EVALUATION OF SWISS HAMMER READINGS

Model NA-5, Serial Number 1758

Report 77-3

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ABSTRACT

Previous results, both in the field and in the laboratory, have indicated that the Swiss Hammer can differentiate between concretes of high and low compressive strength. The purpose of this study is to correlate Swiss Hammer rebound value with compressive strength for a variety of samples and to describe the use of the resulting data base for predicting compressive strengths from Swiss Hammer readings.

INTRODUCTION

Test specimens, whether Job or Progress, are generally required for each concrete pour. Unless otherwise specified, these specimens are prepared in accordance with AASHTO T23 (Making and Curing Concrete Compression and Flexural Test Specimens in the Field).

Occasionally, the compressive strength of these specimens is below the specified strength for the class of concrete being tested, and an obvious concern for the safety of the structure ensues. Since replicate test specimens are often not available, and since it is known that improper preparation and handling can drastically change the compressive strength of a specimen, it would be desirable to have an independent means for estimating compressive strength.

The Swiss Hammer is possibly one such method. However, in order to achieve maximum utility, it is necessary to determine both its accuracy and its limitations. Statistical analysis of the compressive strength and Swiss Hammer value of 199 test specimens was undertaken to determine whether the Swiss Hammer can be a useful tool for predicting compressive strength.

MATERIALS AND APPARATUS

All specimens tested were the standard 6" x 12" cylinders prepared in cardboard molds by standard procedures under field or laboratory conditions and aged from seven to sixty days. An effort was made to use aggregates and cements from as wide a variety of sources as possible in order that a representative range of values might be obtained.

The Swiss Hammer, purchased on November 14, 1975, from Forney's Incorporated (RD #2, Route 18, South Wampum, Pennsylvania) was of type NA-5 manufactured by E.O. Schmidt of Basel, Switzerland. The manufacturer's serial number is 1758, and the Vermont Department of Highways serial number is 28HD357.

The compressive strength apparatus was a "Super L" hydraulic universal testing machine of 200,000 lbs. capacity manufactured by Tinius Olsen, Whitlow Grove, Pennsylvania, and purchased from H.G. Graff Company, Boston, Massachusetts. The accuracy of this apparatus was checked and certified by the Tinius Olsen Corporation on April 2, 1976.

PROCEDURE

Swiss Hammer readings were obtained on a series of 199 saturated, surface-dry cylindrical specimens scheduled to be tested for compressive strength by the Materials Laboratory. After loading to 150 psi in the Tinius Olsen compression apparatus, a total of fifteen Swiss Hammer readings were obtained on the central two-thirds of the curved surface of each sample, along three vertical meridians equidistantly spaced about the circumference.

After the three highest and three lowest values were dropped, the remaining nine were averaged and recorded. The compressive strength measurement was made as usual and the results recorded.

The data were forwarded to State Information Systems, which prepared a scatter diagram and computed best fit polynomials of first, second, and third degree in the x coordinate. Compressive strength was taken as the y coordinate, and Swiss Hammer value as the x coordinate.

Examination of the scatter diagram and subsequent determination of the correlation coefficient showed that the data were not well enough correlated to make the use of a higher than first degree regression polynomial worthwhile, but that there was sufficient correlation to draw meaningful conclusions. Using the calculated regression line and standard statistical procedures for calculating confidence limits, the confidence limit (See Table 1), the top of the confidence interval (See Table 2), and the bottom of the confidence interval (See Table 3) were calculated for five confidence levels ranging from 90% to 99.5%. Tables 4 and 5 were prepared by interpolating Tables 2 and 3 to obtain compressive strength values in units of 100 psi.

RESULTS AND DISCUSSION

Compressive strengths and Swiss Hammer readings were compared over a wide range of values in both variables. A correlation coefficient of 0.799 was calculated. This was not high enough to warrant the use of a best fit polynomial of greater than first degree.

The confidence range at various confidence levels was calculated from the regression line and standard statistical formulas for confidence interval. These results are presented in Tables 1 through 3. These tables were inverted i.e. the independent and dependent variables were interchanged, in Tables 4 and 5.

All tables are based on the 199 data points. If different or additional data had been used, a different set of tabulated values would have resulted. How close these values would be to those obtained from the original data base is still to be determined. Work to obtain another set of data points is continuing. It is not expected that the tables will be materially altered, but this remains to be proven.

CONCLUSIONS

It has been demonstrated that there is a useful degree of correlation between compressive strength and Swiss Hammer rebound values of structural concrete. While the degree of correlation does not permit the use of sophisticated curve-fitting techniques, it is sufficient to draw meaningful conclusions about the compressive strength of specimens for which only Swiss Hammer readings are available.

A series of tables relating compressive strength to Swiss Hammer readings at five confidence levels ranging from 90% to 99.5% has been prepared. The calculation can easily be extended to lower confidence levels if desired.

TABLE NO. 1

The Confidence Interval - t distribution with infinite degrees of freedom

Swiss Hammer Rebound Number	Computed Compressive Strength from Regression Line	Confidence Level .10	.05	.025	.01	.005
15	1586	591	759	905	1074	1189
16	1797	587	754	898	1066	1180
17	2007	583	748	892	1058	1172
18	2217	580	744	886	1051	1164
19	2428	576	739	881	1045	1158
20	2638	573	735	876	1040	1151
21	2848	570	732	872	1035	1146
22	3059	568	729	868	1030	1141
23	3269	566	726	865	1026	1137
24	3479	564	724	862	1023	1133
25	3690	563	722	860	1021	1131
26	3900	562	721	859	1019	1129
27	4111	561	720	858	1018	1128
28	4321	561	720	858	1018	1127
29	4531	561	720	858	1018	1127
30	4742	562	721	859	1019	1128
31	4952	562	722	860	1020	1130
32	5162	564	723	862	1023	1133
33	5373	565	725	864	1026	1136
34	5583	567	728	867	1029	1140
35	5793	569	731	871	1033	1144
36	6004	572	734	875	1038	1150
37	6214	575	738	879	1044	1156
38	6425	579	742	884	1050	1162
39	6635	582	747	890	1056	1170
40	6845	586	752	896	1064	1178

Use of this Table

Example - If Swiss Hammer rebound number is 22, there is a 5% chance that the compressive strength lies above 3059 + 729 and a 5% chance that it lies below 3059 - 729.

Linear interpolation between integral Swiss Hammer values is permitted.

Linear interpolation between various confidence levels is not permitted.

TABLE NO. 2

Top of Confidence Interval

Swiss Hammer	Confidence Level .10	.05	.025	.01	.005
15	2177	2345	2491	2660	2775
16	2384	2551	2695	2863	2977
17	2590	2755	2899	3065	3179
18	2797	2961	3103	3268	3381
19	3004	3167	3309	3473	3586
20	3211	3373	3514	3678	3789
21	3418	3580	3720	3883	3994
22	3627	3788	3927	4089	4200
23	3835	3995	4134	4295	4406
24	4043	4203	4341	4502	4612
25	4253	4412	4550	4711	4821
26	4462	4621	4759	4919	5029
27	4672	4831	4969	5129	5239
28	4882	5041	5179	5339	5448
29	5092	5251	5389	5549	5658
30	5304	5463	5601	5761	5870
31	5514	5674	5812	5972	6082
32	5726	5885	6024	6185	6295
33	5938	6098	6237	6399	6509
34	6150	6311	6450	6612	6723
35	6362	6523	6664	6826	6937
36	6576	6738	6879	7042	7154
37	6789	6952	7093	7258	7370
38	7004	7167	7309	7475	7587
39	7217	7382	7525	7691	7805
40	7431	7597	7741	7909	8023

Use of this Table

Example - If Swiss Hammer rebound number is 30 there is:

1. A 10% chance that the compressive strength will be above 5304 psi and a 90% chance that it will be below 5304 psi.
2. A 5% chance that the compressive strength will be above 5463 psi and a 95% chance that it will be below 5463 psi.
3. A 2.5% chance that the compressive strength will be above 5601 psi and a 97.5% chance that it will be below 5601 psi.
4. A 1% chance that the compressive strength will be above 5761 psi and a 99% chance that it will be below 5761 psi.
5. A .5% chance that the compressive strength will be above 5870 psi and a 99.5% chance that it will be below 5870 psi.

TABLE NO. 3

Bottom of Confidence Interval

Swiss Hammer	Confidence Level .10	.05	.025	.01	.005
15	995	827	681	512	397
16	1210	1043	899	736	617
17	1424	1259	1115	949	835
18	1637	1473	1331	1166	1053
19	1852	1689	1547	1383	1270
20	2065	1903	1762	1598	1487
21	2278	2116	1976	1813	1702
22	2491	2330	2191	2029	1918
23	2703	2543	2404	2243	2132
24	2915	2755	2617	2456	2346
25	3127	2968	2830	2659	2559
26	3338	3179	3041	2881	2779
27	3550	3391	3253	3093	2983
28	3760	3601	3463	3303	3194
29	3970	3811	3673	3513	3404
30	4180	4021	3883	3723	3614
31	4390	4230	4092	3932	3822
32	4598	4439	4300	4139	4029
33	4808	4648	4509	4347	4237
34	5016	4855	4716	4554	4443
35	5224	5062	4922	4760	4649
36	5432	5270	5129	4966	4854
37	5639	5476	5335	5170	5058
38	5845	5683	5541	5375	5263
39	6053	5888	5745	5579	5465
40	6259	6093	5949	5781	5667

Use of this Table
Example - If Swiss Hammer rebound number is 30 there is:

1. A 10% chance that the compressive strength will be below 4180 psi and a 90% chance that it will be above 4180 psi.
2. A 5% chance that the compressive strength will be below 4021 psi and a 95% chance that it will be above 4021 psi.
3. A 2.5% chance that the compressive strength will be below 3883 psi and a 97.5% chance that it will be above 3883 psi.
4. A 1% chance that the compressive strength will be below 3723 psi and a 99% chance that it will be above 3723 psi.
5. A .5% chance that the compressive strength will be below 3614 psi and a 99.5% chance that it will be above 3614 psi.

TABLE NO. 4

Minimum Swiss Hammer Readings Needed to Ensure that Required Compressive Strength has been Attained at Desired Confidence Level

Required Compressive Strength	Confidence Level				
	90%	95%	97.5%	99%	99.5%
3000	24.4	25.2	25.8	26.6	27.1
3100	24.9	25.6	26.3	27.0	27.5
3200	25.3	26.1	26.8	27.5	28.0
3300	25.8	26.6	27.2	28.0	28.5
3400	26.3	27.0	27.7	28.5	29.0
3500	26.8	27.5	28.2	28.9	29.5
3600	27.2	28.0	28.7	29.4	29.9
3700	27.7	28.5	29.1	29.9	30.4
3800	28.2	28.9	29.6	30.4	30.9
3900	28.7	29.4	30.1	30.8	31.4
4000	29.1	29.9	30.6	31.3	31.9
4100	29.6	30.4	31.0	31.8	32.3
4200	30.1	30.9	31.5	32.3	32.8
4300	30.6	31.3	32.0	32.8	33.3
4400	31.0	31.8	32.5	33.3	33.8
4500	31.5	32.3	33.0	33.7	34.3
4600	32.0	32.8	33.4	34.2	34.8
4700	32.5	33.3	33.9	34.7	35.2
4800	33.0	33.7	34.4	35.2	35.7
4900	33.4	34.2	34.9	35.7	36.2
5000	33.9	34.7	35.4	36.2	36.7
5100	34.4	35.2	35.9	36.7	37.2
5200	34.9	35.7	36.3	37.1	37.7
5300	35.4	36.1	36.8	37.6	38.2
5400	35.8	36.6	37.3	38.1	38.7
5500	36.3	37.1	37.8	38.6	39.2

Use of this Table

Example 1 - If 4000 psi compressive strength is required and a Swiss Hammer rebound number of 30.0 is obtained then there is more than a 95% chance and less than a 97.5% chance that the concrete is 4000 psi or more in compressive strength.

Example 2 - If 4000 psi compressive strength is required at a minimum confidence level of 90% then the minimum permissible Swiss Hammer reading is 29.1.

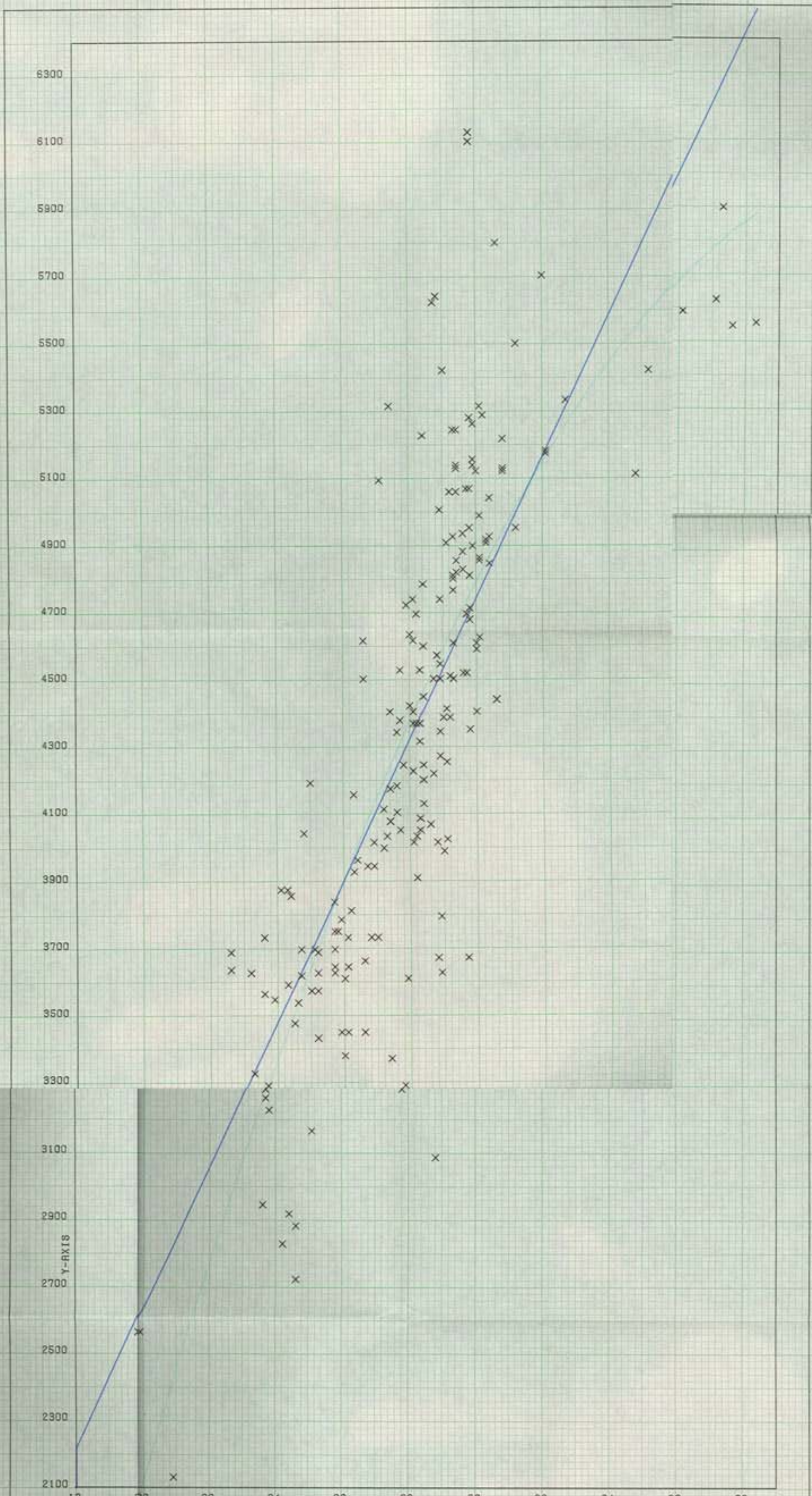
TABLE NO. 5

Maximum Swiss Hammer Reading Needed to Ensure that the Required Compressive Strength has Failed to be Attained at Desired Confidence Level

Required Compressive Strength	Confidence Level				
	90%	95%	97.5%	99%	99.5%
3000	19.0	18.2	17.5	16.7	16.1
3100	19.5	18.7	18.0	17.2	16.6
3200	19.9	19.2	18.5	17.7	17.1
3300	20.4	19.6	19.0	18.2	17.6
3400	20.9	20.1	19.4	18.6	18.1
3500	21.4	20.6	19.9	19.1	18.6
3600	21.9	21.1	20.4	19.6	19.1
3700	22.4	21.6	20.9	20.1	19.6
3800	22.8	22.1	21.4	20.6	20.1
3900	23.3	22.5	21.9	21.1	20.5
4000	23.8	23.0	22.4	21.6	21.0
4100	24.3	23.5	22.8	22.1	21.5
4200	24.7	24.0	23.3	22.5	22.0
4300	25.2	24.5	23.8	23.0	22.5
4400	25.7	24.9	24.3	23.5	23.0
4500	26.2	25.4	24.8	24.0	23.5
4600	26.7	25.9	25.2	24.5	23.9
4700	27.1	26.4	25.7	24.9	24.4
4800	27.6	26.9	26.2	25.4	24.9
4900	28.1	27.3	26.7	25.9	25.4
5000	28.6	27.8	27.1	26.4	25.9
5100	29.0	28.3	27.6	26.9	26.3
5200	29.5	28.8	28.1	27.3	26.8
5300	30.0	29.2	28.6	27.8	27.3
5400	30.5	29.7	29.1	28.3	27.8
5500	30.9	30.2	29.5	28.8	28.2

Use of this Table

Example - If a compressive strength of 4000 psi is required and a Swiss Hammer rebound number at or below 23.8 is obtained, there is at least a 90% chance that the required strength has not been reached. If the Swiss Hammer reading is below 21.6, there is at least a 99% chance that the goal has not been reached.



VERMONT DEPARTMENT OF HIGHWAYS
POLYNOMIAL BEST FIT CALCULATIONS AND PLOT

PROJECT NAME SWISS HAMMER CONVERSION PLOT
PROJECT NO.
USER J. TALBOT
DIVISION MATERIALS
EVALUATION OF SWISS HAMMER READINGS
HORIZ. SCALE ONE INCH =2 UNITS — 2
VERT. SCALE ONE INCH =200 UNITS — 200
DATE PLOTTED 02/22/77

LEGEND
X X X ORIGINAL POINTS
CURVE OF DEGREE 1
CURVE OF DEGREE 2
CURVE OF DEGREE 3
CURVE OF DEGREE 4
CURVE OF DEGREE 5
CURVE OF DEGREE 6