

# Modeling of Soundness Property-Coarse Aggregates

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## Abstract

In the past several attempts have been made to develop a relationship between the compaction characteristics and the CBR of different groups of soil. Large scale road constructions are taking place over the length and breadth of India due to adoption of various intensified activities in road construction in India like PMGSY, etc. As a result huge quantity of aggregate material is being needed for the constructions of sub-base in most of the situations. For that aggregates are collected from extensive areas. Such aggregates may have larger variations in their engineering properties due to variety of reasons. But proper estimation of variation in properties of the materials used for construction work can only ensure the satisfactory performance of the constructed road with cost effectiveness. The soundness property test result is one of the important parameter used effectively for such assessment. But in practice only limited number of such tests could be performed for evaluating these engineering properties because of high cost and time required for testing and as a result, it is difficult to reveal detailed variation in the soundness values to enable rational, economic and also safe construction. One of the most important property of aggregates is the resistance to weathering action or soundness. The stone aggregates should retain the strength characteristics and should not disintegrate under adverse weather conditions including alternate dry and wet/freeze-thaw cycles or in other words the aggregates should have enough durability or resistance to weathering action. In absence of adequate information from performance studies, a laboratory test simulating accelerated weathering condition is created to judge durability or soundness of aggregates. Soundness test takes at least 10 days for completion. In such cases if the estimation of the soundness value could be developed on the basis of some tests which are quick to perform, less time consuming and cheap, then the process will help the constructors enormously. In this view an attempt has been made to develop a correlation between the various physical characteristics of aggregates from different sources across Kashmir valley and adjoining areas in J&K, so as to develop a mathematical model depicting relationship between other physical characteristics & soundness property of aggregates. Using various softwares (such as NLREG-Nonlinear Regression and Curve Fitting; MRA&F; XLSTAT), a general relationship between the soundness property and other various characteristics of aggregates (from J&K) has been developed. In this study comparison of soundness property with various other properties of aggregates by the help of mathematical models and validation of the devised mathematical models has been made.

**Keywords: Coarse Aggregates, Soundness Property**

## I. INTRODUCTION

Aggregate forms the major part of the pavement structure and it is the prime material used in pavement construction. Aggregates have to primarily bear load stresses occurring on the roads and runways. Aggregates often serve as granular base course underlying the 'superior pavements. Thus the properties of the aggregates are of considerable significance to the highway engineers. Aggregates which are used in the surface course have to withstand the high magnitude of load stresses and wear and tear due to abrasive action of traffic. The aggregates in the pavements are also subjected to impact due to the moving wheel loads. The resistance to impact or toughness is another desirable property of aggregates. The stones should retain the strength and hardness and should not disintegrate under adverse weather conditions including alternate wet-dry and freeze-thaw cycles, or in other words the stones should have enough durability. The presence of air voids or pores in stones also may indicate the

suitability and strength characteristics of the stones. All aggregates which happen to fall in a particular size range may not have the same strength and durability when compared with cubical, angular or rounded particles of the same stone. Too flaky and elongated aggregates are avoided as far as possible as they can be crushed under the roller and traffic loads. Rounded aggregate may be preferred in cement concrete mix due to better workability for the same proportion of cement paste and same water cement ratio, whereas rounded particles are not preferred in granular base course and water bound macadam construction but angular Heavy moving loads on the surface of flexible pavements may cause some temporary deformation of the pavement layers resulting in possible relative movement and mutual rubbing of aggregate particles. One of the most important property of aggregates is the resistance to weathering action or soundness .The stone aggregates should retain the strength characteristics and should not disintegrate under adverse weather conditions including alternate dry and wet/freeze-thaw cycles or in other words the aggregates should have enough durability or resistance to weathering action. As huge quantity of aggregate material is required for almost all of constructions, the aggregates are thus collected from extensive areas. Hence, proper estimation of variation in properties of the materials (that are procured from a different site) is required before actual construction work is accomplished and then can only ensure the satisfactory performance of the construction with cost effectiveness. The soundness property test result is one of the important parameter used effectively for such assessment.

## II. OBJECTIVES

In practice only limited number of soundness tests could be performed for evaluating the engineering properties of aggregates because of high cost and time required for testing and as a result it is difficult to reveal detailed variations in soundness property test so as to enable rational, economic and safer construction. This test takes at least 10 days for completion (as per IRC recommendations, a sample has to undergo at least 5 cycles of alternate freeze-thaw conditions before finally sieving the sample and each cycle takes at least 2 days for completion). In such cases if the estimation of the soundness property could be developed on the basis of some tests which are quick to perform, less time consuming and cheap, then the process will help the constructors enormously. Thus, the objectives of this research attempt are:

- 1) To find out the engineering parameters/ properties of aggregates from various sources across the Kashmir Valley.
- 2) To devise and setup the concept of saving time and minimization of cost by the derived relationship.
- 3) To develop a correlation between the various physical characteristics of aggregates from different sources across Kashmir Valley and adjoining areas in J&K and to develop a mathematical model depicting relationship between these physical characteristics & soundness property of aggregates
- 4) To devise Mathematical Models depicting relation between characteristics of aggregates and their soundness property.
- 5) To validate the devised Mathematical Models.

## III.METHODOLOGY

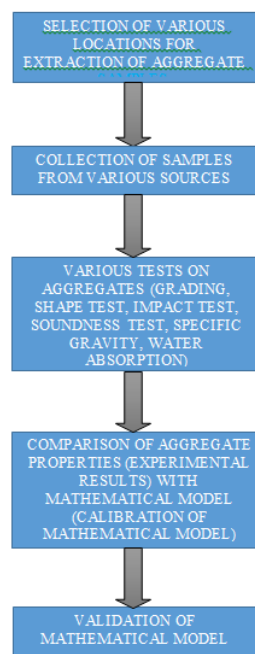


Fig. 1: Methodology

## IV. EXPERIMENTAL WORK

Test results of aggregates obtained from different sources are given as under:

### A. Sieve Analysis or Grading of Coarse Aggregates [1]

(SOURCE-1: Brengi River-Kashmir J&K)

Result: Fineness Modulus =  $(\sum \text{cumulative \%age weight retained})/100$

Fineness Modulus = 5.53

1) Results of Aggregate Impact Test [2]

(SOURCE-1: Brengi River-Kashmir J&K)

Result: Aggregate Impact Value (Percent Fines) =  $100W_2/W_1$  (%) = 14.25

2) Results of Shape Test- Flakiness Index Test [3]

(SOURCE-1: Brengi River-Kashmir J&K)

Result: Flakiness Index = 17.01 %

3) Results of Shape Test-Elongation Index Test [4]

(SOURCE-1: Brengi River-Kashmir J&K)

Result: Elongation Index = 5.35 %

4) Results of Specific Gravity and Water Absorption Tests [5]

(SOURCE-1: Brengi River-Kashmir J&K)

– Size of aggregates: 20 mm

– Type of aggregates: Coarse

Result: Specific gravity =  $W_4/(W_3-W_s)$  = 2.52

Water Absorption=  $(W_3-W_4)*100/W_4$  % = 2.72

5) Results of Soundness Test [6]

(SOURCE-1: Brengi River-Kashmir J&K)

Type of reagent used:  $Na_2SO_4$

Number of cycles: 05

Result: %age passing finer sieve after test (actual percent loss) = 0.95

Weighted average (corrected % loss = 0.77

### B. Sieve Analysis or Grading of Coarse Aggregates [1]

(SOURCE-2: Doru River-Kashmir J&K)

Result: Fineness Modulus =  $(\sum \text{cumulative \%age weight retained})/100$

Fineness Modulus = 5.11

1) Results of Aggregate Impact Test [2]

(SOURCE-2: Doru River-Kashmir J&K)

Result: Aggregate Impact Value (Percent Fines) =  $100W_2/W_1$  (%) = 15

2) Results of Shape Test- Flakiness Index Test

(SOURCE-2: Doru River-Kashmir J&K)

Result: Flakiness Index = 14.45 %

3) Results of Shape Test-Elongation Index Test

(SOURCE-2: Doru River-Kashmir J&K)

Result: Elongation Index = 12.13 %

4) Results of Specific Gravity and Water Absorption Tests

(SOURCE-2: Doru River-Kashmir J&K)

– Size of aggregates: 20 mm

– Type of aggregates: Coarse

Result: Specific gravity =  $W_4/(W_3-W_s)$  = 2.68

Water Absorption=  $(W_3-W_4)*100/W_4$  (%) = 2.66

5) Results of Soundness Test

(SOURCE-2: Doru River-Kashmir J&K)

Type of reagent used:  $Na_2SO_4$

Number of cycles: 05

Result: %age passing finer sieve after test (actual percent loss) = 0.9

Weighted average (corrected % loss = 0.8

### C. Sieve Analysis or Grading of Coarse Aggregates [1]

(SOURCE-3: Sangri Dragad River-Awantipora, Kashmir J&K)

Result: Fineness Modulus =  $(\sum \text{cumulative \%age weight retained})/100$

Fineness Modulus = 5.80

1) *Results of Aggregate Impact Test [2]*

(SOURCE-3: Sangri Dragad River-Awantipora, Kashmir J&K)

Result: Aggregate Impact Value (Percent Fines) =  $100W_2/W_1$  (%) = 11.25

2) *Results of Shape Test- Flakiness Index Test*

(SOURCE-3: Sangri Dragad River-Awantipora, Kashmir J&K)

Result: Flakiness Index = 29.27 %

3) *Results of Shape Test-Elongation Index Test*

(SOURCE-3: Sangri Dragad River-Awantipora, Kashmir J&K)

Result: Elongation Index = 36.45 %

4) *Results of Specific Gravity and Water Absorption Tests*

(SOURCE-3: Sangri Dragad River-Awantipora, Kashmir J&K)

– Size of aggregates: 20 mm

– Type of aggregates: Coarse

Result: Specific gravity =  $W_4/(W_3-W_s)$  = 2.08

Water Absorption =  $(W_3-W_4)*100/W_4$  (%) = 2.11

5) *Results of Soundness Test*

(SOURCE-3: Sangri Dragad River-Awantipora, Kashmir J&K)

Type of reagent used:  $Na_2SO_4$

Number of cycles: 05

Result: %age passing finer sieve after test (actual percent loss) = 1.37

Weighted average (corrected % loss) = 1.1

**D. Sieve Analysis or Grading of Coarse Aggregates [1]**

(SOURCE-4: Lassipora-Kulgam, Kashmir J&K)

Result: Fineness Modulus =  $(\sum \text{cumulative \%age weight retained})/100$

Fineness Modulus = 5.36

1) *Results of Aggregate Impact Test [2]*

(SOURCE-4: Lassipora-Kulgam, Kashmir J&K)

Result: Aggregate Impact Value (Percent Fines) =  $100W_2/W_1$  (%) = 13

2) *Results of Shape Test- Flakiness Index Test*

(SOURCE-4: Lassipora-Kulgam, Kashmir J&K)

Result: Flakiness Index = 25.76 %

3) *Results of Shape Test-Elongation Index Test*

(SOURCE-4: Lassipora-Kulgam, Kashmir J&K)

Result: Elongation Index = 15.12 %

4) *Results of Specific Gravity and Water Absorption Tests*

(SOURCE-4: Lassipora-Kulgam, Kashmir J&K)

– Size of aggregates: 20 mm

– Type of aggregates: Coarse

Result: Specific gravity =  $W_4/(W_3-W_s)$  = 2.12

Water Absorption =  $(W_3-W_4)*100/W_4$  (%) = 2.47

5) *Results of Soundness Test*

(SOURCE-4: Lassipora-Kulgam, Kashmir J&K)

Type of reagent used:  $Na_2SO_4$

Number of cycles: 05

Result: %age passing finer sieve after test (actual percent loss) = 0.89

Weighted average (corrected % loss) = 0.66

**E. Sieve Analysis or Grading of Coarse Aggregates [1]**

(SOURCE-5: Awantipora Nalla, Kashmir J&K)

Result: Fineness Modulus =  $(\sum \text{cumulative \%age weight retained})/100$

Fineness Modulus = 5.8

1) *Results of Aggregate Impact Test [2]*

(SOURCE-5: Awantipora Nalla, Kashmir J&K)

Result: Aggregate Impact Value (Percent Fines) =  $100W_2/W_1$  (%) = 17.5

2) *Results of Shape Test- Flakiness Index Test*

(SOURCE-5: Awantipora Nalla, Kashmir J&K)

Result: Flakiness Index = 35.54 %

3) *Results of Shape Test-Elongation Index Test*

(SOURCE-5: Awantipora Nalla, Kashmir J&K)

Result: Elongation Index = 9.07 %

4) *Results of Specific Gravity and Water Absorption Tests*

(SOURCE-5: Awantipora Nalla, Kashmir J&K)

– Size of aggregates: 20 mm

– Type of aggregates: Coarse

Result: Specific gravity =  $W_4/(W_3-W_s) = 2.64$

Water Absorption =  $(W_3-W_4)*100/W_4$  (%) = 3.54

5) *Results of Soundness Test*

(SOURCE-5: Awantipora Nalla, Kashmir J&K)

Type of reagent used:  $Na_2SO_4$

Number of cycles: 05

Result: %age passing finer sieve after test (actual percent loss) = 1.95

Weighted average (corrected % loss) = 1.04

**F. Sieve Analysis or Grading of Coarse Aggregates [1]**

(SOURCE-6: Tral Nalla, Kashmir J&K)

Result: Fineness Modulus =  $(\sum \text{cumulative \%age weight retained})/100$

Fineness Modulus = 5.63

1) *Results of Aggregate Impact Test [2]*

(SOURCE-6: Tral Nalla, Kashmir J&K)

Result: Aggregate Impact Value (Percent Fines) =  $100W_2/W_1$  (%) = 13

2) *Results of Shape Test- Flakiness Index Test*

(SOURCE-6: Tral Nalla, Kashmir J&K)

Result: Flakiness Index = 7.56 %

3) *Results of Shape Test-Elongation Index Test*

(SOURCE-6: Tral Nalla, Kashmir J&K)

Result: Elongation Index = 17.43 %

4) *Results of Specific Gravity and Water Absorption Tests*

(SOURCE-6: Tral Nalla, Kashmir J&K)

– Size of aggregates: 20 mm

– Type of aggregates: Coarse

Result: Specific gravity =  $W_4/(W_3-W_s) = 2.46$

Water Absorption =  $(W_3-W_4)*100/W_4$  (%) = 6.92

5) *Results of Soundness Test*

(SOURCE-5: Awantipora Nalla, Kashmir J&K)

Type of reagent used:  $Na_2SO_4$

Number of cycles: 05

Result: %age passing finer sieve after test (actual percent loss) = 1.34

Weighted average (corrected % loss) = 0.97

**G. Sieve Analysis or Grading of Coarse Aggregates [1]**

(SOURCE-7: Ganderbal Quarry, Kashmir J&K)

Result: Fineness Modulus =  $(\sum \text{cumulative \%age weight retained})/100$

Fineness Modulus = 5.245

1) *Results of Aggregate Impact Test [2]*

(SOURCE-7: Ganderbal Quarry, Kashmir J&K)

Result: Aggregate Impact Value (Percent Fines) =  $100W_2/W_1$  (%) = 20

2) *Results of Shape Test- Flakiness Index Test*

(SOURCE-7: Ganderbal Quarry, Kashmir J&K)

Result: Flakiness Index = 14.21%

3) *Results of Shape Test-Elongation Index Test*

(SOURCE-7: Ganderbal Quarry, Kashmir J&K)

Result: Elongation Index = 11.14 %

4) *Results of Specific Gravity and Water Absorption Tests*

(SOURCE-7: Ganderbal Quarry, Kashmir J&K)

– Size of aggregates: 20 mm

– Type of aggregates: Coarse

Result: Specific gravity =  $W_4 / (W_3 - W_s) = 2.52$   
Water Absorption =  $(W_3 - W_4) * 100 / W_4$  (%) = 5.5

5) *Results of Soundness Test*

(SOURCE-7: Ganderbal Quarry, Kashmir J&K)

Type of reagent used:  $Na_2SO_4$

Number of cycles: 05

Result: %age passing finer sieve after test (actual percent loss) = 1.61

Weighted average (corrected % loss) = 1.09

**H. Sieve Analysis or Grading of Coarse Aggregates [1]**

(SOURCE-8: Athwajan Quarry, Kashmir J&K)

Result: Fineness Modulus =  $(\sum \text{cumulative \%age weight retained}) / 100$

Fineness Modulus = 5.40

1) *Results of Aggregate Impact Test [2]*

(SOURCE-8: Athwajan Quarry, Kashmir J&K)

Result: Aggregate Impact Value (Percent Fines) =  $100W_2 / W_1$  (%) = 7.5

2) *Results of Shape Test- Flakiness Index Test*

(SOURCE-8: Athwajan Quarry, Kashmir J&K)

Result: Flakiness Index = 20.77 %

3) *Results of Shape Test-Elongation Index Test*

(SOURCE-8: Athwajan Quarry, Kashmir J&K)

Result: Elongation Index = 22.6 %

4) *Results of Specific Gravity and Water Absorption Tests*

(SOURCE-8: Athwajan Quarry, Kashmir J&K)

– Size of aggregates: 20 mm

– Type of aggregates: Coarse

Result: Specific gravity =  $W_4 / (W_3 - W_s) = 2.55$

Water Absorption =  $(W_3 - W_4) * 100 / W_4$  (%) = 3.54

5) *Results of Soundness Test*

(SOURCE-8: Athwajan Quarry, Kashmir J&K)

Type of reagent used:  $Na_2SO_4$

Number of cycles: 05

Result: %age passing finer sieve after test (actual percent loss) = 0.85

Weighted average (corrected % loss) = 0.70

**I. Sieve Analysis or Grading of Coarse Aggregates [1]**

(SOURCE-9: Bandipora Quarry, Kashmir J&K)

Result: Fineness Modulus =  $(\sum \text{cumulative \%age weight retained}) / 100$

Fineness Modulus = 5.36

1) *Results of Aggregate Impact Test [2]*

(SOURCE-9: Bandipora Quarry, Kashmir J&K)

Result: Aggregate Impact Value (Percent Fines) =  $100W_2 / W_1$  (%) = 11

2) *Results of Shape Test- Flakiness Index Test*

(SOURCE-9: Bandipora Quarry, Kashmir J&K)

Result: Flakiness Index = 18.70%

3) *Results of Shape Test-Elongation Index Test*

(SOURCE-9: Bandipora Quarry, Kashmir J&K)

Result: Elongation Index = 15.63 %

4) *Results of Specific Gravity and Water Absorption Tests*

(SOURCE-9: Bandipora Quarry, Kashmir J&K)

– Size of aggregates: 20 mm

– Type of aggregates: Coarse

Result: Specific gravity =  $W_4 / (W_3 - W_s) = 1.90$

Water Absorption =  $(W_3 - W_4) * 100 / W_4$  (%) = 0.98

5) *Results of Soundness Test*

(SOURCE-9: Bandipora Quarry, Kashmir J&K)

Type of reagent used:  $Na_2SO_4$

Number of cycles: 05

Result: %age passing finer sieve after test (actual percent loss) = 2.20

Weighted average (corrected % loss = 1.61

**J. Sieve Analysis or Grading of Coarse Aggregates [1]**

(SOURCE-10: Kishtwar Quarry, Jammu J&K)

Result: Fineness Modulus =  $(\sum \text{cumulative \%age weight retained})/100$

Fineness Modulus = 5.80

**1) Results of Aggregate Impact Test [2]**

(SOURCE-10: Kishtwar Quarry, Jammu J&K)

Result: Aggregate Impact Value (Percent Fines) =  $100W_2/W_1$  (%) = 11.75

**2) Results of Shape Test- Flakiness Index Test**

(SOURCE-10: Kishtwar Quarry, Jammu J&K)

Result: Flakiness Index = 27.006 %

**3) Results of Shape Test-Elongation Index Test**

(SOURCE-10: Kishtwar Quarry, Jammu J&K)

Result: Elongation Index = 24.07 %

**4) Results of Specific Gravity and Water Absorption Tests**

(SOURCE-10: Kishtwar Quarry, Jammu J&K)

Size of aggregates: 20 mm

Type of aggregates: Coarse

Result: Specific gravity =  $W_4 / (W_3 - W_s) = 2.49$

Water Absorption =  $(W_3 - W_4) * 100 / W_4$  (%) = 3.77

**5) Results of Soundness Test**

(SOURCE-10: Kishtwar Quarry, Jammu J&K)

Type of reagent used: Na<sub>2</sub>SO<sub>4</sub>

Number of cycles: 05

Result: %age passing finer sieve after test (actual percent loss) = 0.96

Weighted average (corrected % loss = 0.75

**V. DATA CALIBRATION & DATA VALIDATION**

Calibration and Validation of the test results of various samples has been done with the help of mathematical models, where each sample represents an individual data point.

**A. Data Calibration**

We have around 46 data points.

On about 36 data points we have done calibration.

For rest of the 10 data points we have done validation.

Table – 1  
Data Calibration

Sample no.	Fineness Modulus	Flakiness Index(%)	Elongation Index(%)	Specific Gravity	Water Absorption	Impact Value(%)	Soundness Value (weighted average corrected % loss)
01	5.53	17.01	5.35	2.52	2.72	14.25	0.77
02	5.11	14.45	12.13	2.68	2.66	15	0.8
03	5.80	29.27	36.45	2.08	2.11	11.25	1.1
04	5.36	25.76	15.12	2.12	2.47	13	0.66
05	5.8	35.34	9.07	2.64	3.54	17.5	1.04
06	5.63	7.56	17.43	2.455	6.92	13	0.97
07	5.24	14.21	11.14	2.52	5.5	14	1.09
08	5.4	20.77	22.6	2.55	3.54	7.5	0.7
09	4.6	13.47	9.30	2.63	3.80	12.5	1.03
10	5.80	13.6	23.194	2.2	4.79	11.25	0.75
11	6.92	31.57	43	2.08	3.5	17	0.89
12	6.36	28.70	35.63	1.90	3.98	18	1.61
13	6.4	14.87	16.71	2.95	2.44	10	0.55
14	6.34	12.96	20.50	2.92	2.44	09	0.24
15	6.16	24.56	34.01	2.01	4.06	15	1.75
16	5.80	17.006	24.07	2.49	3.77	11.75	0.43
17	5.35	19.93	27.27	2.71	1.95	13	0.86
18	5.426	15.31	25.34	2.67	2.5	15	0.83
19	6.335	15.02	22.125	2.74	1.5	13.75	0.53
20	6.151	18.77	28.74	2.75	2.02	16	0.92

21	6.71	14.33	17.96	2.77	2.03	12	0.68
22	5.45	19.34	20.30	2.87	2.25	7	0.30
23	5.67	14.56	22.90	2.56	2.55	11	0.53
24	5.34	13.67	21.75	2.77	2.34	10	0.41
25	5.85	15.90	23.78	2.86	2.68	12	0.65
26	5.25	10.98	20.50	2.97	2.30	16	0.30
27	6.71	30.45	30.56	1.95	3.32	15	1.30
28	5.65	27.98	25.8	2.25	2.95	13	0.83
29	5.84	18.23	22.75	2.83	2.67	11	0.60
30	5.80	21.74	23.87	2.75	2.43	14	0.67
31	6.10	30.45	30.95	1.97	4.10	16	1.10
32	5.67	22.90	26.65	2.27	2.87	12	0.87
33	5.45	17.26	24.24	2.42	2.54	13	0.56
34	5.34	15.23	23.64	2.87	2.42	14	0.48
35	5.30	16.45	22.90	2.86	2.30	15	0.41
36	5.75	11.97	25.65	2.70	2.56	13	0.60
37	5.50	19.58	25.75	2.43	2.67	10	0.71
38	5.56	23.87	28.35	2.47	2.70	11	0.73
39	5.90	28.12	29.30	2.85	2.98	13	0.93
40	5.58	17.26	22.95	2.45	2.75	10	0.75
41	5.40	14.34	16.70	2.85	2.54	15	0.50
42	5.75	15.45	27.65	2.84	2.64	11	0.60
43	5.80	13.09	22.75	2.43	2.78	13	0.70
44	5.85	23.65	25.30	2.47	2.54	14	0.74
45	6.50	13.96	34.85	2.04	4.56	17	1.27
46	5.95	12.95	26.87	2.78	2.98	14	0.97

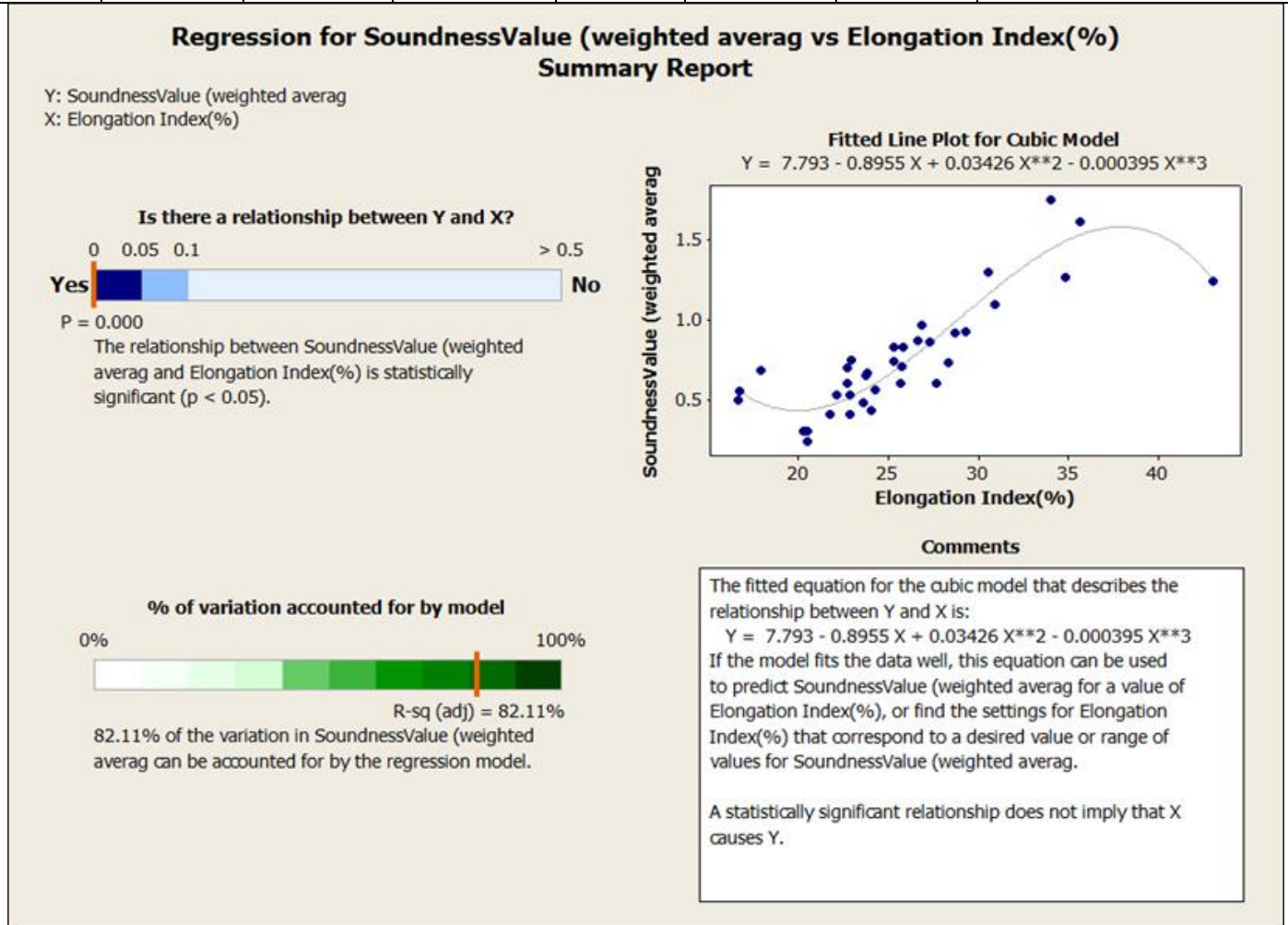


Fig. 1: Regression Model (Summary Report) Soundness Value Vs Elongation Index (%)

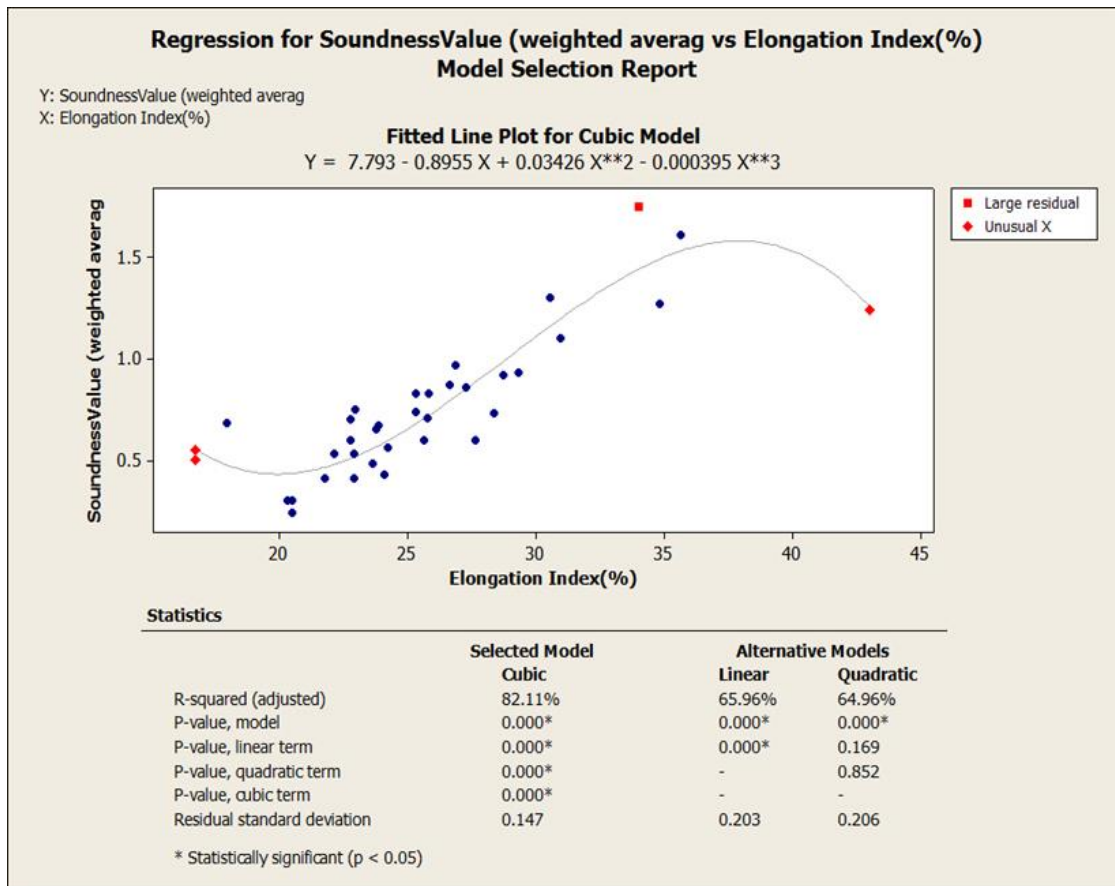


Fig. 2: Regression Model (Selection Report) Soundness Value Vs Elongation Index (%)

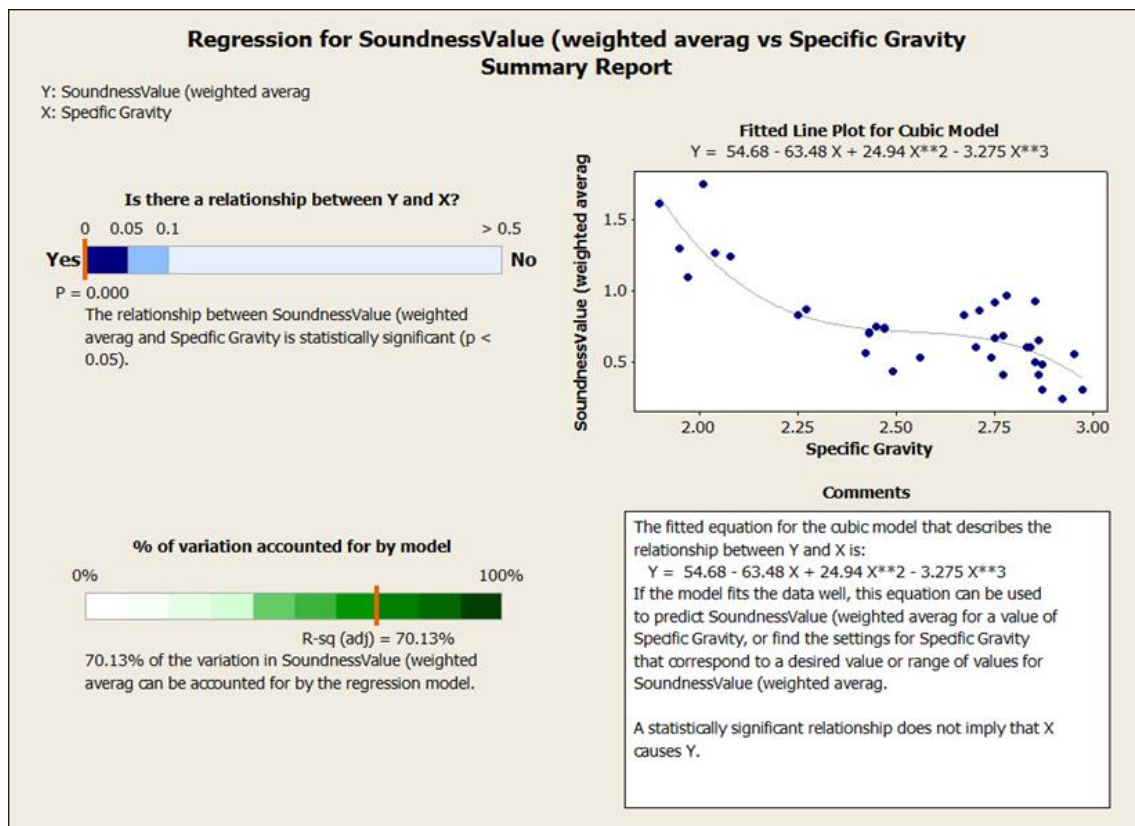


Fig. 3: Regression Model (Summary Report) Soundness Value Vs Specific Gravity

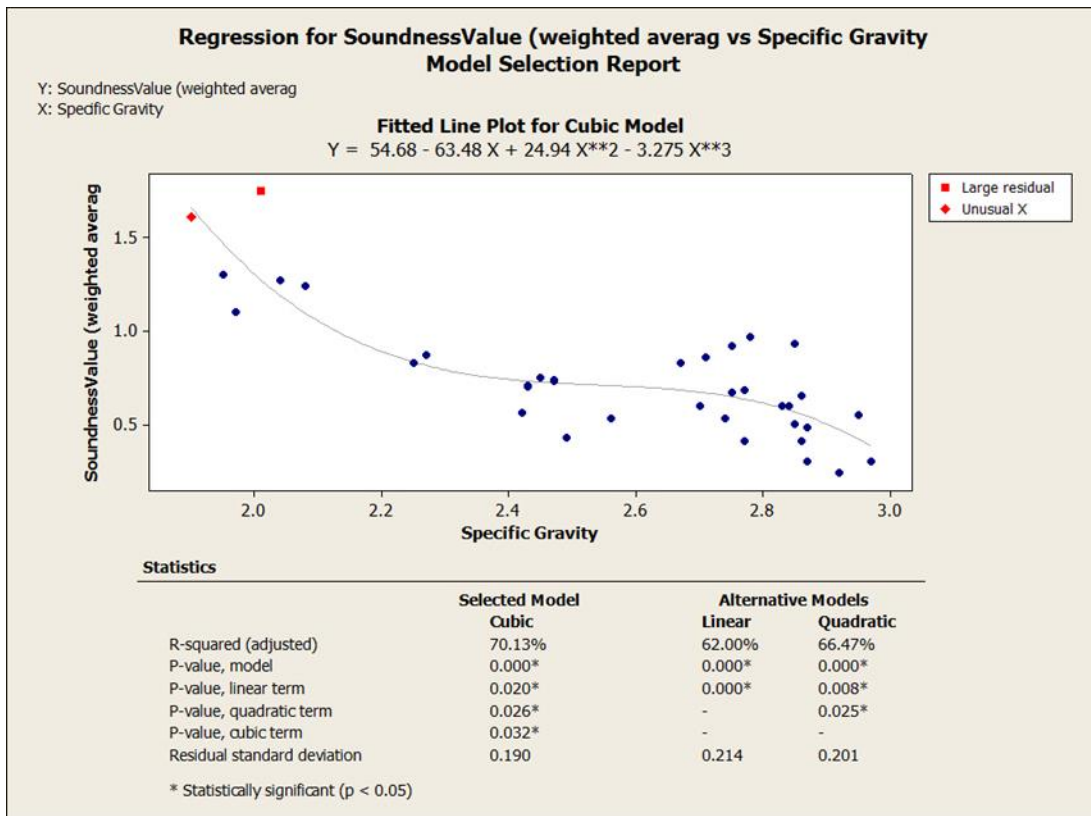


Fig. 4: Regression Model (Selection Report) Soundness Value Vs Specific Gravity

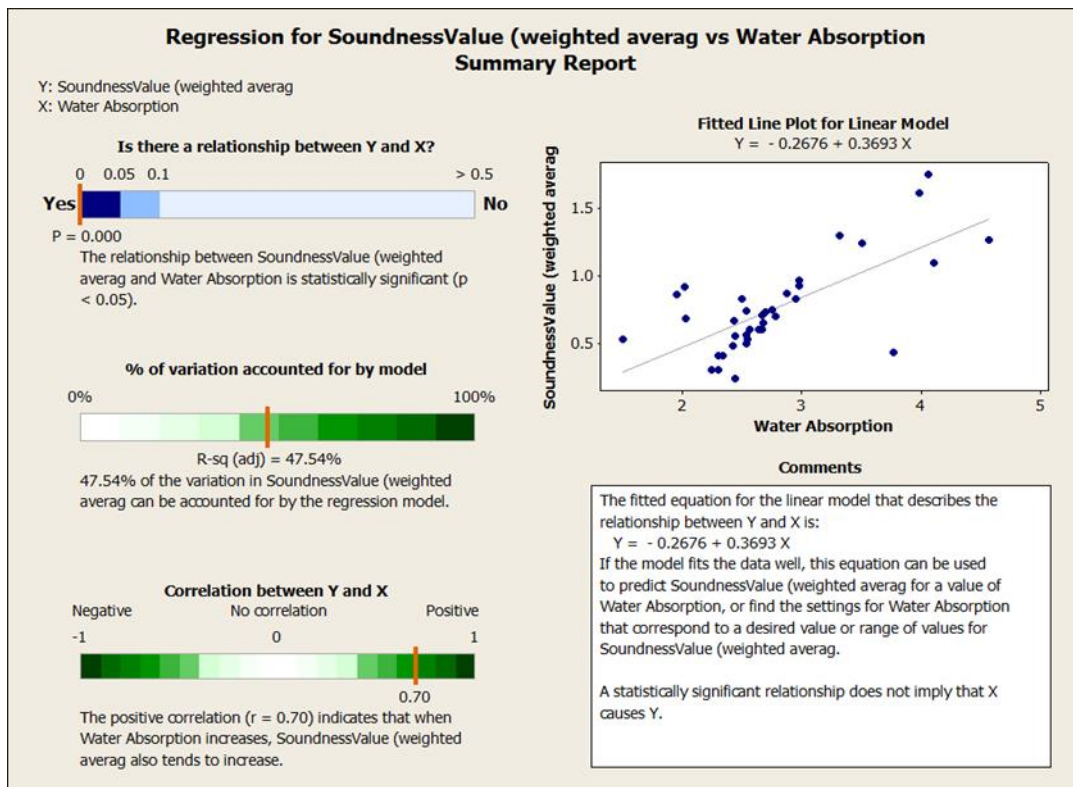


Fig. 5: Regression Model (Summary Report) Soundness Value Vs Water Absorption

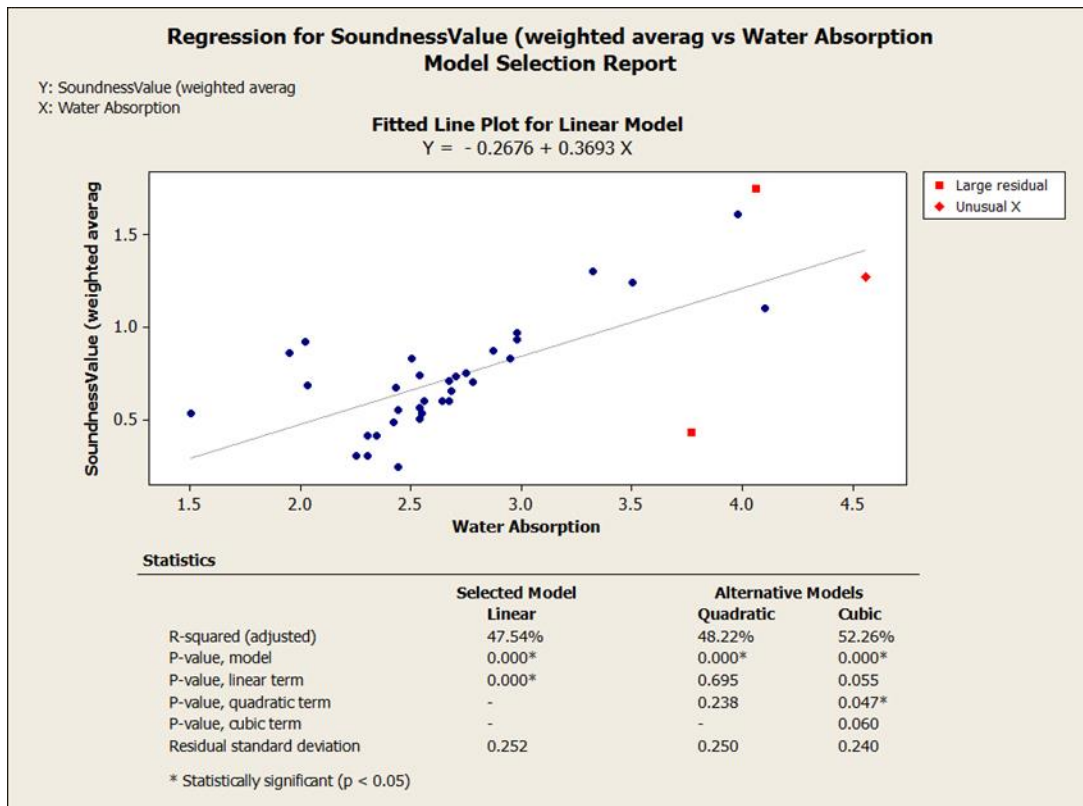


Fig. 6: Regression Model (Selection Report) Soundness Value Vs Water Absorption

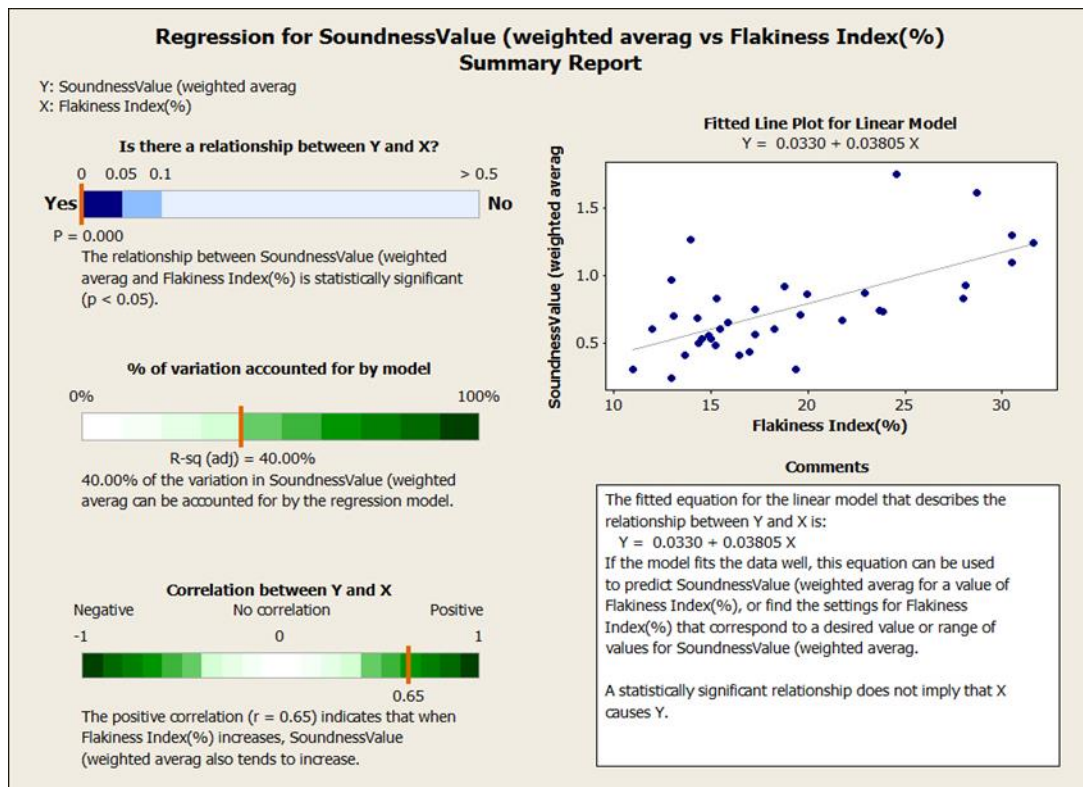


Fig. 7: Regression Model (Summary Report) Soundness Value Vs Flakiness Index (%)

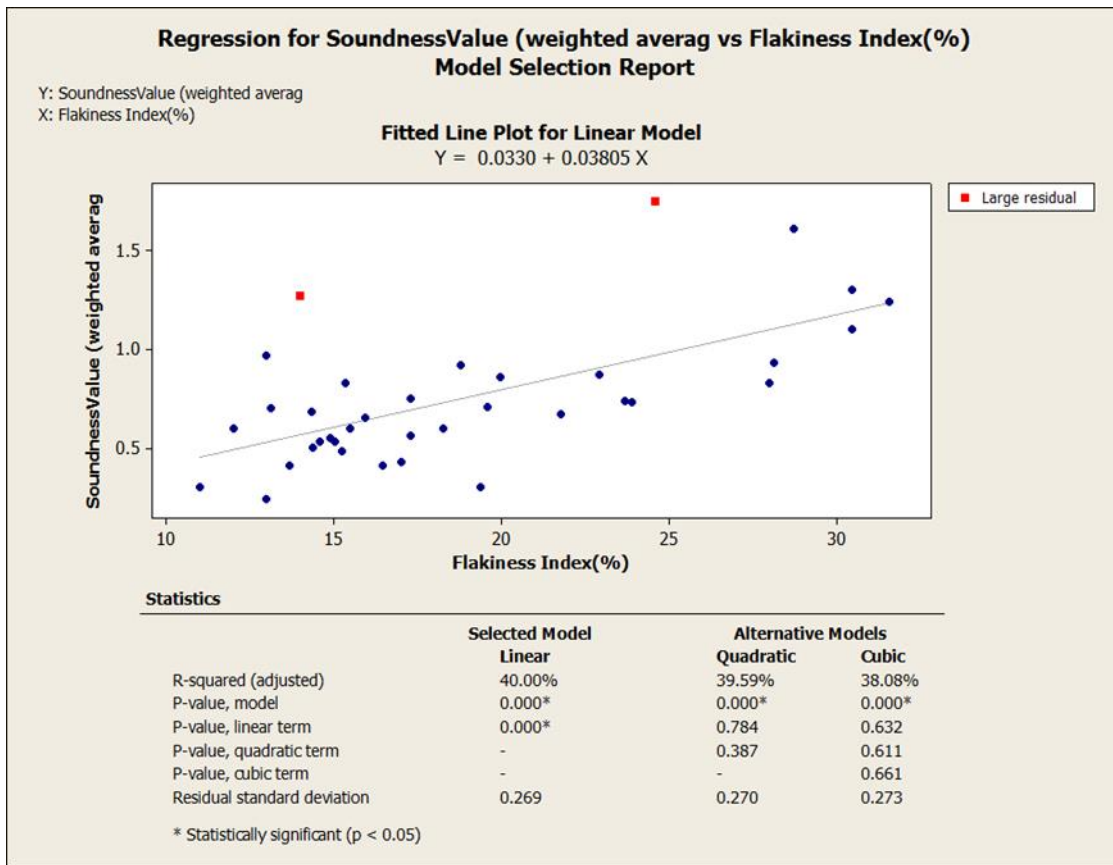


Fig. 8: Regression Model (Selection Report) Soundness Value Vs Flakiness Index (%)

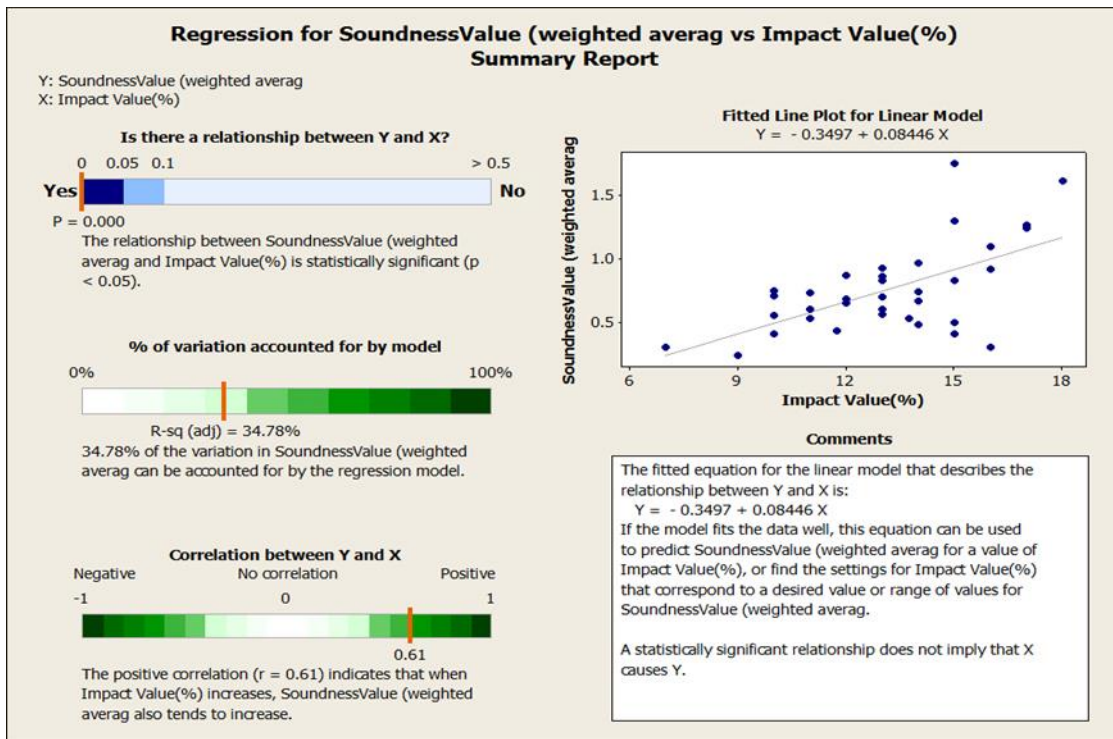


Fig. 9: Regression Model (Summary Report) Soundness Value Vs Impact Value (%)

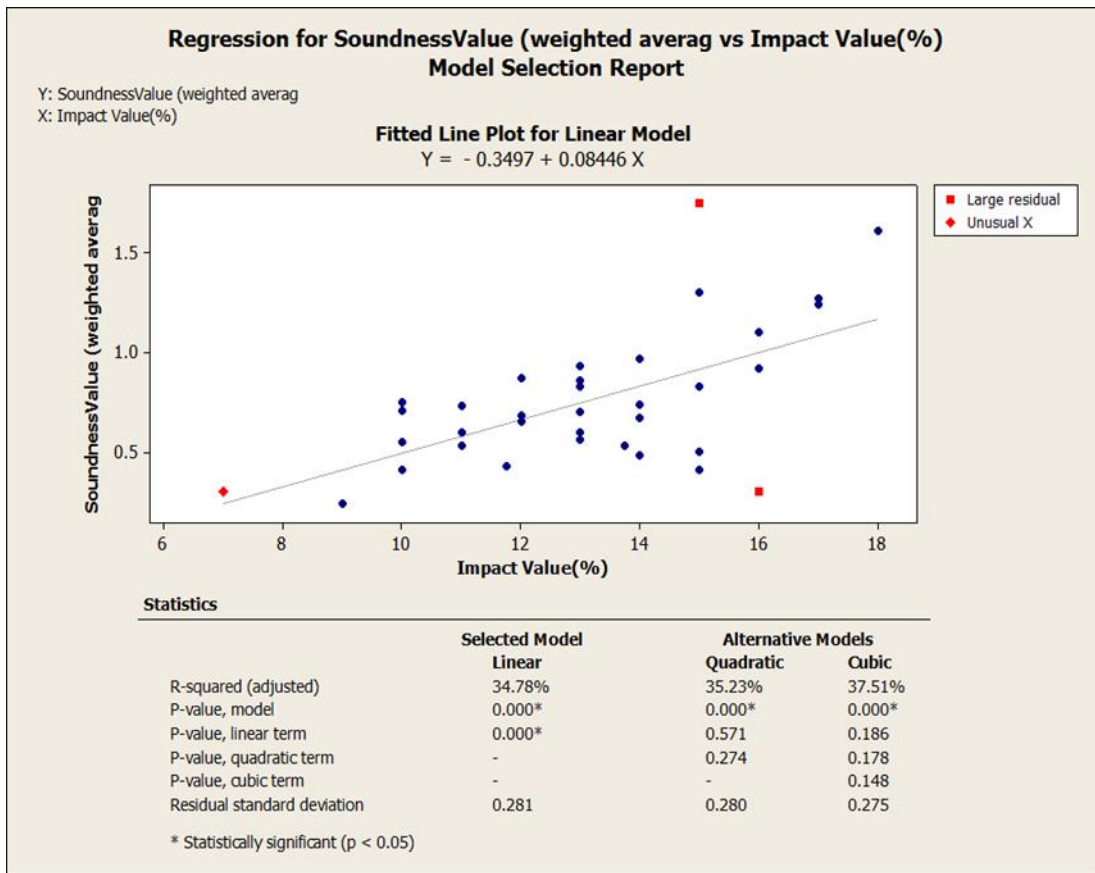


Fig. 10: Regression Model (Selection Report) Soundness Value Vs Impact Value (%)

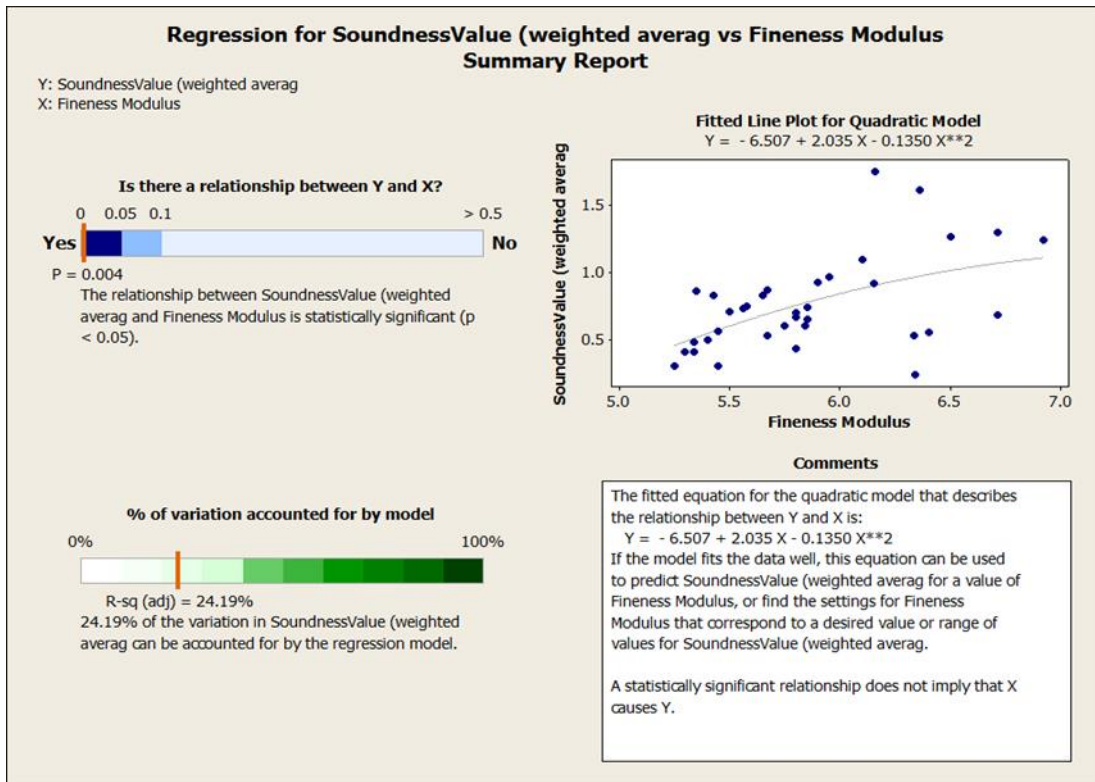


Fig. 11: Regression Model (Summary Report) Soundness Value Vs Fineness Modulus

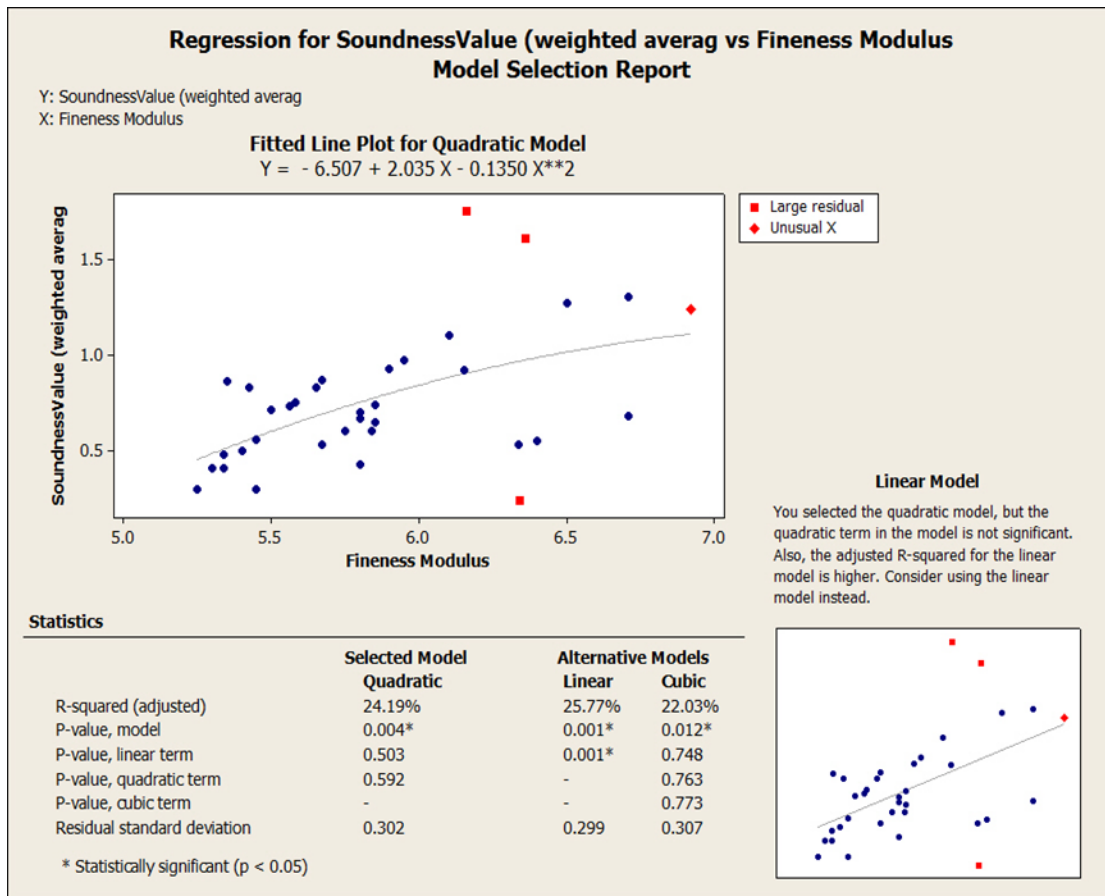


Fig. 12: Regression Model (Selection Report) Soundness Value Vs Fineness Modulus

Table – 2

General Regression Analysis: Relation b/w (Soundness Value) vs (Fineness Modulus, Flakiness Index, Elongation Index, Specific Gravity, Water absorption & Impact Value )

Sr. No.	Types of variables	RELATION	R sqrd value	P value (<0.05)
01	Soundness & Fineness Modulus	$y = -6.507 + 2.035x - 0.1350x^2$	24.19%	0.00
02	Soundness & Flakiness index	$y = 0.0330 + 0.03805x$	40.00%	0.004
03	Soundness & Elongation Index	$y = 7.793 - 0.8955x + 0.03426x^2 - 0.000395x^3$	82.11%	0.00
04	Soundness & Impact Value	$y = -0.3497 + 0.08446x$	34.78%	0.00
05	Soundness & Specific Gravity	$y = 54.68 - 63.48x + 29.94x^2 - 3.275x^3$	70.13%	0.00
06	Soundness & Water Absorption	$y = -0.2676 + 0.3693x$	47.14%	0.00

1) Regression Equation

$$\text{Soundness Value (weighted average)} = -0.220871 + 0.117839 * \text{Fineness Modulus} + 0.00559452 * \text{Flakiness Index}(\%) + 0.0199209 * \text{Elongation Index}(\%) - 0.308374 * \text{Specific Gravity} + 0.0465761 * \text{Water Absorption} + 0.0253914 * \text{Impact Value}(\%)$$

Summary of Model

R-Sq = 79.53%

R-Sq(adj) = 75.29%

B. Data Validation

We have around 46 data points.

On about 36 data points we have done calibration.

For rest of the 10 data points we have done validation.

Table - 3  
Data Validation Table

Sample no	Calculated values of soundness w.r.t	Calculated values of soundness w.r.t	Calculated values of soundness w.r.t	Calculated values of soundness w.r.t impact	Calculated values of soundness w.r.t	Calculated values of soundness w.r.t Water	Calculated average value of soundness	Experimental Values of soundness	%age Error

	<i>Elongation index</i>	<i>Fineness modulus</i>	<i>fakiness index</i>	<i>value</i>	<i>Specific Gravity</i>	<i>absorption</i>			
01	0.92	0.6	0.68	0.85	0.68	0.74	0.75	0.77	2.46
02	1.27	0.4	0.58	0.91	0.64	0.71	0.75	0.8	6.25
03	1.54	0.75	1.15	0.6	1.07	0.51	0.94	1.10	14.5
04	0.72	0.52	1.01	0.75	0.99	0.64	0.77	0.66	16.7
05	2.1	0.75	1.38	1.13	0.66	1.03	1.175	1.04	13
06	0.5	0.67	0.32	0.75	0.69	2.28	0.87	0.97	10.3
07	1.5	0.45	0.57	0.83	0.68	1.76	0.97	1.09	11
08	0.5	0.55	0.82	0.28	0.67	1.03	0.64	0.70	<b>C. 8.6</b>
09	2.1	0.57	0.55	0.71	0.66	1.13	0.95	1.03	7.76
10	0.52	0.75	0.55	0.6	0.86	1.5	0.80	0.75	6.67
Average	1.16	0.601	0.76	0.74	0.76	1.1	0.86	0.89	9.7

Mean %age error: 9.7%

Table – 4  
Percentage Error wrt Experimental Data

<i>Sr. No.</i>	<i>Types of variables</i>	<i>RELATION</i>	<i>%AGE ERROR w.r.t Experimental Values.</i>
01	<i>Soundness &amp; Fineness Modulus</i>	$y = -6.507 + 2.035x - 0.1350x^2$	32.5
02	<i>Soundness &amp; Flakiness Index</i>	$y = 0.0330 + 0.03805x$	14.6
03	<i>Soundness &amp; Elongation Index</i>	$y = 7.793 - 0.8955x + 0.03426x^2 - 0.000395x^3$	30
04	<i>Soundness &amp; Impact Value</i>	$y = -0.3497 + 0.08446x$	16.8
05	<i>Soundness &amp; Specific Gravity</i>	$y = 54.68 - 63.48x + 24.94x^2 - 3.275x^3$	14.6
06	<i>Soundness &amp; Water Absorption</i>	$y = -0.2676 + 0.3693x$	23.5

## VI. CONCLUSION & FUTURE SCOPE

From the above study based on experimental work and mathematical regression analysis, following conclusions are made:

- 1) We can easily get the soundness values of aggregates of any sample, directly by using relations between the soundness and various other characteristics of aggregates without doing any experimental work.
- 2) Obtained relations would prove to be useful in saving time and money, particularly in regions subjected to harsh weather conditions (Kashmir Valley) because the pavements get damaged due to weathering action more oftenly.
- 3) We can easily get the variations of soundness property of aggregates with their other characteristics.

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