Development of an Alternative Test Procedure to "BS812" for Accelerated Polishing of RoadStones

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ABSTRACT

This paper embodies the results of a comprehensive study of the relationship between polished stone value (PSV) and the petrology of a range of natural aggregates drawn form commercially operating quarries in the UK.

Initially, the polished stone value of each aggregate was measured in a programme of standard tests, in order to make a basis for the comparison of any alternative test procedure to be adopted.

The main objective of the research has been to establish an alternative test procedure for ranking the polish-resisting capabilities of each aggregate as a potential replacement for that specified in BS 812: part 114: 1989.

The latter employs a standard 6-hours laboratory test (3-hours with coarse, followed by 3-hours with a fine polishing medium). Samples of aggregates, form 33 quarries have been assembled and test specimens made in accordance with the procedure described in BS812: part 114: 1989.

Results obtained in the program demonstrate that a shorter and simpler test procedure is capable of producing reproducible results displaying a strong correlation with those of the standard test.

Keywords: Accelerated Polishing, Aggregates, BS812, Skid Resistance, Polished Stone Values, PSV and Standard Test.

1. INTRODUCTION

The in-situ skidding resistance of a road surface is dependent on the properties of the aggregate exposed, the flow of vehicles passing over it and road geometry insofar as this determines vehicle maneuvers. Target values of skid resistance are met by the choice of an aggregate having appropriate resistance to polishing under the action of traffic. This is measured as part of a standard test known as the Accelerated Polishing Test followed by the measurement of Polished Stone Value (PSV), using a simple pendulum testing device.

The BS accelerated polishing test, whilst simple in concept, is time-consuming. It consists of two 3-hours polishing stages using different polishing agents, with attention to the polishing machine between the stages and measurement of the PSV at the end. A pilot study[1] undertaken at QMWC in which the standard test was interrupted in order to assess interim degrees of polish, indicated that the majority of the reduction in frictional resistance produced during the whole test occurred during the early part of the second 3-hour period. This suggested that it may be possible to devise a shorter test procedure and led to this research work.

The present programme of research was carried out using 33 different types of aggregates total of 924 test specimens from various geological classification groups. A list of aggregates used, together with their geological classification is included in Table 1.

The development of the Accelerated Polishing Machine[2] has enabled engineers and highway designers to choose an appropriate PSV of aggregate for each section of road, since aggregates polish more rapidly at locations where tyre forces are relatively high (e.g. bends, approaches to junctions and pedestrian crossings) rather than on straight sections.

The development of the portable skid resistance tester by what was then (1952) the Road Research Laboratory, (RRL) [2 &3], was the starting point for the design of the instrument and was an attempt to solve the problem faced by the highway engineer in relation to roads having similar appearances but distinctly different degrees of resistance to skidding. It provided a basically simple instrument with which to measure, in effect, the degree of polish of different surfaces. After the development of accelerated polishing and portable skid resistance testing equipment to provide a simple and rapid method of checking skid resistance in local areas, it was approved and standardized in the form of a British Standard. Initially it was published as BS 812: 1960 and during the years to date researchers have carried out research on many aspects of BS 812.

2. LIST OF ACCUMULATED AGGREGATES

Compilation, classification and building up a library of aggregate was an important task of this research. It was clear at the outset that limited time and manpower and resources precluded sampling and testing of all surface aggregate rocks in Britain to simplify the task of selection only 33 different types of aggregates were selected and tested. Aggregate from regions within reasonable reach and accessibility in the United Kingdom have been collected. These aggregates have been documented and subjected to various testing procedures during this programme.

3. TEST REGIMES

In order to investigate the feasibility of an alternative test procedure to BS 812 for accelerated polishing of road surfacing aggregates, six different series of tests were

carried out, test specimens for which were prepared according to BS 812: Part 114: 1989[4].

- **Series 1.** Standard 6-Hour Test (Pendulum values recorded at 0 and 6 hours)
- **Series 2.** Interrupted After 3-Hours Coarse and Fine Emery (Pendulum values recorded at 0, 3 and 6 hours using the Coarse and Fine medium)
- **Series 3.** Interrupted 1-Hour Using Coarse and Fine Emery (Pendulum values recorded at 0 ,1, 2, 3, 4, 5 and 6 hours)
- **Series 4.** Interrupted 1-Hour Using Emery Flour (Pendulum values recorded at 0 ,1, 2 and 3 hours using only fine medium)
- **Series 5.** Interrupted every 15-Minutes Using Emery Flour (Pendulum values recorded at 0, 15, 30, 45, 60, 120 and 180 minutes using only fine medium)
- **Series 6.** Extended Polishing Test Using Emery Flour (Pendulum values recorded at 0 ,3, 6, 9, 15, 18, 21, 24, 27 and 30 hours using only fine medium)

3.1 SERIES 1. STANDARD 6-HOUR TEST

From 3 different types of aggregate, 4 test specimens of each type were chosen, together with an additional two test specimens of standard Control Stone (1982)[5]. Initially test specimens were subjected to a Standard Test using the Accelerated Polishing Machine, and 6-hours of polishing (3-hours with corn emery followed by 3-hours of emery flour) was performed according to the test procedure defined in BS 812: Part 114: 1989[4].

Table 2 shows the pendulum values obtained for the standard 6-hours test at 0-hour and 6-hours. These Standard Test results provide the basis for comparison of any future alternative proposed testing procedures emerging through the findings of this research. After arranging the test specimens into groups, 11 sets of tests were arranged. The pendulum values obtained for standard test at 6-hour shows that for aggregates D1,D2,D3 the control stone No.4, was 47, for E1,E2,E3 control No. 5 ,was 46 and for aggregates G1,G2,G3, the control No 7 was 46 (Table 2). Since for these three group the pendulum values of control stone were below the specified range by BS 812 (49.5-55.5), hence these groups were rejected. An investigation was carried out to find out the factors for low pendulum value for control stone, such as tyre wear, temperature, slider wear, method of accelerated polishing and testing sample preparation but all were ruled out. The other factor which the author has noticed was the presence of an aggregate of arenaceous rocks which these type of rocks provide skid resistance due to plucking and the action of tyre pulls out the sand grains out of the surface texture exposing to new grains beneath, and constantly renewing surface that does not polish. But the grains are plucked too quickly the aggregate will wear away leaving a smooth surface. This action of plucking of grains was helping the accelerated polishing to have an effect of more excessive polishing on the test specimens which had resulted in low pendulum values of control stone.

3.2 SERIES 2. INTERRUPTED AFTER 3-HOURS COARSE AND FINE EMERY

Samples for this test were prepared in accordance to BS 812: Part 114: 1989[4]. In this test the test specimens were subjected to Accelerated Polishing. The initial pendulum values were recorded, then test specimens were mounted on the road wheel and using corn emery as the polishing agent, they were subjected to 3-hours of polishing. All 14 test specimens

were removed from the periphery of the road wheel, washed and cleaned thoroughly and the pendulum values were obtained by the use of British Pendulum Tester (BPT) and the values thus obtained known as the British Pendulum Number (BPN). All 14 test specimens were then re-mounted on the road wheel and were subjected to a further 3-hours of polishing using emery flour as the polishing agent. On completion of the test, final pendulum values were obtained.

The main purpose of carrying out the interrupted 3-hours test was to try to establish whether it was corn emery or emery flour which has the most significant effect on the extent of polishing of test specimens, or in other words on pendulum values. Table 3 contains pendulum values obtained at initial (0-hour) stage, 3-hours and 6-hours.

Examining the values measured after 3-hours, it becomes clear that the pendulum values at the end of corn emery stage shows a decrease compared with that measured before polishing began. By the end of the 3-hour stage polishing with emery flour however, the pendulum value has decreased substantially. In fact this was contrary to the findings in the pilot study by Ferguson[1] where all the aggregates on the test run showed an increase in pendulum values at the end of 3-hours polishing with coarse emery. This was the reason which prompted the author to suggest altogether eliminating the corn emery stage.

Recognition of this phenomenon has led the author to carry out further tests in order to investigate the feasibility of completely eliminating the corn emery stage, in an alternative test procedure, thus adopting the use of emery flour as the sole polishing agent in all further testing procedures.

3.3 SERIES 3. INTERRUPTED 1-HOUR USING COARSE AND FINE EMERY

Samples were prepared according to BS 812: Part 114: 1989 [4]. This test was run for a total of 6-hours but interrupted at hourly intervals in order to investigate the progressive extent of polishing. The abrasive used for polishing during the first 3-hours was corn emery followed by emery flour for the second 3-hours of polishing. The results obtained from these tests show that most of the polishing occurs during the emery flour stage (second 3-hours of polishing).

3.4 SERIES 4. INTERRUPTED 1-HOUR USING EMERY FLOUR

Having carried out a programme of standard tests, those interrupted every hour (3-hours of corn emery followed by 3-hours of emery flour) and interrupted every 1-hour using coarse and fine, comparison of results shows that greater polish of the test specimens was developed during the emery flour stage. Substantiation of this indication was obtained from the results of a further 11 tests. In Series 4- tests the abrasive used was solely emery flour. The duration of test was 3-hours; they were interrupted at intervals of 1-hour and the pendulum values recorded.

Analyis of these results clearly illustrates that most of the polishing occurs during the first hour of the emery flour stage. From the above tests and observation, it was decided that two further tests were required, interrupted every 15-minutes for the first hour and recording the pendulum values, thereafter interrupting every hour for a total of 3-hours using emery flour and interrupted every three hours for a total of 30-hours again using emery flour. The main objectives of carrying out the above two tests was to try and establish more specifically when pendulum values decrease during the first hour of polishing, and the extended polishing totaling 30-hours tests to find out when they become constant and no further polishing occurs.

3.5 SERIES 5. INTERRUPTED EVERY 15-MINUTES USING EMERY FLOUR

Since the previous programme of tests repeatedly illustrated that most polishing occurs during the first hour, an attempt was made to investigate the progressive development of this polished state. Tests were carried out on all 11 sets by interrupting the test every 15 minutes for the first hour and recording the pendulum values and thereafter interrupting every hour for a total of 3-hours. Results from the tests interrupted every 15 minutes demonstrated that most polishing occurs during the first hour. A series of correlation coefficients were obtained by comparing pendulum values from standard 6-hour tests against those measured after 15, 30, 45 and 60 minutes. The results are tabulated in Table 4. The correlation coefficients obtained were 0.70, 0.79, 0.85 and 0.84 for standard values compared with those measured after 15, 30, 45 and 60 minutes respectively.

3.6 SERIES 6. EXTENDED POLISHING TEST USING EMERY FLOUR

After carrying out several tests and having established that the polishing occurs mostly during the first 3-hour of emery flour, one further and final test was carried out which lasted for 30 hours, and was interrupted every 3-hours, pendulum values of interrupted every 3-hours through to 30 hours are presented in table 6. Extended polishing was conducted in a series of tests to determine whether additional exposure would produce significant changes in rate or level of polishing. Analyzing the results it is clearly demonstrated that most polishing occurs within the first 3 hours and from 3 - 30 hours polishing occurs but the amount of further polishing (reduction in pendulum value) is relatively small. Table 7 shows the pendulum values of interrupted at 3-hourly intervals the grand mean pendulum value obtained for standard test was 49.63 and for 30-hours was 50.41 this shows that an average increase of 1.5% in pendulum values.

Table 5 shows a summary of correlation coefficients obtained from the extended polishing when solely emery flour is used as the polishing agent. The correlation coefficient when data of standard test are plotted against the fine polishing was found to be at the peak value of 0.90 at 3-hours (see Figure 1), showing the best correlation on comparison with 1-hour and 2-hours.

3.7 STATISTICAL ANALYSIS OF TEST RESULTS

The Pearson's[6] (product moment) correlation coefficient has been applied by assuming that the variables are normally distributed. By applying equation 1 the Correlation Coefficient has been obtained. Further computer analysis of the results was carried out using the Cricket Graph 1.3.1 statistical package on Apple Macintosh computer, This enabled the analysis of the Correlation Coefficient by two methods and obtaining the compatibility of two methods manually calculating and double checking by computer.

$$r = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sqrt{\left\{\left[\sum x^2 - \frac{(\sum x)^2}{n}\right]\left[\sum y^2 - \frac{(\sum y)^2}{n}\right]\right\}}} \qquad \text{Eq.1}$$

Where :

r = Correlation Coefficient

n = number of readings

x & y = variables

3.8 STATISTICAL CORRELATION OF STANDARD 6-HOURS TEST WITH INTERRUPTED 1-HOUR TEST

The pendulum values obtained from the 11 sets of Standard Test results has been plotted in Figure 2 against the pendulum values from the Interrupted 1-hour totaling a period of 6 hours of polishing, (Coarse & Fine). The correlation coefficient between pendulum values for the standard test and those of the same test interrupted at hourly intervals (series 3) was obtained as 0.94.

4. STATISTICAL CORRELATION O F STANDARD 6-HOURS WITH PROPOSED 3-HOURS INTERRUPTED FINE

The pendulum values obtained from the 11 sets of Standard Test results has been plotted in Figure 1 against the pendulum values for the Proposed 3-hours Interrupted Fine, indicating a correlation coefficient of 0.90. Table 6 shows the ranking of aggregates based on the decreasing pendulum values/PSV of standard and proposed 3-hour excluding the control stone. Although the correlation coefficient between the pendulum values for standard test and proposed test is 0.90, but generally the proposed test has produced a higher pendulum values. Table 8 shows the pendulum values, the grand mean pendulum values for the 6-hours standard test was found to be 49.64 and for proposed test was 54.32.

5. SUMMARY OF TEST RESULTS

In order to investigate the feasibility of an alternative test procedure to BS 812 accelerated polishing of road surfacing aggregates, the author has carried out standard 6-hours test on all the 33 different types of aggregates accumulated for the proposed program of test using the accelerated polishing machine. The test specimens were subjected to the procedure defined in BS 812 commonly known as bs standard 6-hours accelerated polishing test and the final psv values were obtained. This provided the basis for comparison on any future alternative test procedures.

The accumulated aggregates were ranked and grouped into sets of 3 different aggregates as well as a control stone which made it into 11 sets for this programme.

In Series 1, Initially BS 6-hours standard accelerated polishing test was carried out on all the 11 sets of aggregates, data collected and analyzed.

Having tested one set from the accumulated aggregates as a standard test, the author decided to carry out some 5 Series of different tests as discussed in order to establish an alternative test regime to BS 812.

Series 2, involved interruption at 3 hours, i.e. at the end of corn emery stage. The pendulum values were recorded, then the test specimens were subjected to a further 3-hours of fine polishing using the emery flour as the polishing agent. This test was performed to see whether the corn emery played an important part in polishing or the fine emery. From the 11 sets of tests it was seen that there was a reduction in pendulum values at the end of first 3-hours of corn emery stage, whereas at the end of 6-hours on completion of test the pendulum values were substantially lower.

Series 3, was run for 6-hours, 3-hours of polishing with corn emery and 3-hours of polishing with emery flour. The test was interrupted at every hour and the pendulum values were recorded. This test was performed to investigate the progressive extent of polishing during each hour. It was concluded that from the results obtained the polishing occurred during the first 3-hours of corn emery but at the transition point of changing the polishing agent to emery flour (i.e. at 3-hours) a sudden drop in reduction of pendulum values was observed.

Series 4. Having carried out the previous test and comparing the data, it emerged that the emery flour stage resulted in the most reduction of pendulum values. Hence an interrupted 1-hour test was carried out (polishing the test specimens solely with emery flour for a total of 3-hours) in order to be able to correlate the final 3-hours of fine polishing with the standard test. The statistical analysis compared the results of the standard 6-hours test with those produced by 3-hours of fine polishing. The correlation coefficient was found to be **0.90**, indicating that these two sets of results were strongly correlated.

Series 5. The results of Series 4 indicated that most of the polishing occurred during the first hour. It was decided to carry out a test for 3-hours interrupting the test at every 15-minutes for the first hour and followed by interrupting at 60-minutes and finally 180-minutes. The statistical analysis revealed that at 15, 30, 45, 60, 120 and at 180 minutes the correlation coefficients obtained were found to be 0.70, 0.79, 0.85, 0.84, 0.85, 0.90 respectively. This indicated that at 3-hours the correlation coefficient of 0.90 was the best correlation obtained. The conclusion drawn was that a test based on 3-hours of polishing using emery flour only could be adopted as an alternative method of accelerated polishing of road surfacing aggregates.

Analysis of an extended polishing test produced a series of correlation coefficients by comparing results from the standard 6-hours test with each of those from 3-hourly interrupted measurements extending to 30-hours. This demonstrated that the strongest correlation (with that of the standard test) was obtained after 3-hours of polishing, but the test specimens from 3-hours to 30-hours showed further small reductions in pendulum values. Generally further polishing after the end of 3-hours can not be justified.

Table 1 - List of 33 aggregates assembled for this research work.

No.	Name of Aggregate	Aggregate Type	Aggregate Source & County of Origin
1	**A1**	Granodiorite	Devon
2	**A2**	Dolerite	Northumberland
3	**A3**	Dolerite	Gwynedd
4	**B1**	Limestone	North Yorkshire
5	**B2**	Granite	Cornwall
6	**B3**	Granite	Devon
7	**C1**	Basalt	Co. Londonderry
8	**C2**	Olivine Basalt	Co. Antrim N.I
9	**C3**	Gritstone	North Yorkshire
10	**D1**	Granite	Cornwall
11	**D2**	Limestone	North Yorkshire
12	**D3**	Granodiorite	Gwynedd
13	**E1**	Hornfels	Devon
14	**E2**	Greywacke	Bath Somerset
15	**E3**	Basalt	West Midland
16	**F1**	Basalt	Shropshire
17	**F2**	Trachyte	Devon
18	**F3**	Leucodiorite	North Yorkshire
19	**G1**	Granite	Cornwall
20	**G2**	Greywacke	Gwynedd
21	**G3**	Limestone	Devon
22	**H1**	Quartz Diorite	Warwickshire
23	**H2**	Granite	Gwynedd
24	**H3**	Granite	Cornwall
25	**K1**	Pyroxene Basalt	Bath Somerset
26	**K2**	Olivine Dolerite	Devon
27	**K3**	Granite	Isle of Man
28	**M1**	Basalt Dolerite	Devon
29	**M2**	Granite	Devon
30	**M3**	Quartz Dolerite	Northumberland
31	**N1**	Granite	**-**
32	**N2**	Basalt	**-**
33	**N3**	Sandstone	**-**

Table 2 - Pendulum values and PSV of standard test at 0-hour and 6-hour.

No.	Aggregate Name	Pendulum Value at 0-hour	Pendulum Value at 6-hours	PSV Standard
1	A1	77	56	56.5
2	A2	75	52	52.5
3	A3	72	54	54.5
4	Control Stone No.1	75	52	-
5	B1	69	57	59.5
6	B2	67	49	51.5
7	B3	68	52	54.5
8	Control Stone No.2	66	50	-
9	C1	72	47	49.5
10	C2	74	50	52.5
11	C3	69	58	60.5
12	Control Stone No.3	68	50	
13	D1	66	43	-
14	D2	71	34	-
15	D3	64	40	-
16	Control Stone No.4	70	47	
17	E1	67	45	-
18	E2	85	62	-
19	E3	68	43	-
20	Control Stone No.5	71	45	-
21	F1	63	41	42.5
22	F2	71	51	52.5
23	F3	70	50	51.5
24	Control Stone No.6	73	51	
25	G1	70	45	-
26	G2	67	49	-
27	G3	62	30	-
28	Control Stone No.7	70	46	-
29	H1	71	53	55.5
30	H2	62	50	52.5
31	H3	85	68	70.5
32	Control Stone No.8	70	50	-
33	K1	70	51	51.5
34	K2	71	58	58.5
35	K3	68	59	59.5
36	Control Stone No.9	72	52	-
37	M1	71	52	53.5
38	M2	60	43	44.5
39	M3	72	50	51.5
40	Control Stone No.10	73	51	-
41	N1	75	55	57.5
42	N2 (IRAN)	77	47	49.5
43	N3	66	46	48.5
44	Control Stone No.11	74	50	-
Grand Mean Pendulum Values		**70.40**	**49.64**	

Table 3 - Pendulum / PSV values for interrupted 3-hours test at 0, 3 and 6-hour.

No.	Aggregate Name	Pendulum Value at 0-hour	Pendulum Value at 3-hours	Pendulum Value at 6-hours	6-h PSV
1	A1	77	72	56	56.5
2	A2	75	67	52	52.5
3	A3	73	69	54	54.5
4	Control Stone No.1	75	66	52	
5	B1	70	67	58	58.5
6	B2	67	64	50	50.5
7	B3	68	65	53	53.5
8	Control Stone No.2	69	66	52	
9	C1	73	64	48	50.5
10	C2	71	65	49	51.5
11	C3	72	66	56	58.5
12	Control Stone No.3	69	63	50	
13	D1	67	60	45	-
14	D2	72	54	36	-
15	D3	63	57	42	-
16	Control Stone No.4	71	61	49	
17	E1	68	54	44	-
18	E2	86	71	60	-
19	E3	67	59	45	-
20	Control Stone No.5	71	62	47	
21	F1	64	53	41	40.5
22	F2	72	63	51	50.5
23	F3	70	64	52	51.5
24	Control Stone No.6	72	65	53	
25	G1	69	57	46	-
26	G2	68	59	49	-
27	G3	63	45	31	-
28	Control Stone No.7	71	58	47	
29	H1	73	63	52	53.5
30	H2	61	59	50	51.5
31	H3	84	78	69	70.5
32	Control Stone No.8	71	59	51	
33	K1	71	62	52	53.5
34	K2	69	68	59	60.5
35	K3	68	67	58	59.5
36	Control Stone No.9	72	63	51	
37	M1	71	66	52	53.5
38	M2	61	54	43	44.5
39	M3	73	62	50	51.5
40	Control Stone No.10	72	61	51	
41	N1	74	69	56	57.5
42	N2	76	60	46	47.5
43	N3	67	58	47	48.5
44	Control Stone No.11	73	64	51	
Grand Mean Pendulum Values		**70.66**	**62.48**	**50.14**	

Table 4 - Summary of Correlation Coefficients at stages during 3-hour test with emery flour only.

No.	Time (Minutes)	Correlation Coefficients
1	**15**	**0.70**
2	**30**	**0.79**
3	**45**	**0.85**
4	**60**	**0.84**
5	**120**	**0.85**
6	**180**	**0.90**

Table 5 - Summary of Correlation Coefficients on Extended polishing with emery flour only.

No.	Time (Hours)	Correlation Coefficients
1	**1**	**0.84**
2	**2**	**0.85**
3	**3**	**0.90**
4	**6**	**0.88**
5	**9**	**0.88**
6	**12**	**0.86**
7	**15**	**0.86**
8	**18**	**0.84**
9	**21**	**0.85**
10	**24**	**0.85**
11	**27**	**0.86**
12	**30**	**0.86**

Table 6 - Ranking of aggregates (based on decreasing pendulum / PSV values) of standard test and proposed 3-hours excluding the control stone.

No.	Aggregate Name	Standard 6-hours	PSV Standard	Proposed 3-hours	PSV Proposed 3-hours
31	H3	68	70.5	73	71.5
18	E2	62	-	68	-
35	K3	59	59.5	63	60.5
11	C3	58	60.5	58	60.5
34	K2	58	58.5	64	61.5
5	B1	57	59.5	60	59.5
1	A1	56	56.5	56	56.5
41	N1	55	57.5	60	57.5
3	A3	54	54.5	54	54.5
29	H1	53	55.5	56	54.5
7	B3	52	54.5	58	57.5
37	M1	52	53.5	61	55.5
2	A2	52	52.5	55	55.5
22	F2	51	52.5	55	55.5
33	K1	51	51.5	57	54.5
30	H2	50	52.5	55	53.5
10	C2	50	52.5	52	54.5
39	M3	50	51.5	59	53.5
23	F3	50	51.5	57	57.5
6	B2	49	51.5	54	53.5
26	G2	49	-	51	51.5
42	N2	47	49.5	54	51.5
9	C1	47	49.5	50	52.5
43	N3	46	48.5	51	48.5
17	E1	45	-	52	-
25	G1	45	-	48	48.5
38	M2	43	44.5	51	45.5
19	E3	43	-	50	-
13	D1	43	-	49	4.5
21	F1	41	42.5	48	48.5
15	D3	40	-	50	50.5
14	D2	34	-	47	47.5
27	G3	30	-	36	36.5
Grand Mean Pendulum Values		**49.70**		**54.90**	

Table 7 - Pendulum values of 3-h interrupted through to 30-h extended polishing.

No.	Standard 6-h	3-h Fine	6-h Fine	9-h Fine	12-h Fine	15-h Fine	18-h Fine	21-h Fine	24-h Fine	27-h Fine	30-h Fine
1	56	56	57	56	55	55	54	53	53	53	52
2	52	55	56	55	54	54	53	52	52	52	51
3	54	54	56	54	53	52	52	51	51	50	49
4	52	52	54	53	52	51	51	50	50	49	48
5	57	60	60	58	57	56	55	55	54	54	54
6	49	54	54	55	54	54	54	54	53	53	53
7	52	58	56	54	53	52	51	50	50	49	49
8	50	53	51	51	50	50	49	51	50	50	50
9	47	50	48	48	47	47	46	46	46	46	46
10	50	52	51	51	50	51	51	51	50	49	49
11	58	58	58	57	57	57	56	56	55	54	53
12	50	50	60	50	49	48	47	47	48	48	48
13	43	49	52	51	50	50	49	49	48	47	46
14	34	47	45	45	46	46	46	46	44	42	40
15	40	50	53	53	52	52	51	51	50	47	46
16	47	52	50	50	49	48	47	47	46	45	44
17	45	52	52	51	50	49	48	48	47	46	45
18	62	68	68	66	65	65	64	63	63	62	61
19	43	50	49	48	47	46	45	44	42	42	42
20	45	45	51	51	50	50	49	49	48	47	47
21	41	48	50	50	49	49	48	48	47	47	47
22	51	55	55	55	55	54	53	52	51	51	50
23	50	57	55	54	53	52	52	51	50	50	50
24	51	52	51	51	50	50	49	51	50	50	50
25	45	48	48	47	46	46	45	44	44	43	43
26	49	51	50	49	48	48	47	47	47	46	46
27	30	36	36	35	34	33	33	32	32	31	31
28	46	52	52	52	51	51	51	50	50	50	50
29	53	56	54	54	53	52	52	52	51	52	51
30	50	55	57	56	56	55	54	53	54	54	54
31	68	73	71	70	70	69	68	67	67	66	66
32	50	54	54	53	52	52	51	52	51	51	50
33	51	57	56	56	55	55	54	54	54	53	52
34	58	64	64	64	63	63	62	62	62	63	62
35	59	63	62	62	61	60	60	59	59	59	59
36	52	55	55	56	56	54	53	54	53	52	53
37	52	61	62	61	61	61	61	60	60	60	60
38	43	51	51	52	52	51	50	50	50	50	50
39	50	59	57	57	57	56	56	56	56	56	56
40	51	58	58	57	57	57	57	55	55	56	55
41	55	60	59	59	57	58	58	58	57	56	56
42	47	54	54	53	53	52	52	52	52	52	52
43	46	51	51	51	50	50	50	50	51	50	50
44	50	55	54	54	54	54	54	53	52	52	52
Grand Mean Pendulum Values	**49.63**	**54.32**	**54.48**	**53.75**	**53.02**	**52.61**	**52.00**	**51.7**	**51.25**	**50.79**	**50.41**

Table 8 - Final pendulum values / PSV of standard test and proposed 3-hours.

No.	Aggregate Name	Standard 6-hours	PSV Standard	Proposed 3-hours	Pendulum difference	PSV Proposed 3-hours
1	A1	56	56.5	56	0	56.5
2	A2	52	52.5	55	3	55.5
3	A3	54	54.5	54	0	54.5
4	Control Stone No.1	52		52	0	
5	B1	57	59.5	60	3	59.5
6	B2	49	51.5	54	5	53.5
7	B3	52	54.5	58	6	57.5
8	Control Stone No.2	50		53	3	
9	C1	47	49.5	50	3	52.5
10	C2	50	52.5	52	2	54.5
11	C3	58	60.5	58	0	60.5
12	Control Stone No.3	50		50	0	
13	D1	43	-	49	6	4.5
14	D2	34	-	47	13	47.5
15	D3	40	-	50	10	50.5
16	Control Stone No.4	47		52	5	
17	E1	45	-	52	7	-
18	E2	62	-	68	6	-
19	E3	43	-	50	7	-
20	Control Stone No.5	45		45	0	-
21	F1	41	42.5	48	7	48.5
22	F2	51	52.5	55	4	55.5
23	F3	50	51.5	57	7	57.5
24	Control Stone No.6	51		52	1	
25	G1	45	-	48	3	48.5
26	G2	49	-	51	2	51.5
27	G3	30	-	36	6	36.5
28	Control Stone No.7	46		52	6	
29	H1	53	55.5	56	3	54.5
30	H2	50	52.5	55	5	53.5
31	H3	68	70.5	73	5	71.5
32	Control Stone No.8	50		54	4	
33	K1	51	51.5	57	6	54.5
34	K2	58	58.5	64	6	61.5
35	K3	59	59.5	63	4	60.5
36	Control Stone No.9	52		55	3	
37	M1	52	53.5	61	9	55.5
38	M2	43	44.5	51	8	45.5
39	M3	50	51.5	59	9	53.5
40	Control Stone No.10	51		58	7	
41	N1	55	57.5	60	5	57.5
42	N2	47	49.5	54	7	51.5
43	N3	46	48.5	51	5	48.5
44	Control Stone No.11	50		55	5	
	Grand Mean Pendulum Values	**49.64**		**54.32**		

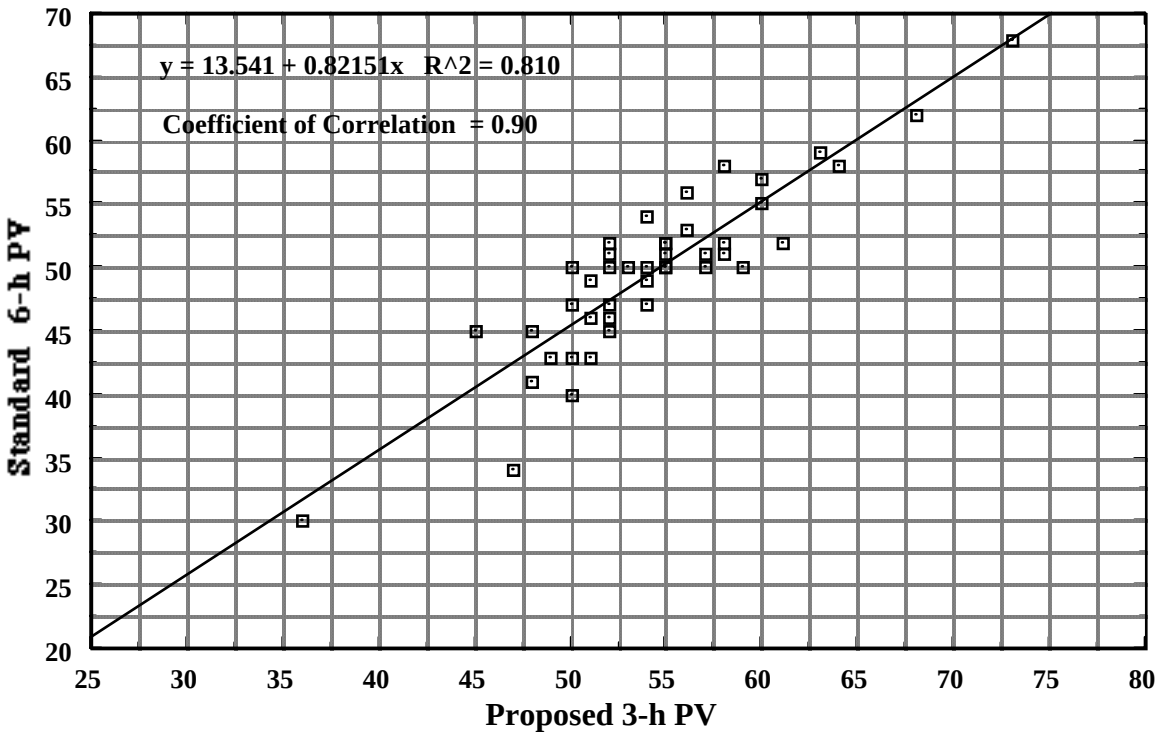

Figure 1 - Graph of standard 6-hours against proposed 3-hours.

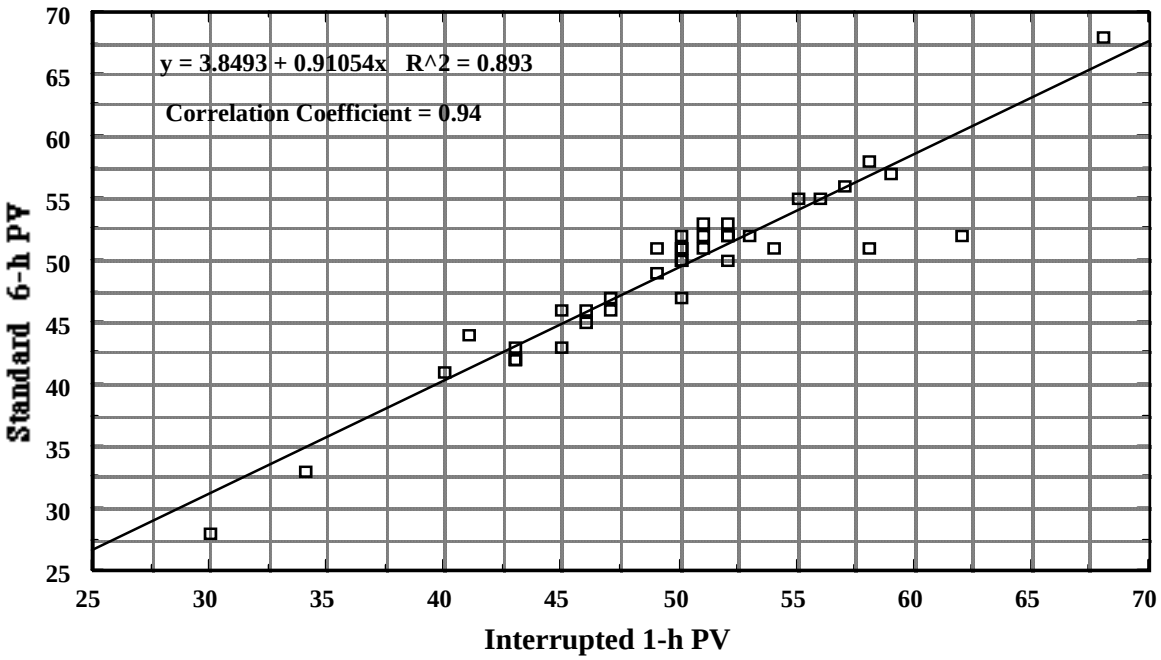

Figure 2 - Graph of standard 6-hours against interrupted 1-hour :(Coarse & Fine).

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