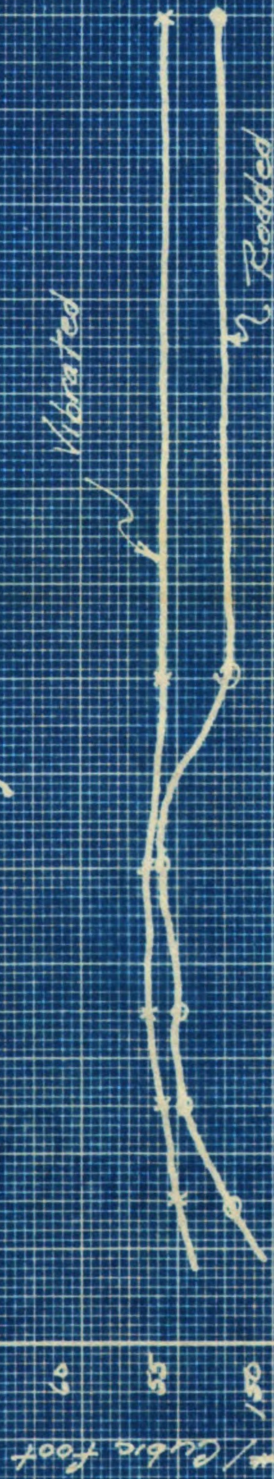


Fig. 10. Effect of Cold Rolling on Steel Elongation

Density Curves



Curves Representing the density
of Vibrated & Rodded Mixes

Days of Moist Curing



Upper photo shows equipment used in forming test cylinders.

Lower photo is a comparison of two cylinders, one formed by rodding (2) and one formed by using the above pictured equipment (3).



Note the honeycomb present in #2 cylinder, and the smooth outer surface of the vibrated sample.

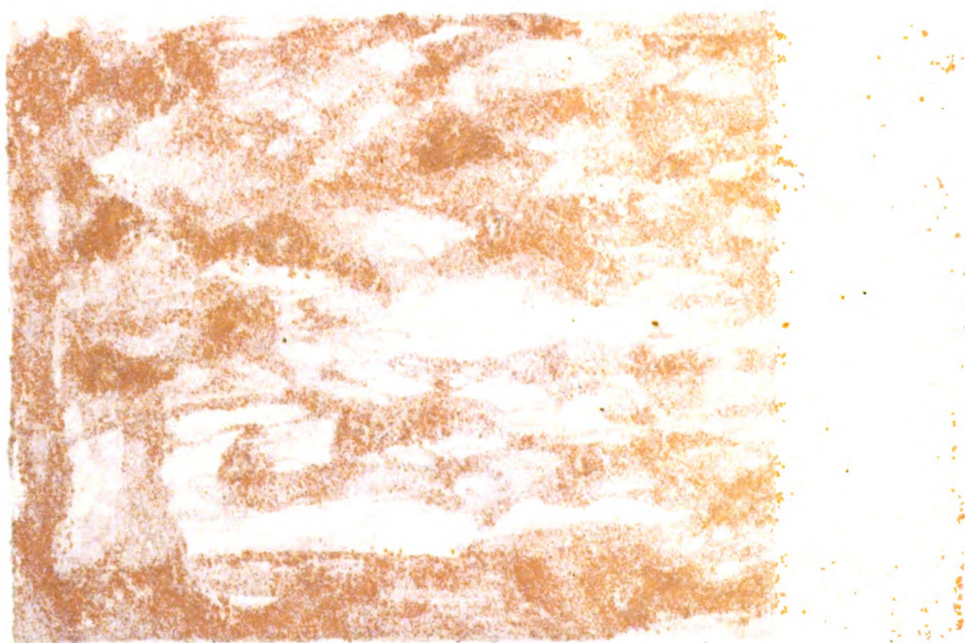




Showing the measurement of the workability
of the mix by the slump cone method



Photo shows the mix as it appeared just be-
fore placing in forms





Photograph of breaks.

Those in the foreground were vibrated and those raised in the rear were formed by the old rodding method.

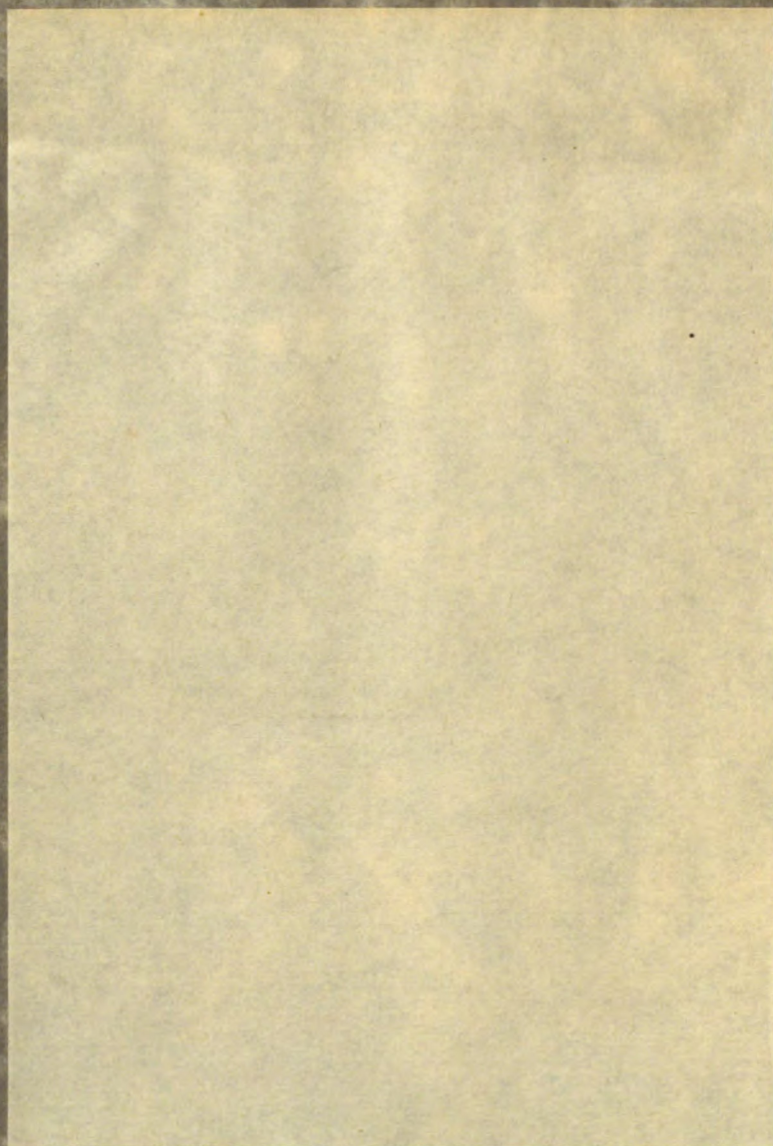


The photo on the left indicates the machine used to break the samples prepared. A cylinder is now in place in the jaws ready to be broken.

Note the swivel head on the stationary upper jaw.



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