Use of the Moisture Induced Stress Tester (MIST) and Appropriate Tests for Evaluation of Hot Mix Asphalt (HMA) Materials

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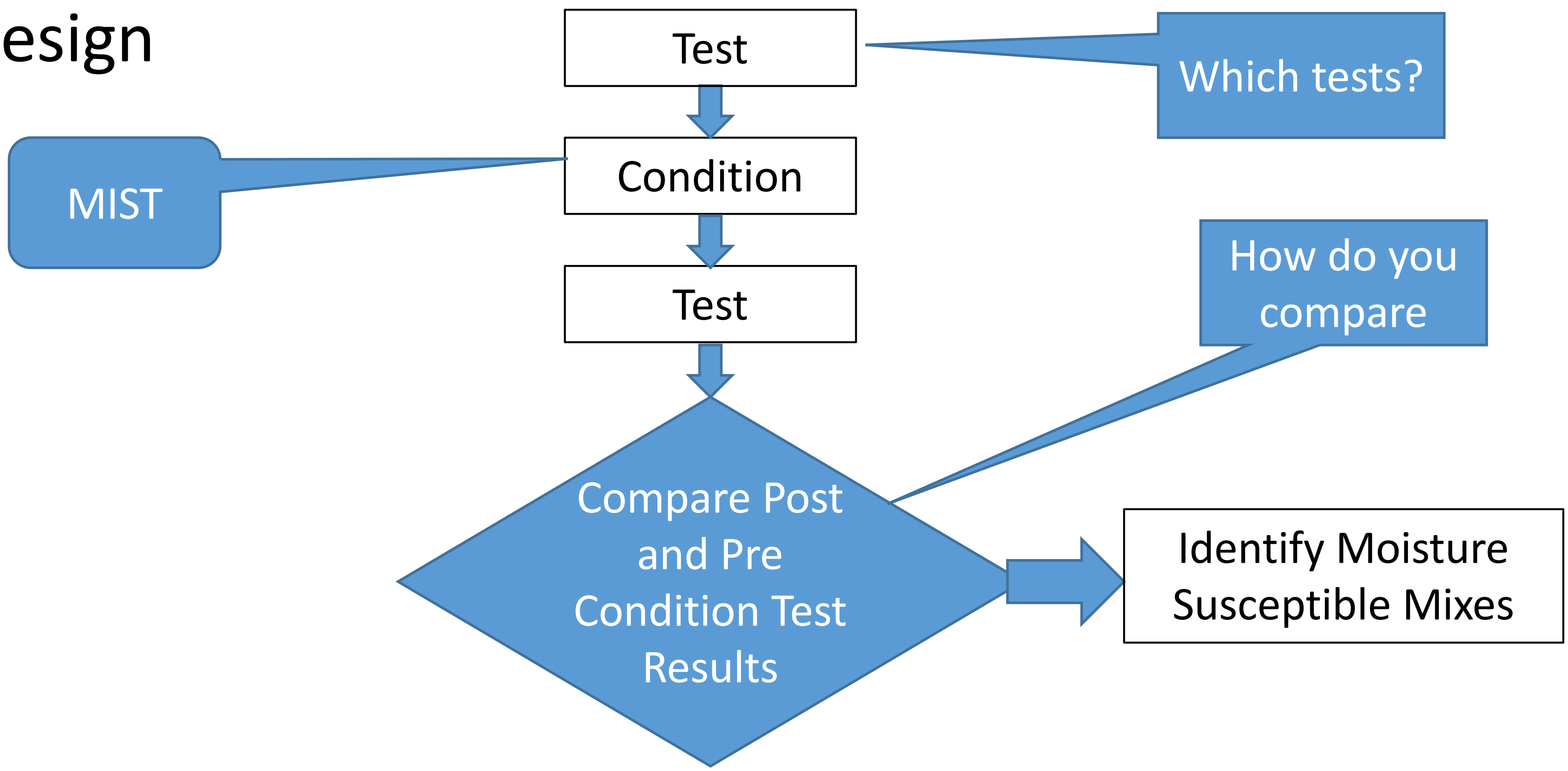
- Objective
- Tests
- Materials
- Results
- Analysis
- Conclusions and Recommendations

Background

- Need a conditioning process along with pre and post conditioning tests to identify moisture susceptible mixes during mix design
- Various methods available
  - AASHTO T283
  - Hamburg Wheel Tracker
  - Moisture Induced Stress Tester
  - Indirect Tensile Strength Tests
  - Dynamic Modulus Tests
  - …

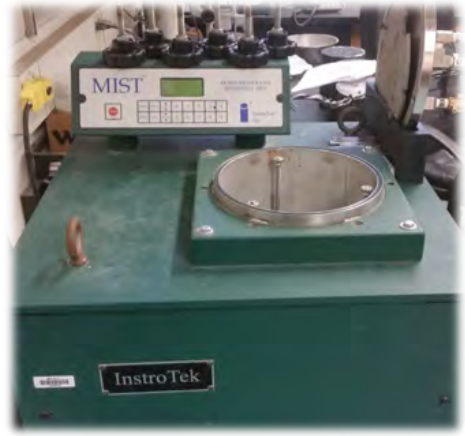
Objective

- To develop a protocol with the use of the MIST and other appropriate tests and analysis procedure to identify moisture susceptible mixes during mix design



Tests

- Conditioning process
  - The MIST
  - Experience with the equipment
    - Good capability to saturate samples
    - Good capability to simulate loading under saturated condition
    - Can use gyratory samples
    - Can use more than one samples at the same time
    - Can vary pressure, temperature and number of cycles
    - Existing ASTM standard
    - Easy to operate, does not take up a lot of space and is relatively low cost

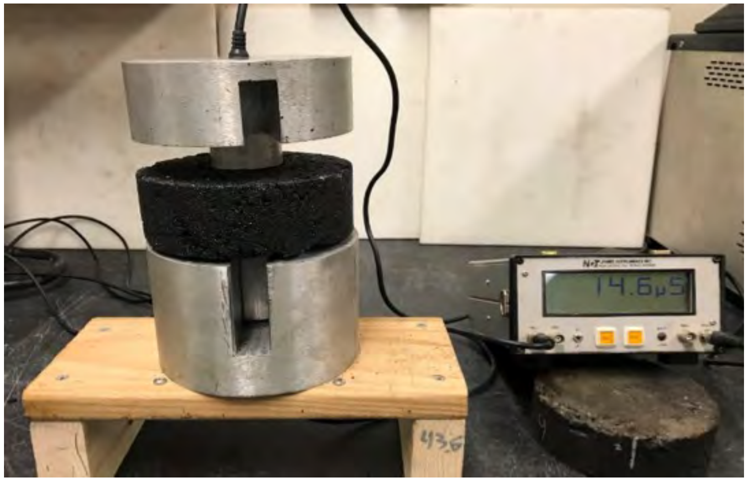


3,500 cycles at 275 kPa and 60°C for PG 64-28 and PG 70-28 mixes and 50°C for PG 58-28 mixes; included a 20 hours dwell period in the beginning.

Tests

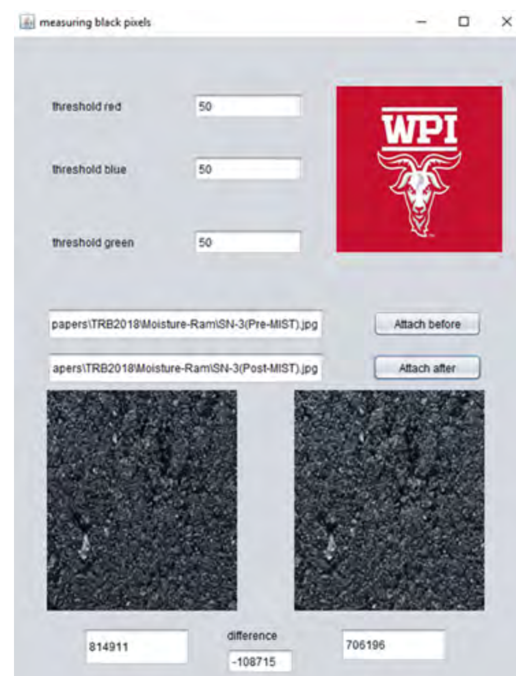
- Indirect Tensile Strength

  - Widely used
  - Gives indication of tensile strength and hence cohesion and adhesion of mixes
  - Relatively simple
  - Can obtain fracture energy
- Ultrasonic Pulse Velocity (UPV)
  - Nondestructive
  - Gives indication of stiffness
  - Can utilize modulus values for design



Tests

- Semi-circular bending test
  - Gives useful parameters such as fracture energy and flexibility index
    - Increasing number of studies and results
    - Can test two samples from one gyratory sample
- Loss of materials – asphalt (dissolved organic content, DOC), aggregates
  - Moisture induces damage in HMA is accompanied by loss of asphalt and aggregates – stripping
- Black Pixel
  - If the mix loses materials, the color should change

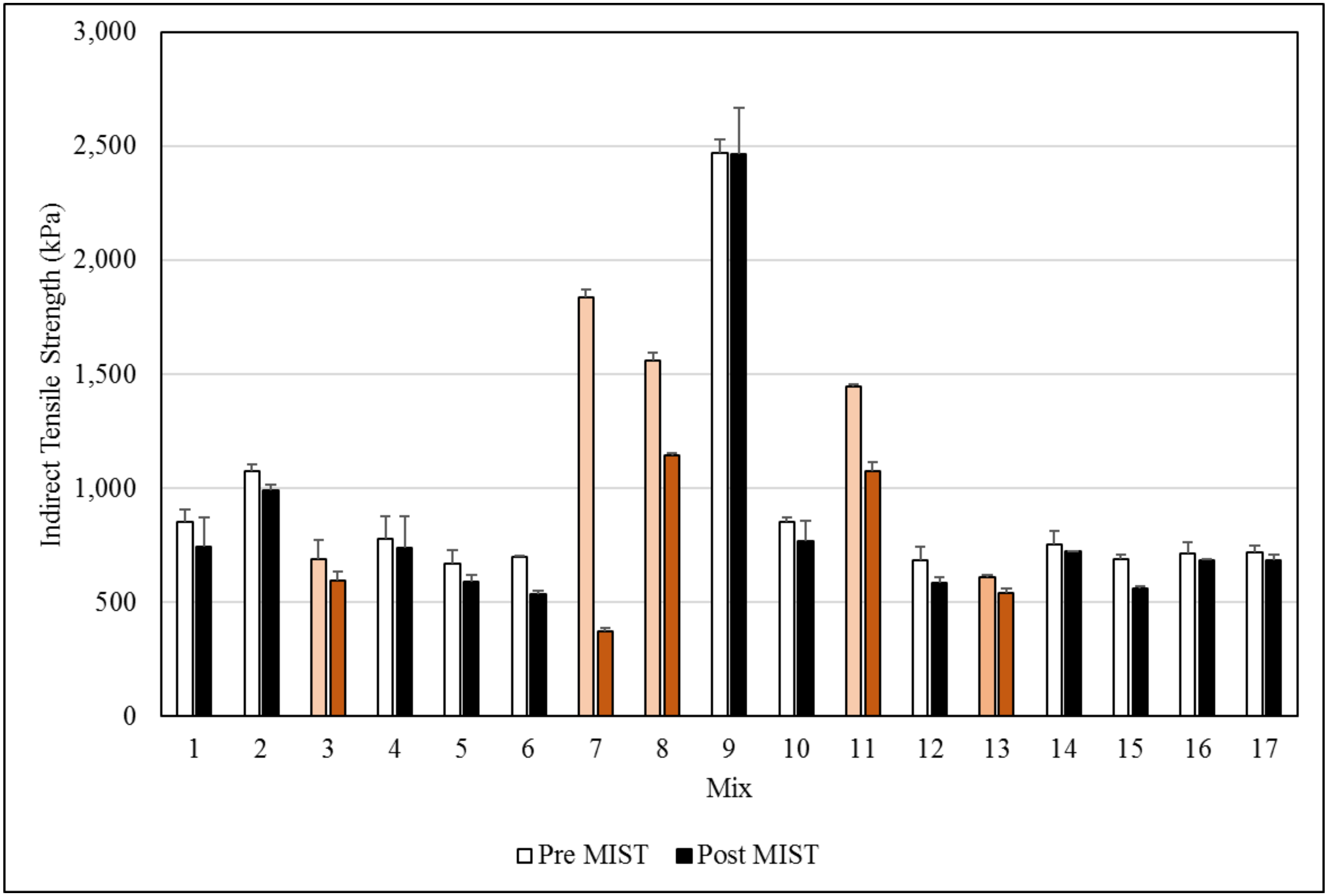


1.18 mm | 0.6 mm | 0.3 mm | 0.15 mm | 0.075 mm

Materials

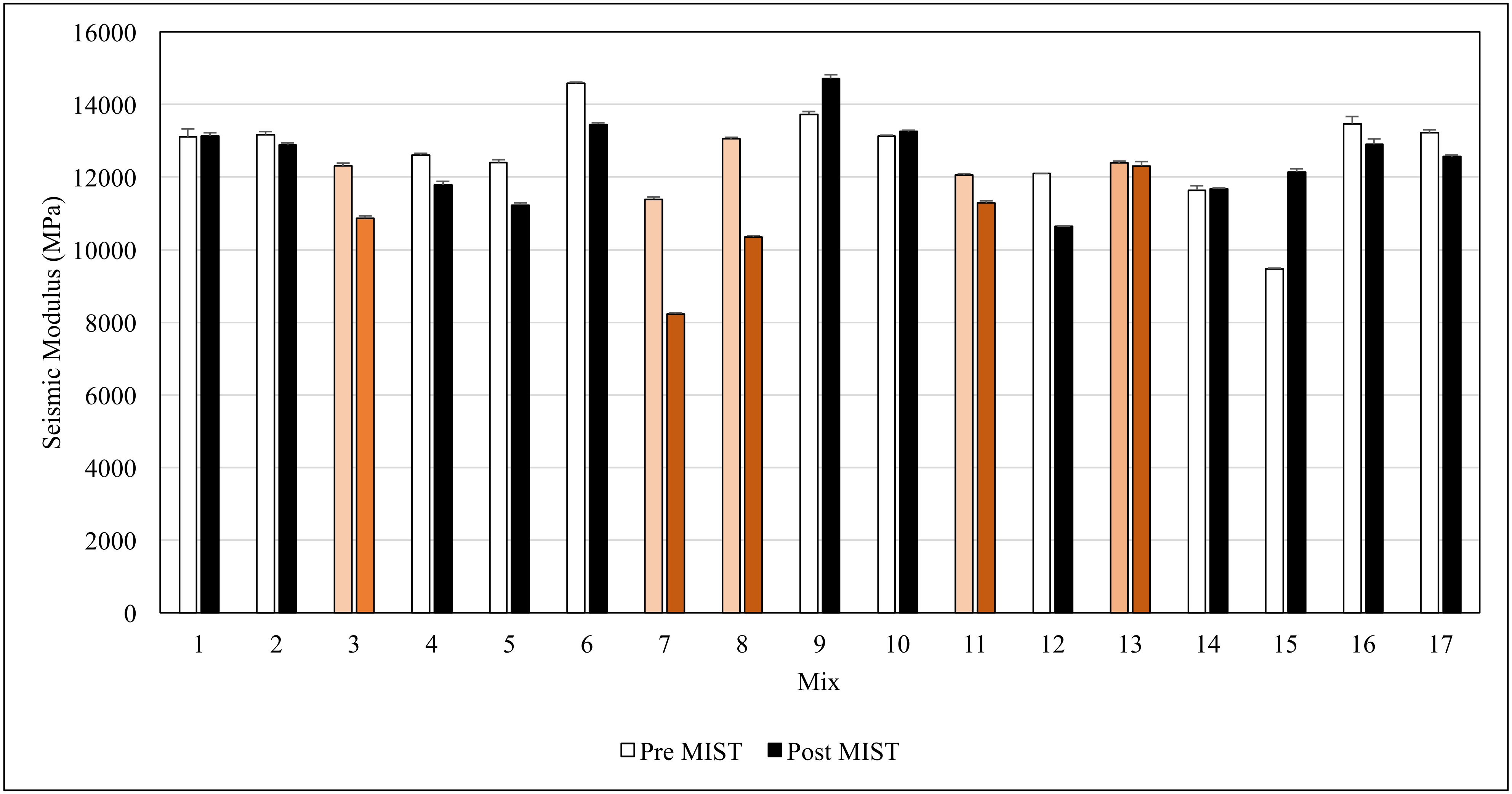
Mix No. /Performance	NMAS (mm)	Binder type	Percentage of binder	Percentage of RAP	Additive
1/good	12.5	PG 64-28	5.6	20	No
2/good	12.5	PG 64-28	5.5	20	No
3/poor	9.5	PG 64-28	6.2	10	No
4/good	9.5	PG 64-28	6.4	20	No
5/good	9.5	PG 64-28	6.5	20	Lime
6/good	12.5	PG 64-28	5.3	20	No
7/poor	9.5	PG 64-28	6.5	0	No
8/poor	9.5	PG 58-28	6	20	Commercial
9/good	12.5	PG 70-28 (Polymer modified binder)	4.9	15	No
10/good	12.5	PG 64-28	5.6	20	No
11/poor	9.5	PG 58-28	6.0	20	No
12/good	9.5	PG 64-28	6.6	20	No
13/poor	12.5	PG 64-28	5.8	0	Lime
14/good	12.5	PG 64-28	5.8	20	No
15/good	12.5	PG 64-28	6.0	10	No
16/good	12.5	PG 64-28	5.7	20	No
17/good	12.5	PG 64-28	5.0	20	No

Results



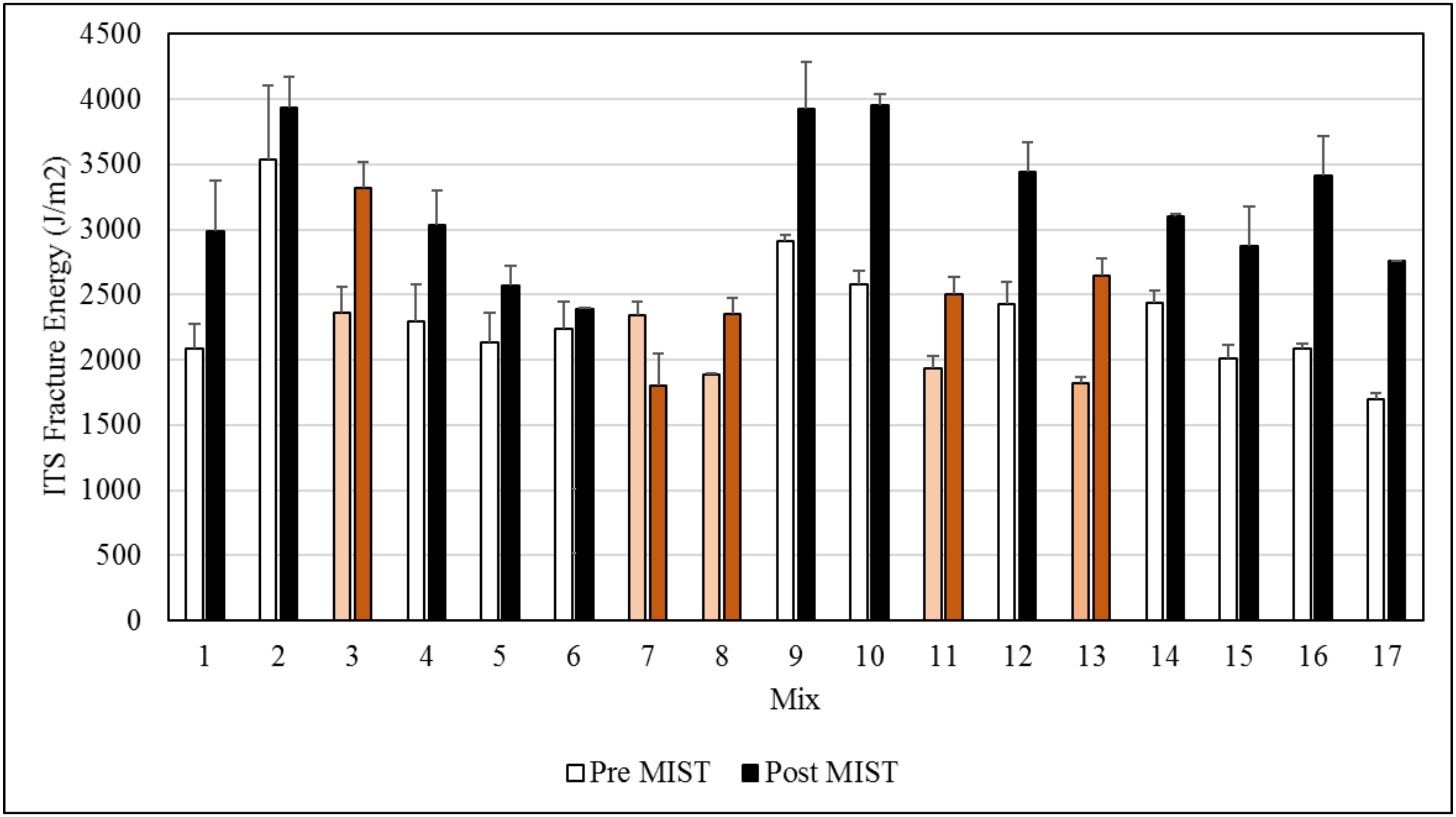
3,000
2,500
2,000
1,500
1,000
500
0
Indirect Tensile Strength (kPa)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Mix
Pre MIST
Post MIST

Results



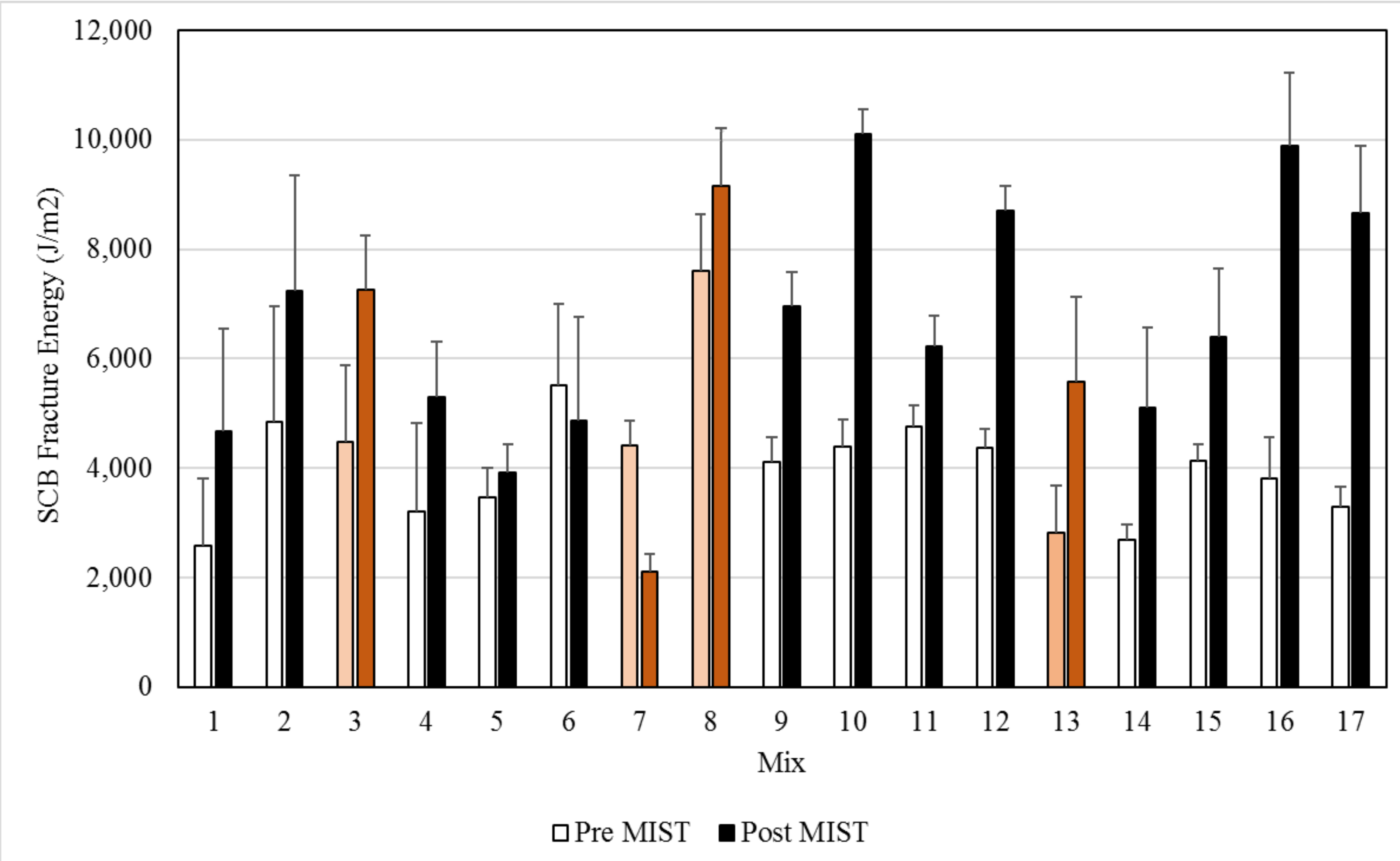
16000
14000
12000
10000
8000
6000
4000
2000
0
Seismic Modulus (MPa)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Mix
Pre MIST
Post MIST

Results



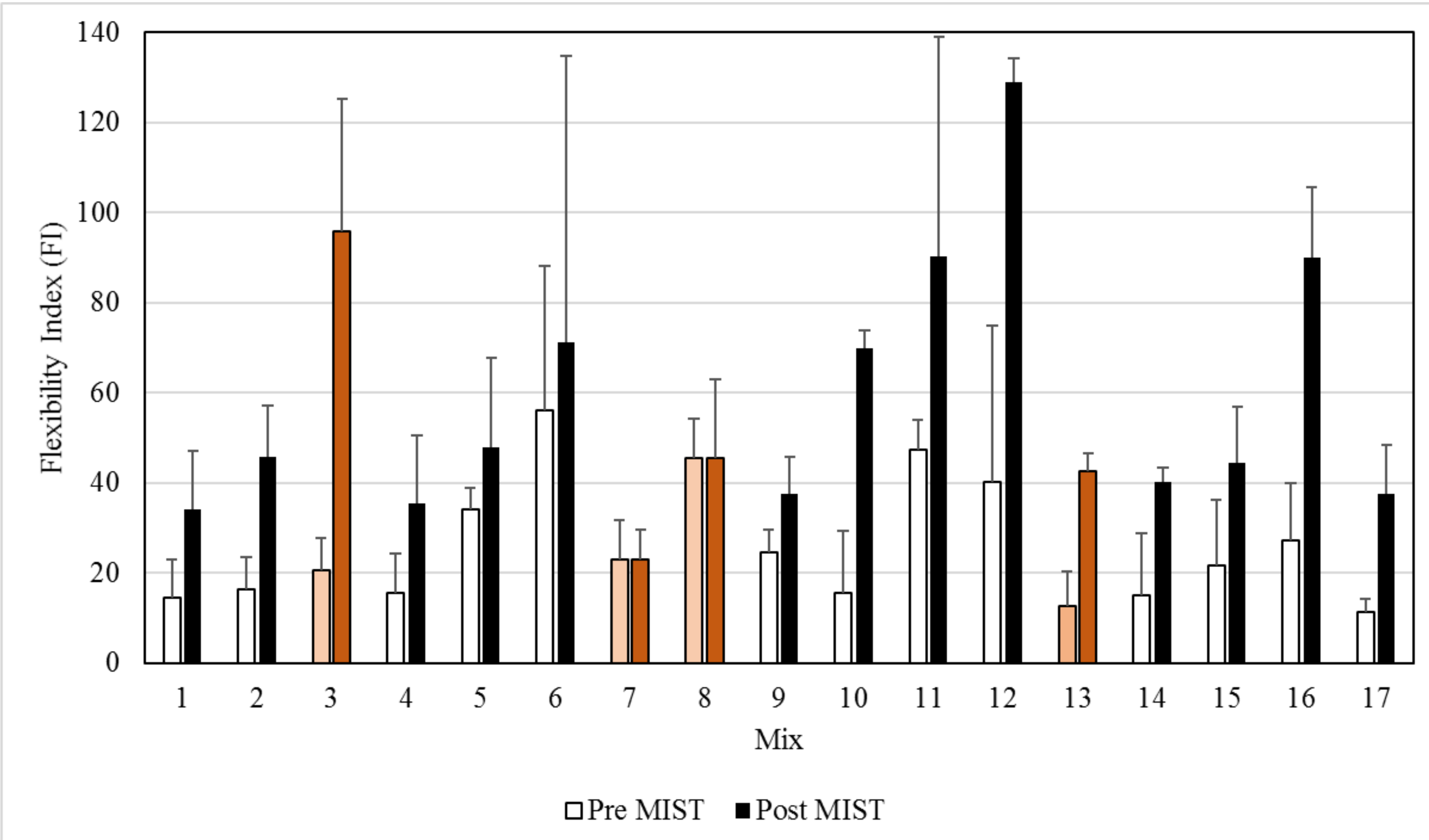
ITS Fracture Energy (J/m2)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Mix
Pre MIST
Post MIST

Results



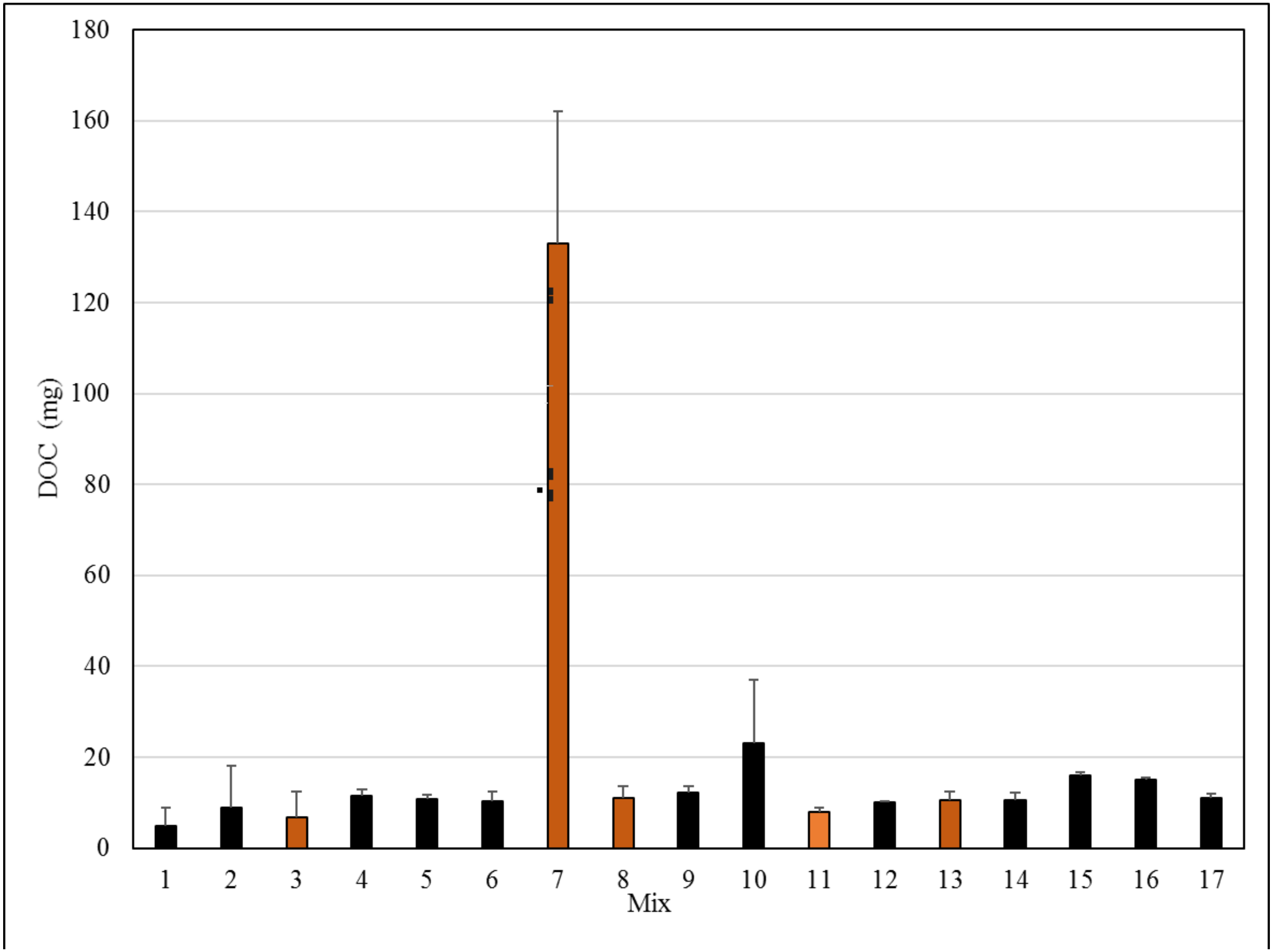
12,000
10,000
8,000
6,000
4,000
2,000
0
SCB Fracture Energy (J/m2)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Mix
Pre MIST
Post MIST

Results



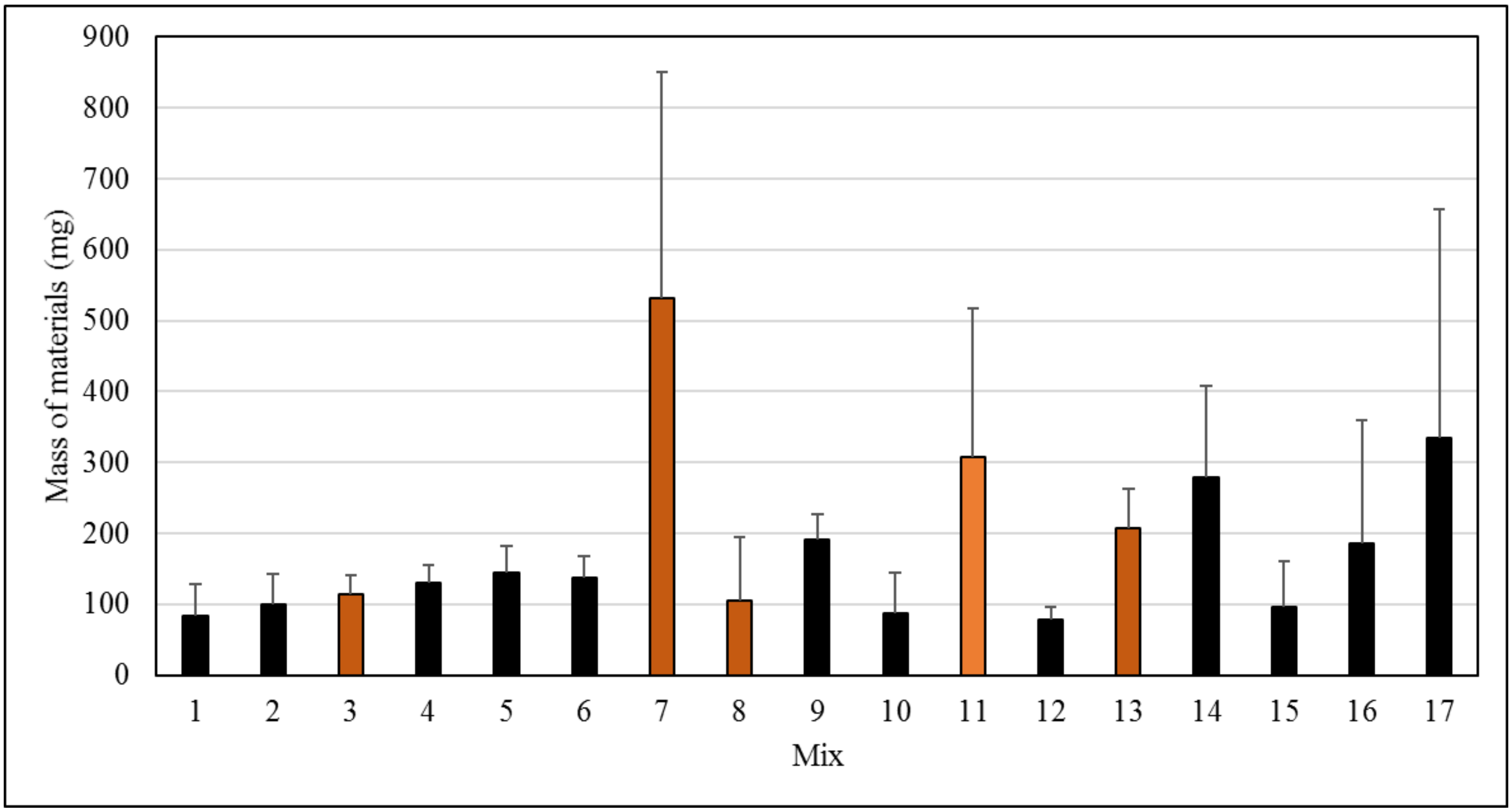
Flexibility Index (FI)
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Mix
Pre MIST
Post MIST

Results



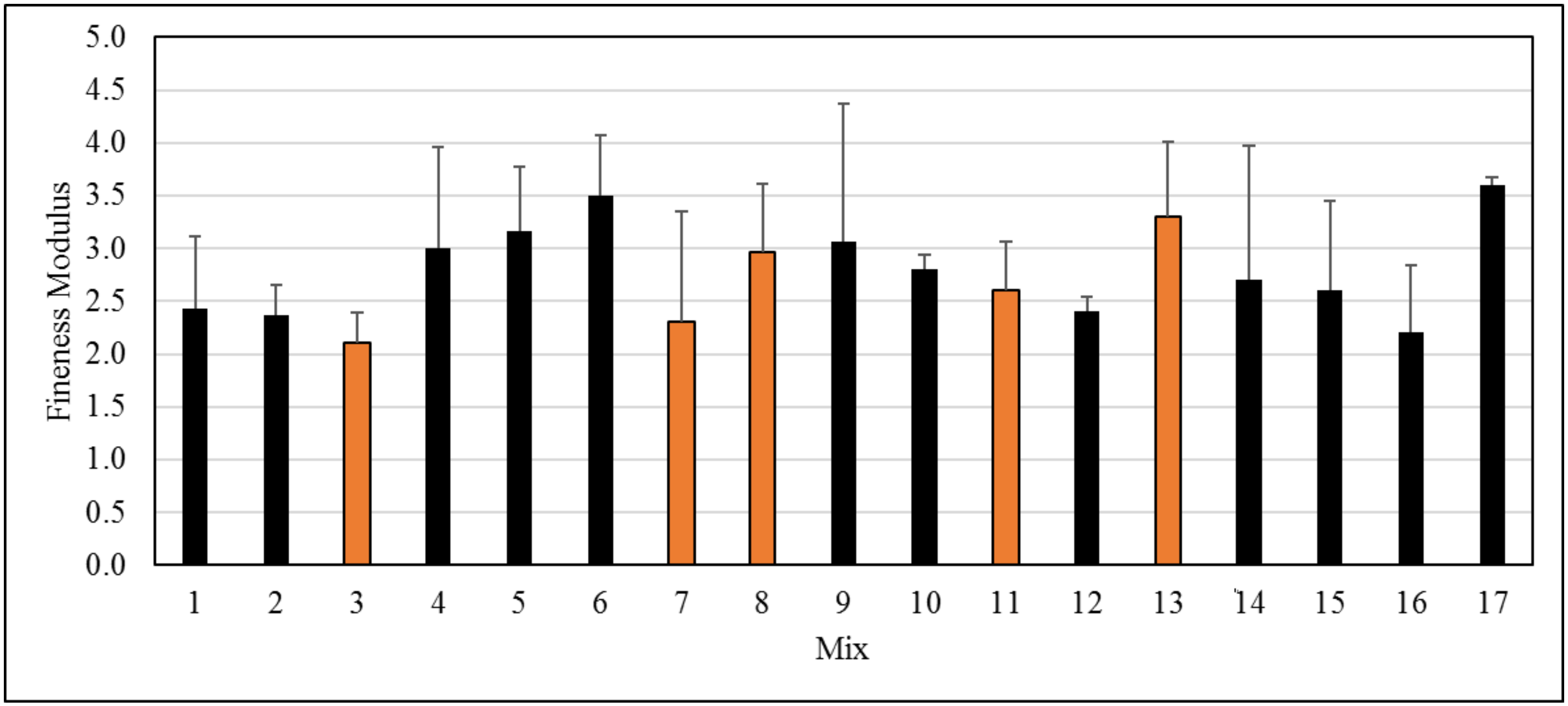
180
160
140
120
100
80
60
40
20
0
DOC (mg)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Mix

Results



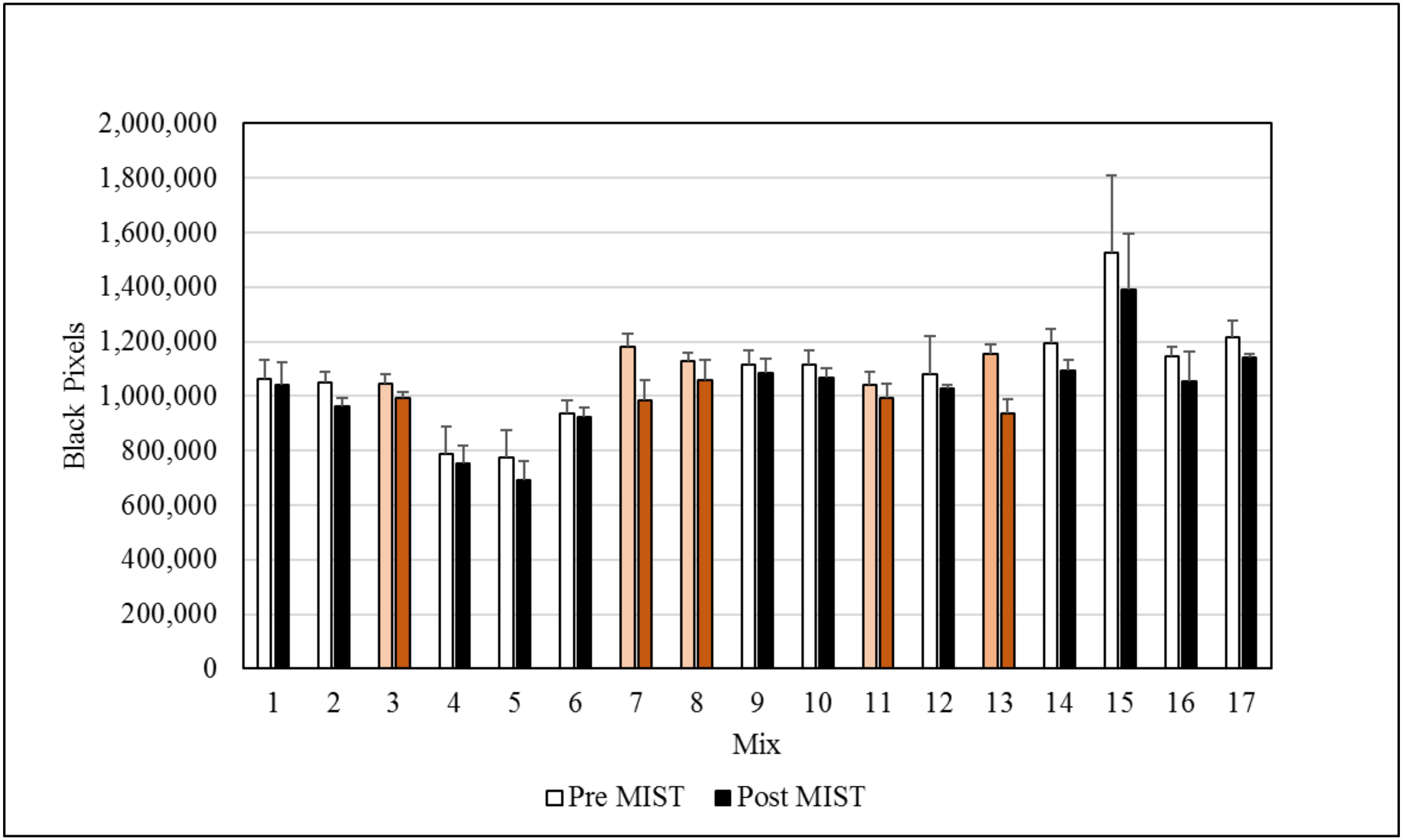
Mass of materials (mg)
900
800
700
600
500
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Mix

Results



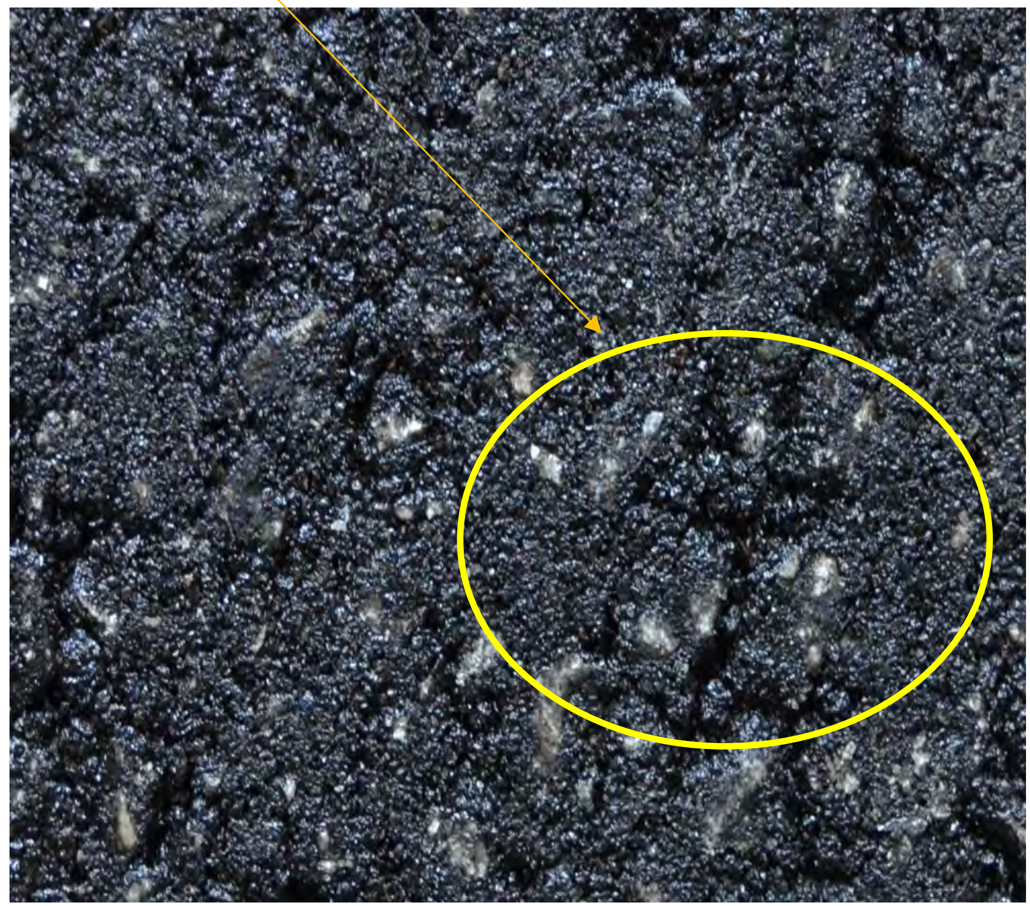
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Fineness Modulus
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Mix

Results



2,000,000
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Black Pixels
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Mix
Pre MIST
Post MIST

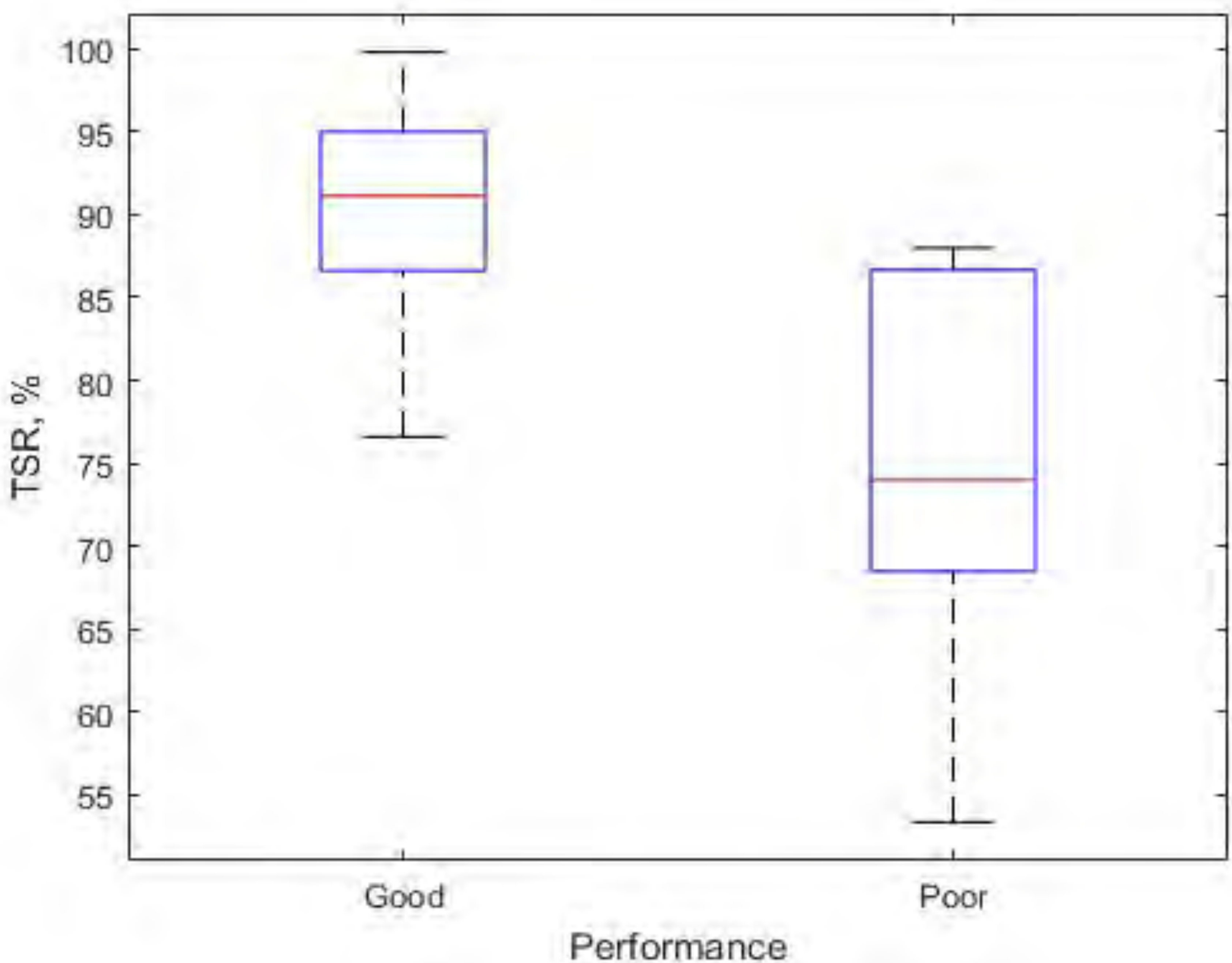
Example of loss of asphalt causing a
reduction in black pixel

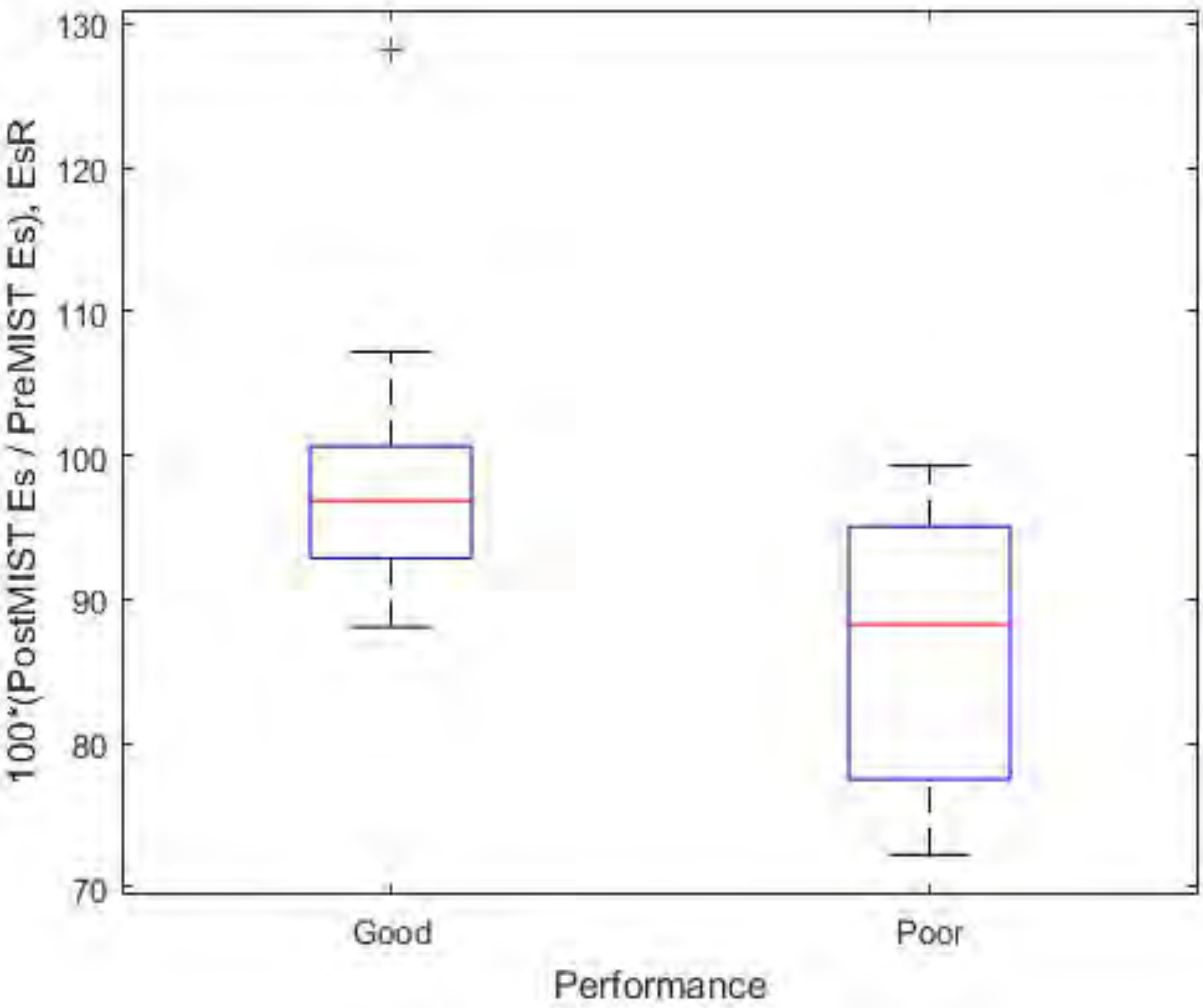


Pre MIST

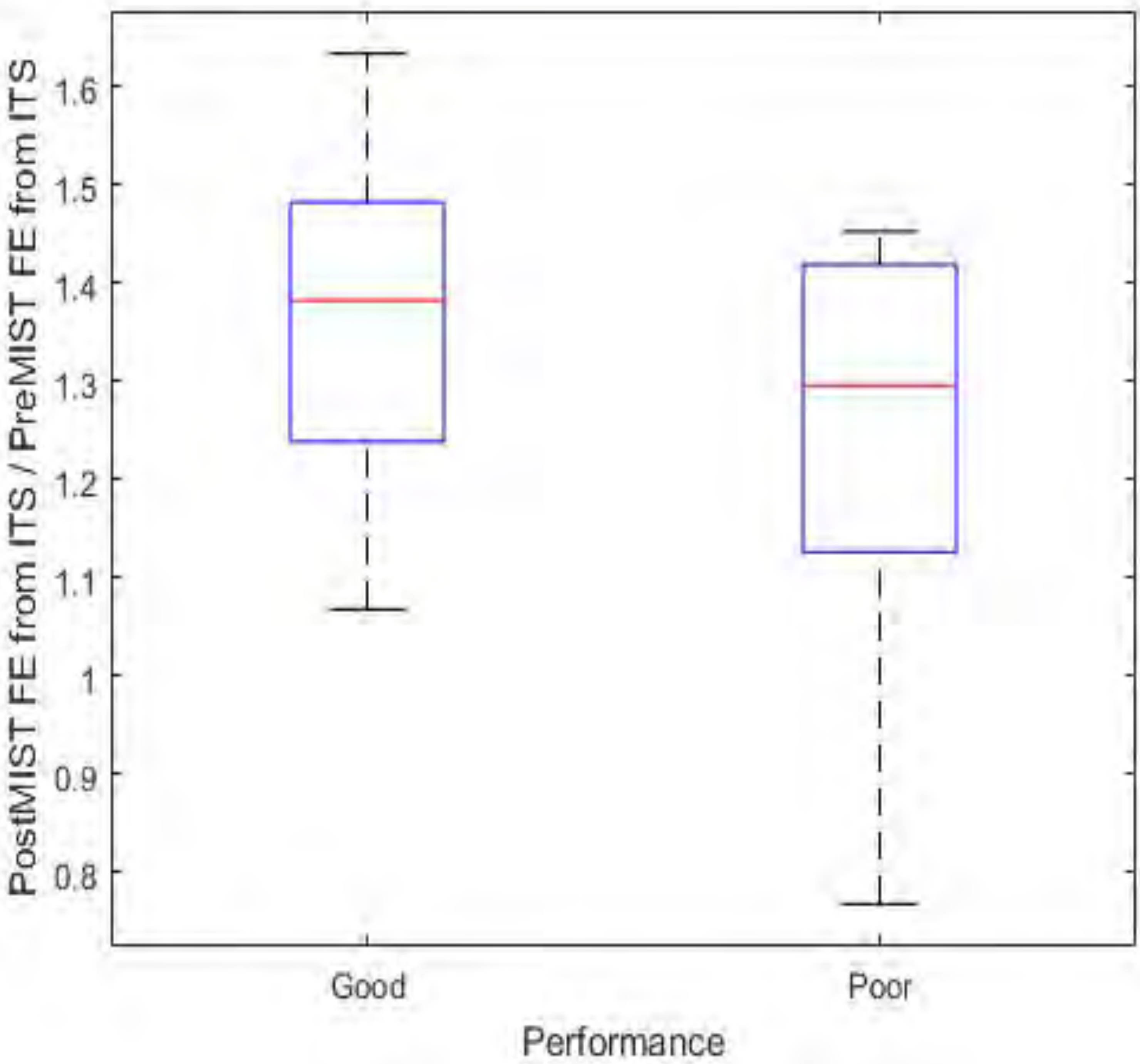
Post MIST

Analysis

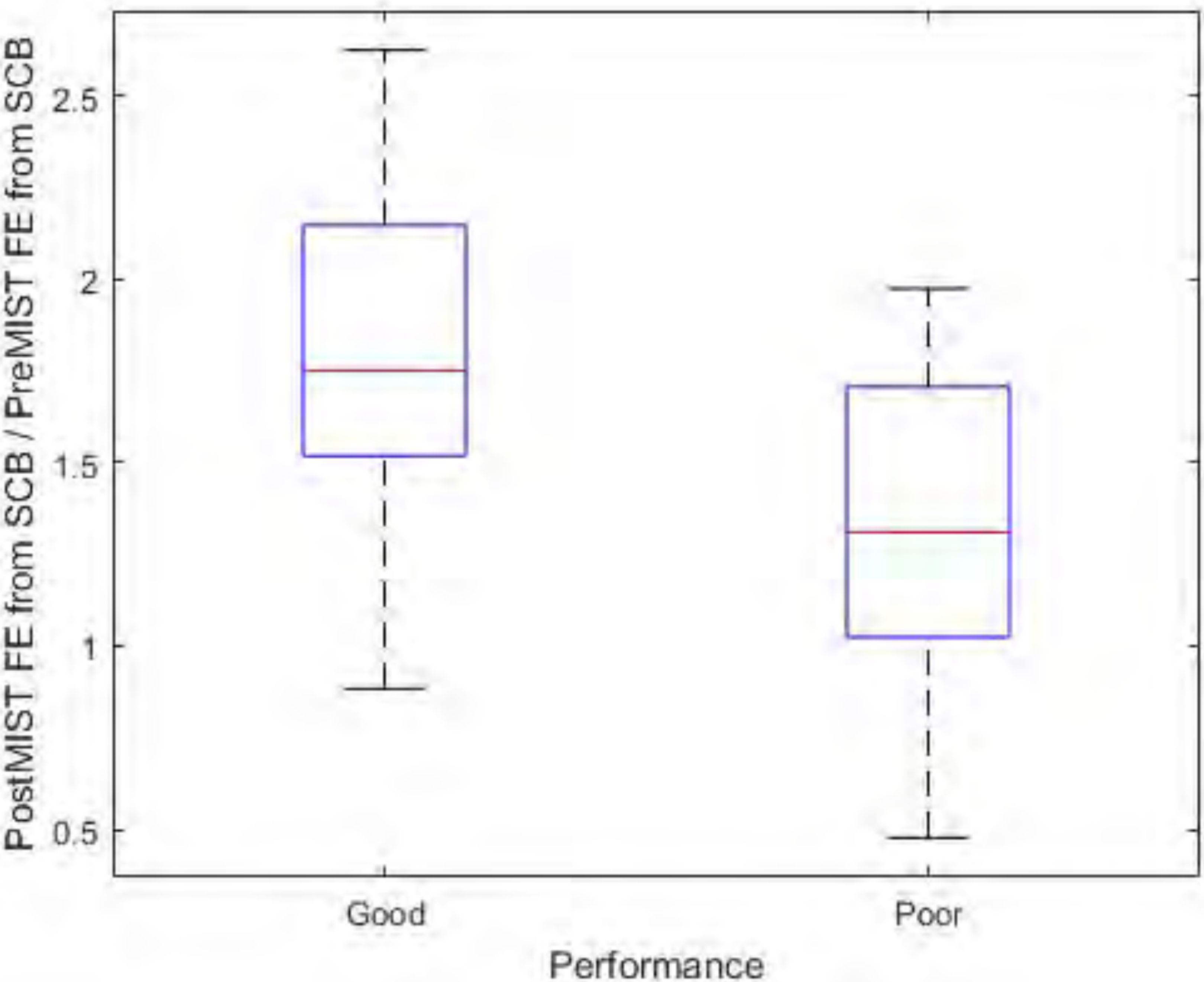

100
95
90
85
80
75
70
65
60
55
TSR, %
Good
Poor
Performance

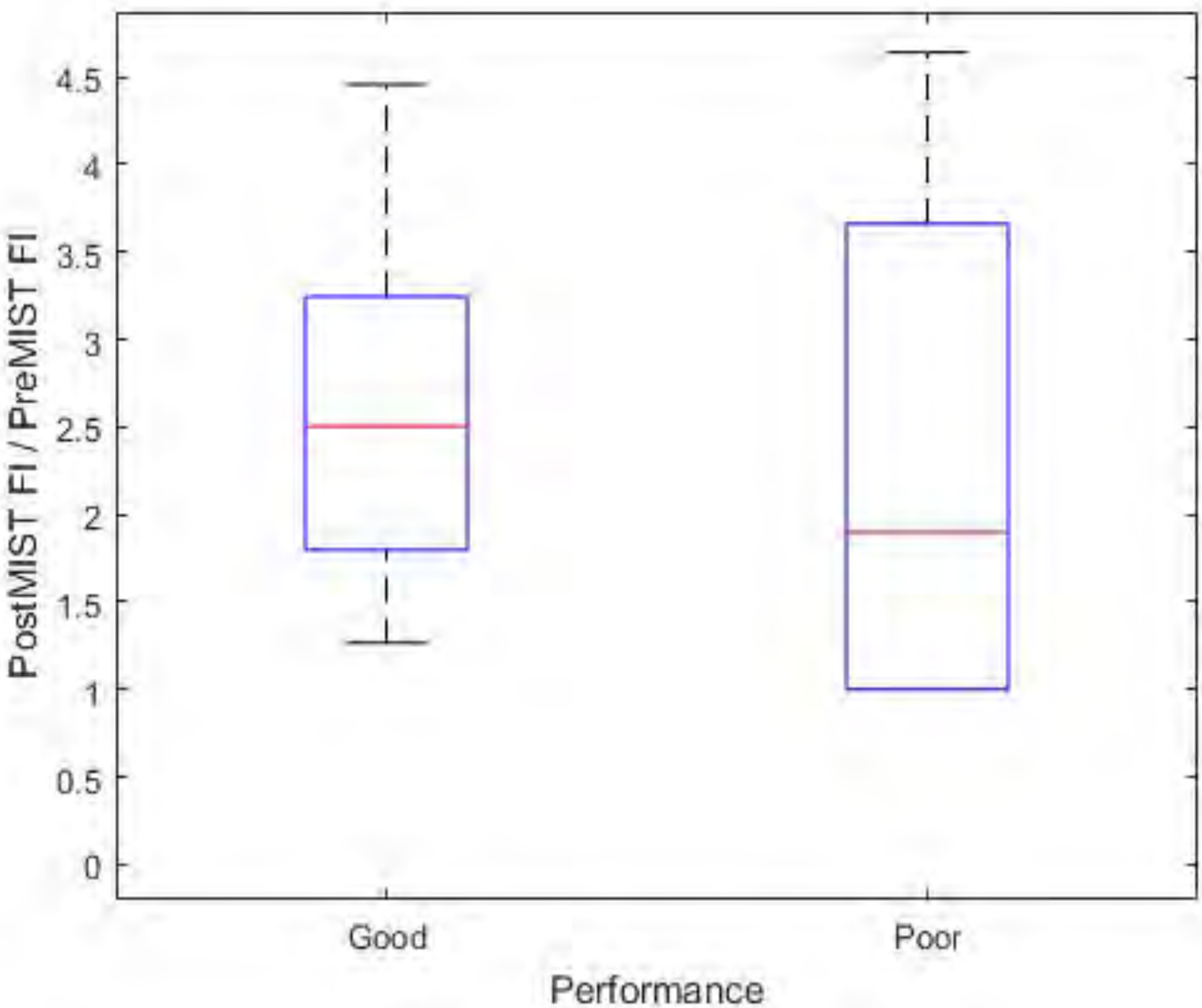


130
120
110
100
90
80
70
100*(PostMIST Es / PreMIST Es), EsR
Good
Poor
Performance

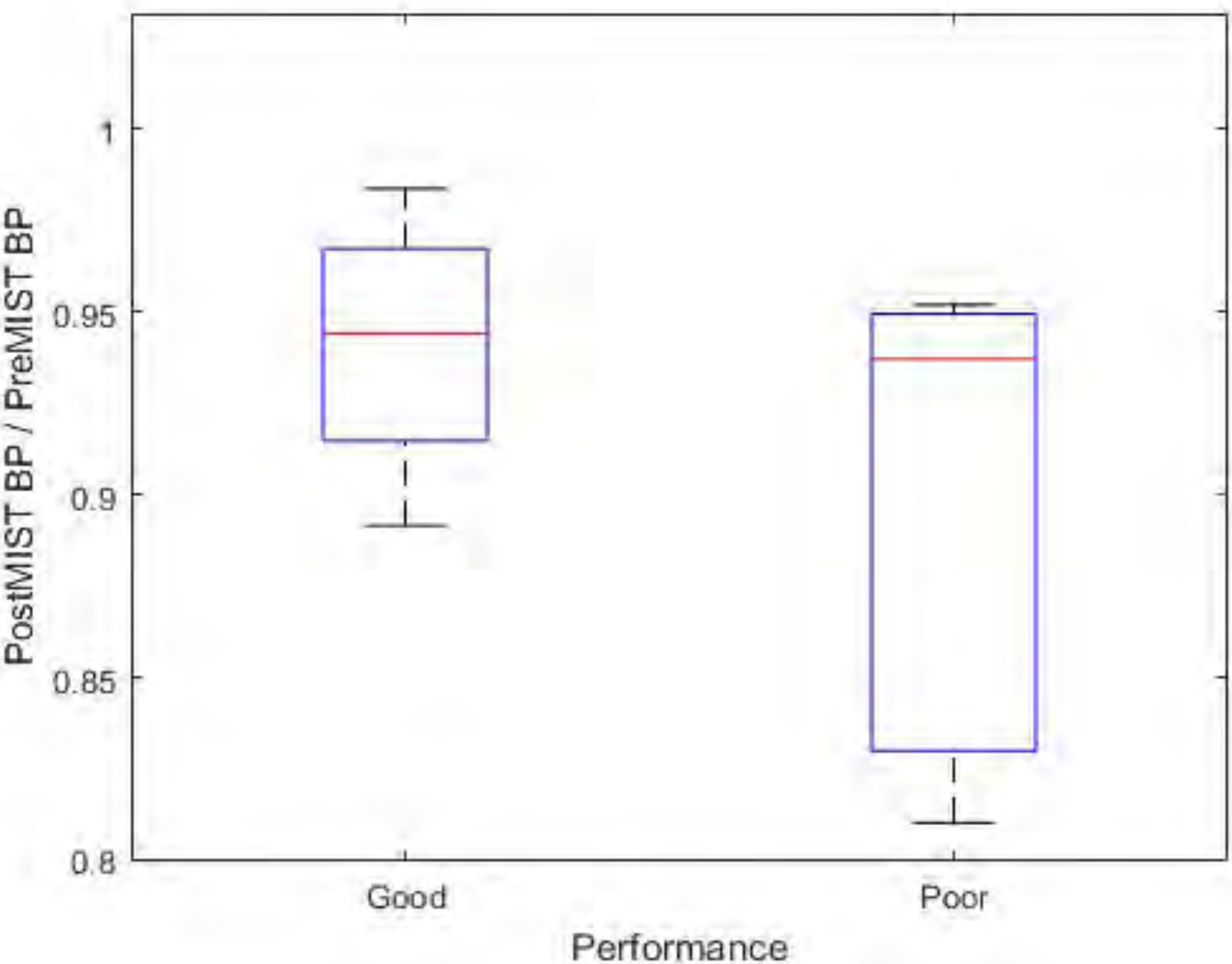


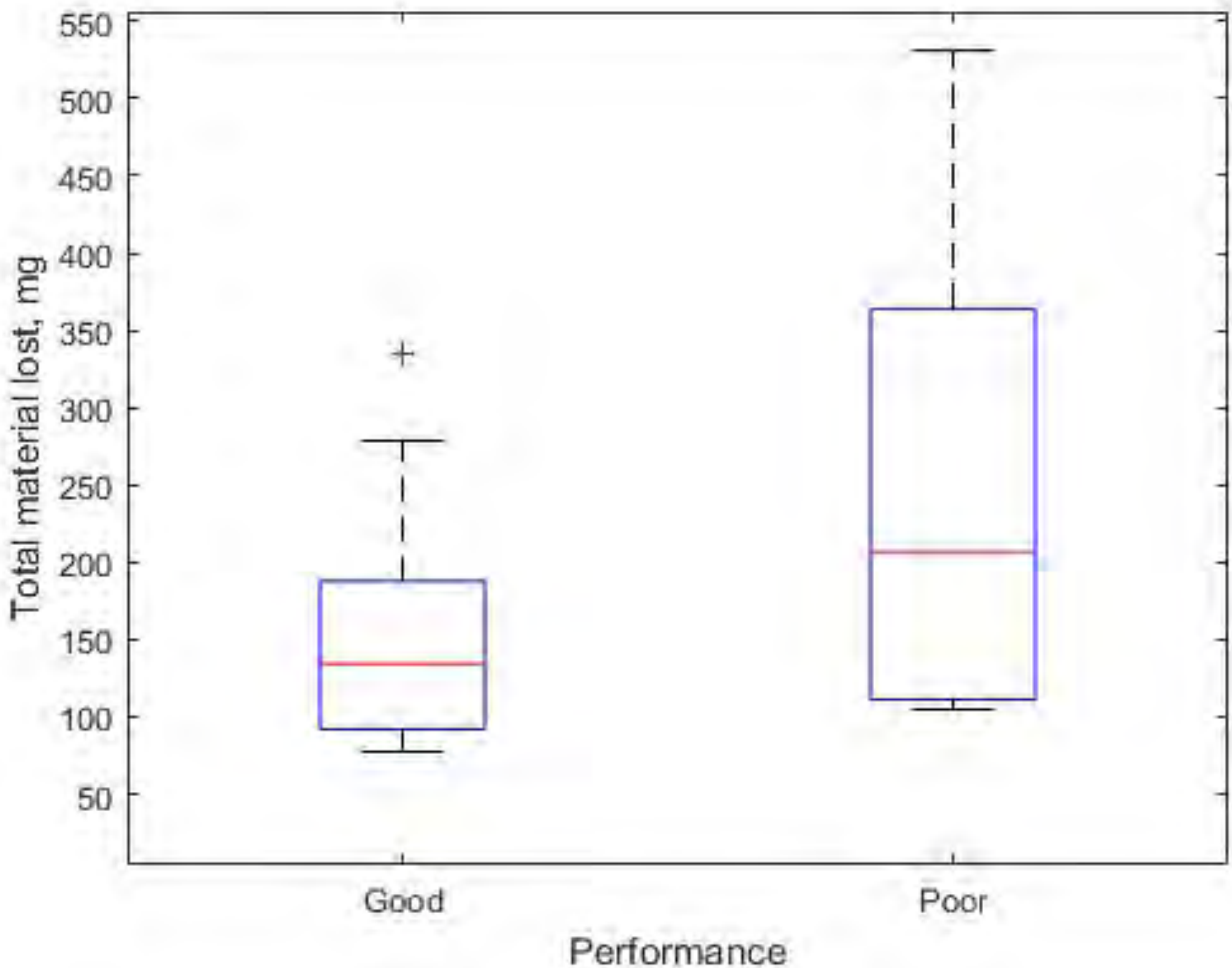
PostMIST FE from ITS / PreMIST FE from ITS
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
Good
Poor
Performance


PostMIST FE from SCB / PreMIST FE from SCB
2.5
2
1.5
1
0.5
Good
Poor
Performance

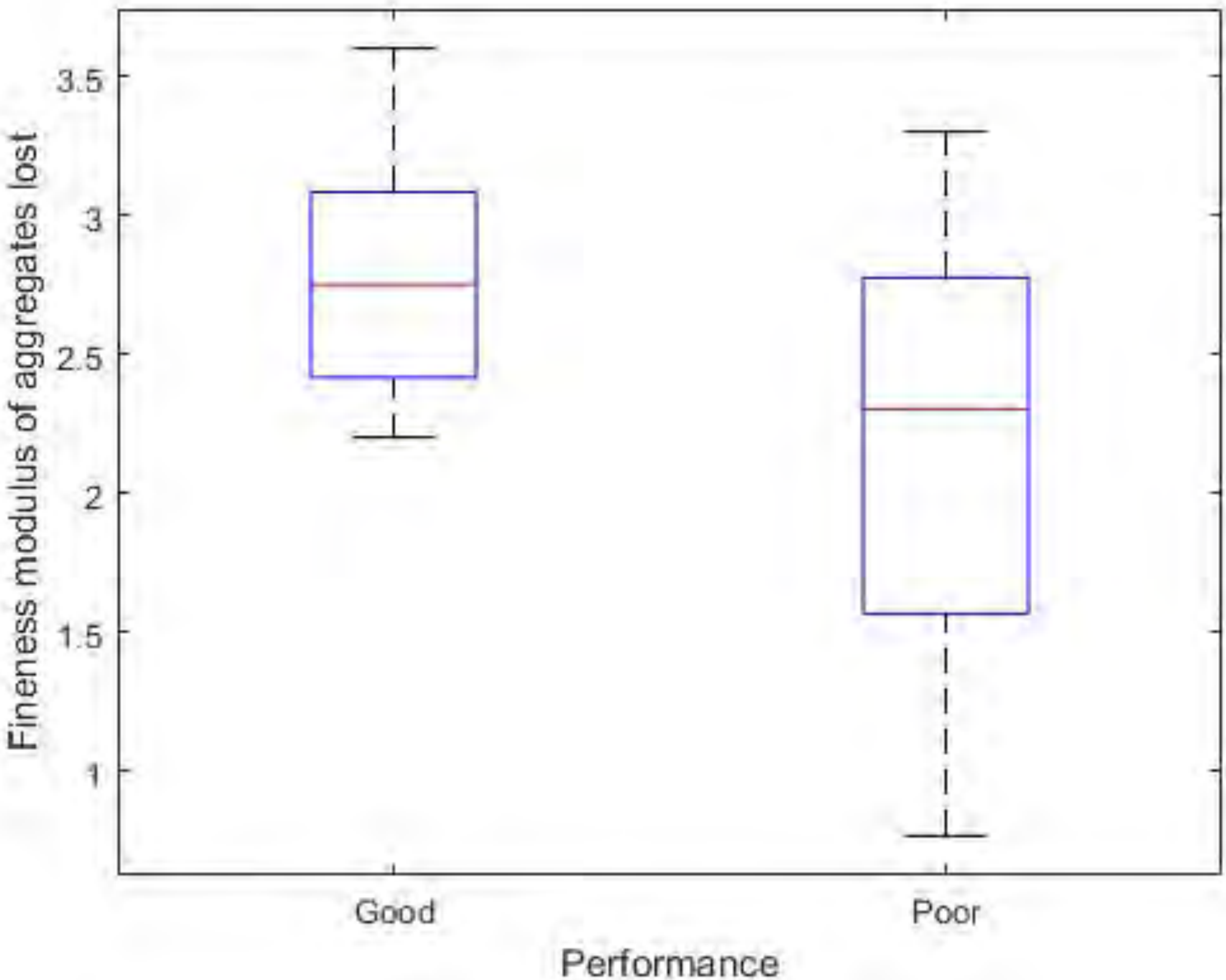


PostMIST FI / PreMIST FI
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Good
Poor
Performance


PostMIST BP / PreMIST BP
1
0.95
0.9
0.85
0.8
Good
Poor
Performance



Total material lost, mg
550
500
450
400
350
300
250
200
150
100
50
Good
Poor
Performance



Fineness modulus of aggregates lost
3.5
3
2.5
2
1.5
1
Good
Poor
Performance

Summary

Mix	TSR, %	Perf.	Add.	Film Thickness, um/VMA	Es loss Sig?	ITS loss Sig?	ITS Fracture Energy Change Sig?	Fineness Modulus of Lost Materials	Black Pixel	
									Change	Sig?
1	87	Good	No	8.92/16.8	No	No	Yes	2.4	21,836	No
2	92	Good	No	9.9/16.8	No	Yes	No	2.4	91,415	Yes
3	86	Poor	No	11.03/18.3	Yes	No	Yes	1.8	53,623	Yes
4	95	Good	No	10.7/18.9	No	No	Yes	3	38,464	No
5	88	Good	Lime	9.03/18.8	Yes	No	No	3.2	84,274	No
6	77	Good	No	10.7/17.2	No	No	No	3.5	15,276	No
7	53	Poor	No	8.83/19.8	Yes	Yes	Yes	2.3	192,807	Yes
8	74	Poor	Com	11.38/16.0	Yes	Yes	Yes	0.8	70,907	No
9	100	Good	No	9.03/16.0	No	No	Yes	2.8	26,420	No
10	90	Good	No	9.59/16.5	No	No	Yes	2.8	46,400	No
11	74	Poor	No	11.38/20.6	Yes	Yes	Yes	2.6	50,083	No
12	86	Good	No	10.08/18	No	No	Yes	2.4	51,753	No
13	88	Poor	Lime	10.14/18.2	No	No	Yes	3.3	219,295	No
14	96	Good	No	10.89/18.3	No	No	Yes	2.7	99,836	No
15	81	Good	No	13.93/17.03	No	No	Yes	2.6	34,947	No
16	95	Good	No	9.67/16.6	No	No	Yes	2.2	92,151	No
17	95	Good	No	11.35/16.3	No	No	Yes	3.6	76,602	No

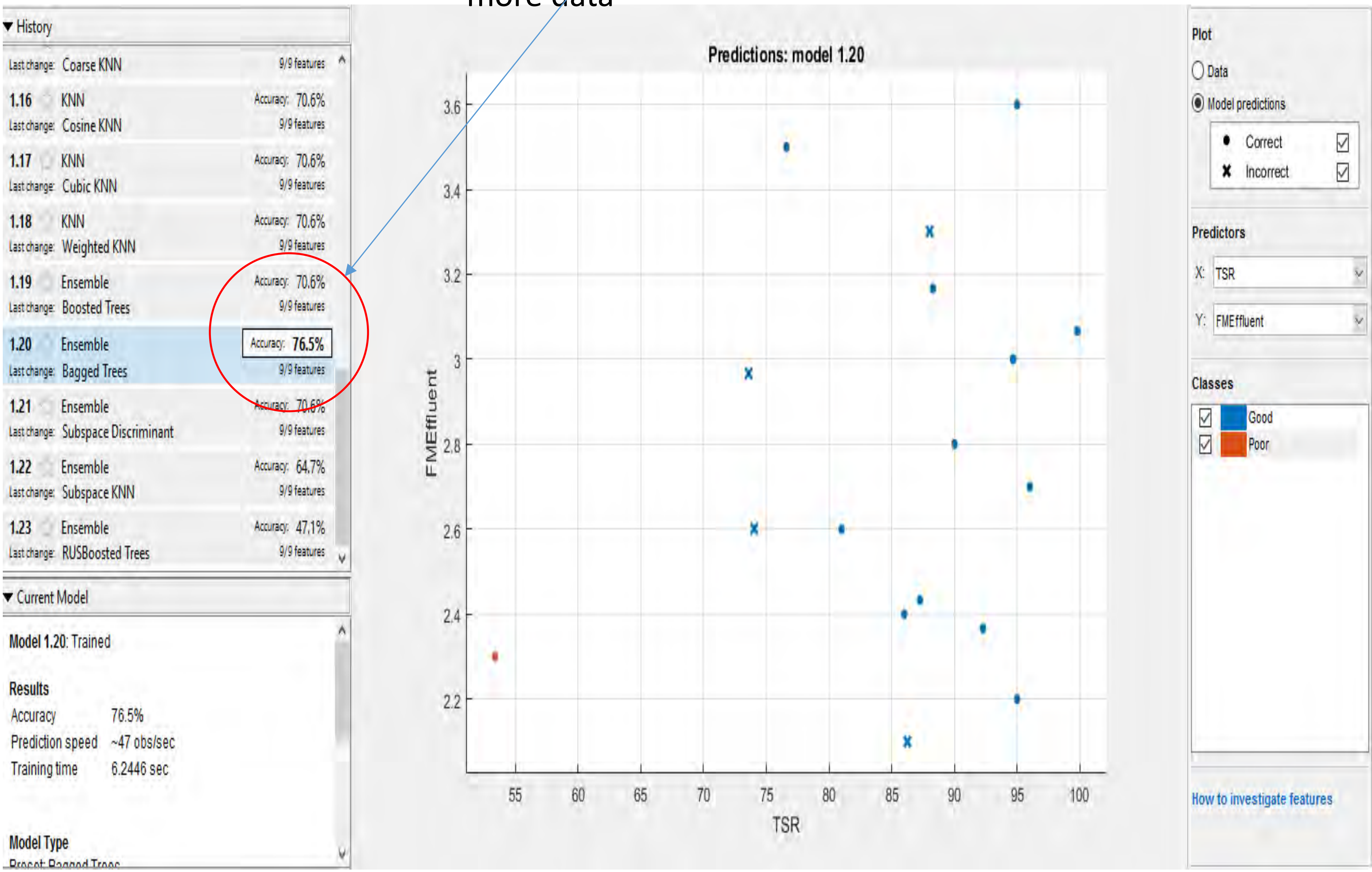
What is a good way of analyzing the data?

- Combine and use Classification
  - Why?
  - Field performance of HMA mixes are not rated according to any scale but are typically characterized as good or poor, which are categorical variables and not numeric variables
- The problem of identifying moisture susceptible and not-susceptible mixes has been considered as a
  - Supervised Machine Learning Classification Problem, since examples of predictors (test results) and corresponding discrete categorical target ('good' or 'poor') are available

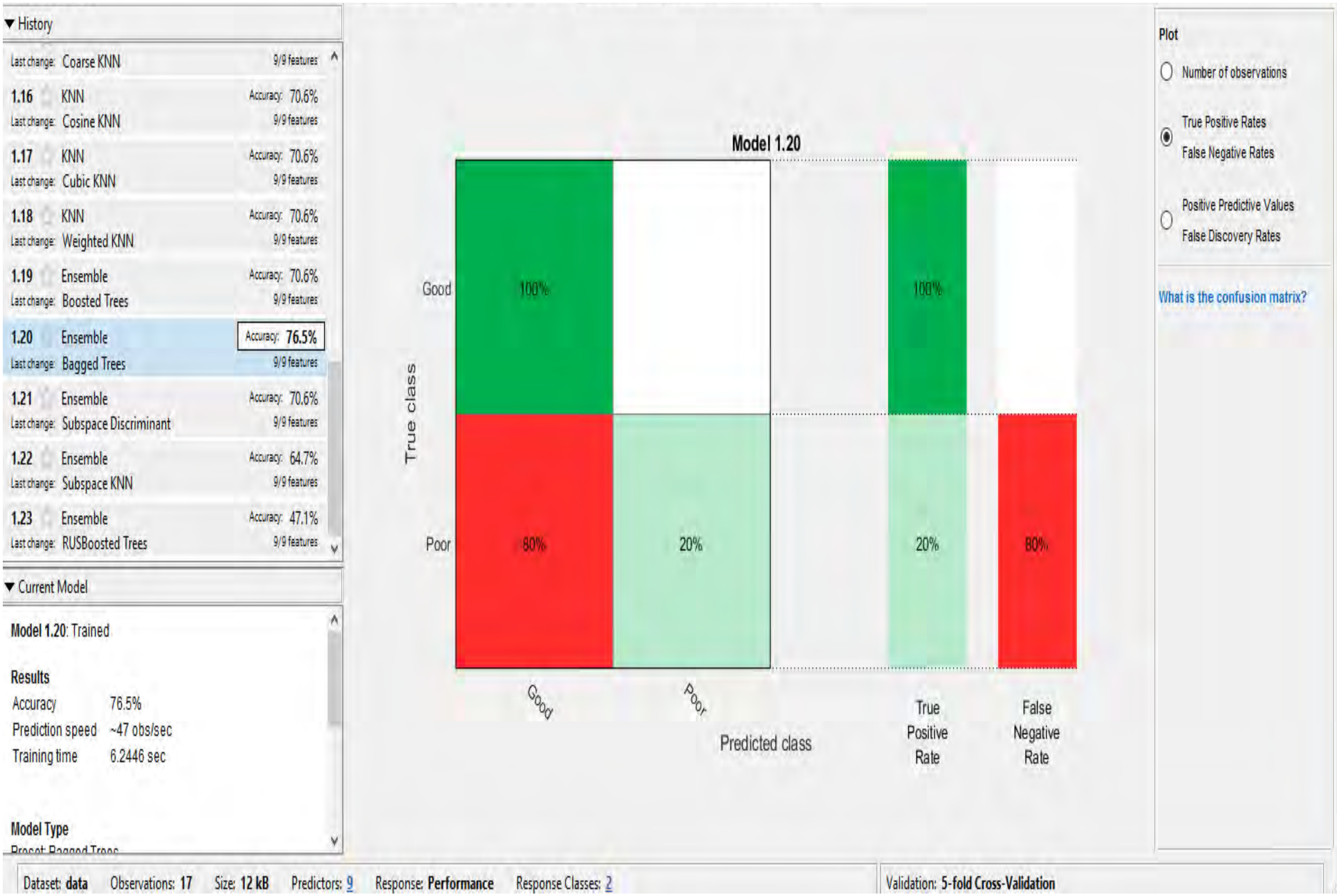
What is a good way to use the data?

- Moisture damage in HMA can occur due to one or more causes, in an isolated and/or combined and/or coupled manner
- Different tests are able to evaluate the potential of different types of moisture damage – all tests are useful
- How can this knowledge be best utilized by the end user?
    - Formulating the problem as a classification problem
    - Using Artificial Neural network ANN
    - Combine the research knowledge and keep improving over time, as more knowledge becomes available

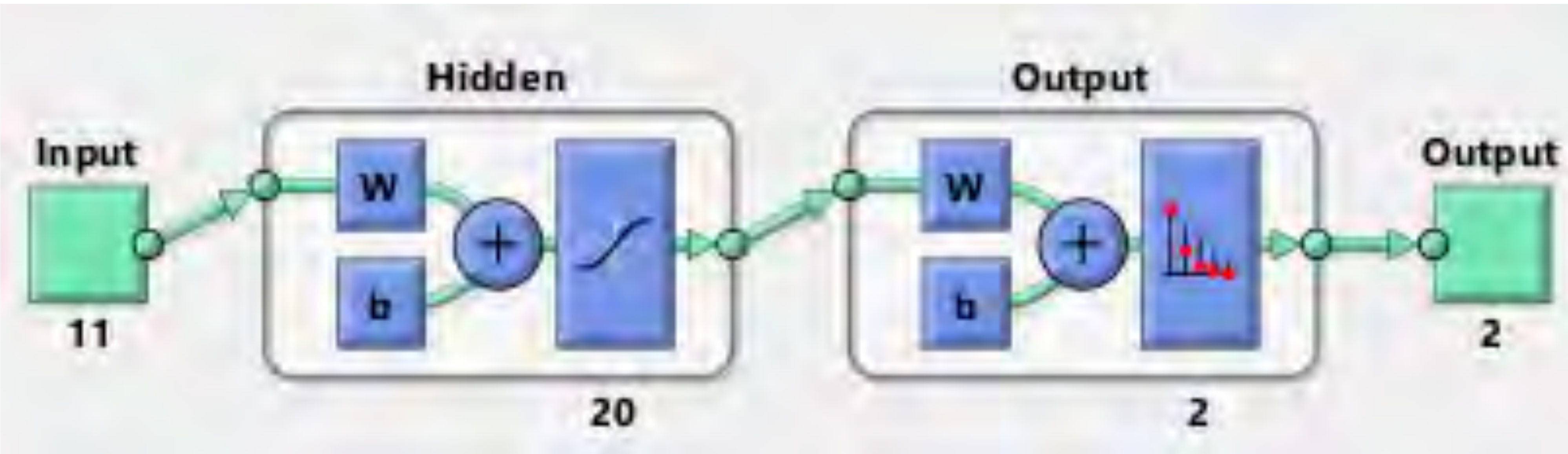
Accuracy could be improved with more data



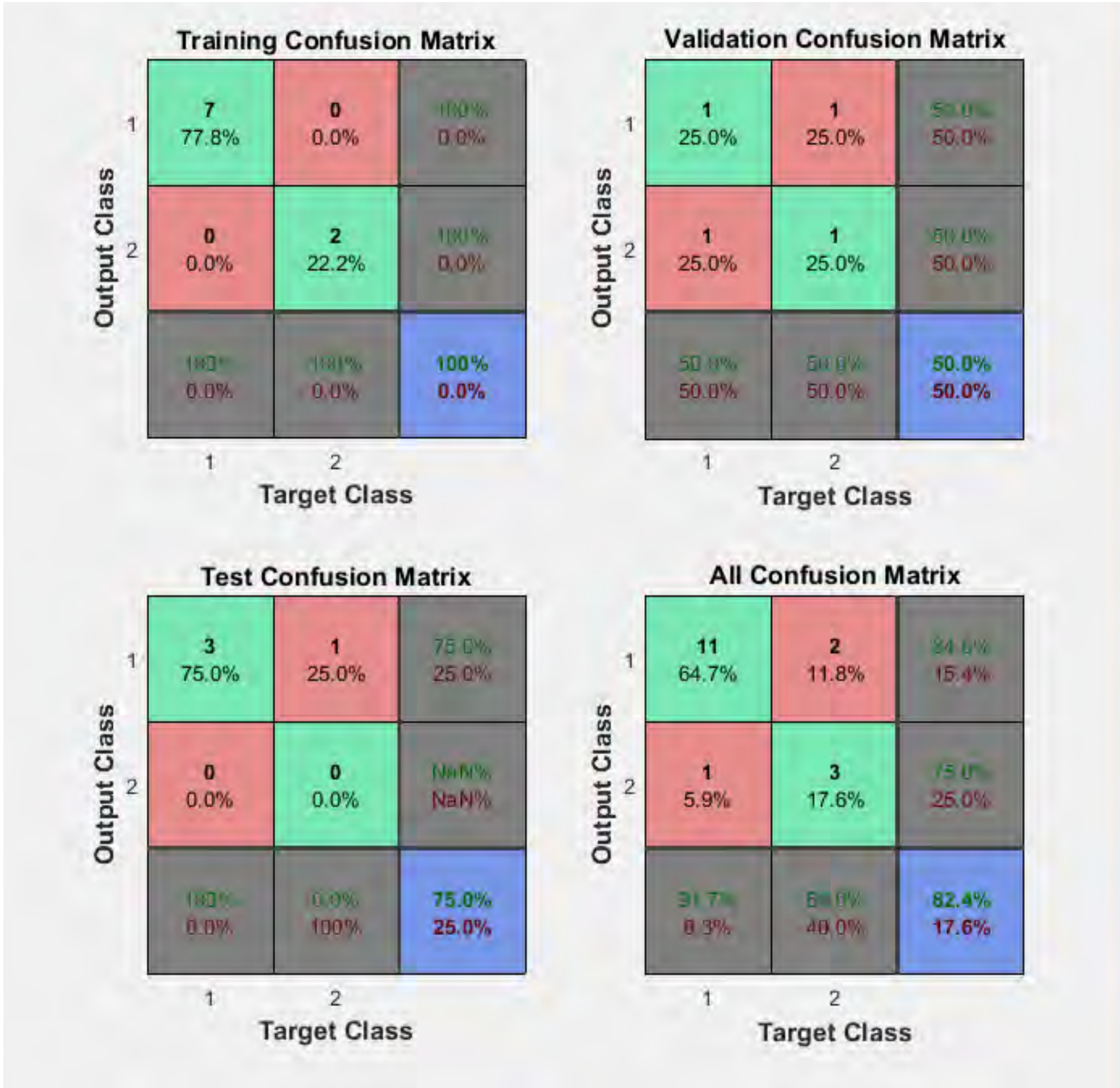
Confusion matrix



Use of Artificial Neural Networks



Use of Artificial Neural Networks



Conclusions and Recommendations

- Seismic Modulus ratio (Pre and Post MIST) seems to be the best indicator of potential of moisture damage
- TSR (Pre and post MIST) is also a good indicator
- There is a decrease in the number of black pixels on the surface of the samples after conditioning; superior performing mixes show a smaller decrease
- Poor performing mixes show a lower fineness modulus of aggregate particles lost during the MIST conditioning process

Conclusions and Recommendations

- A consideration of combination of loss in seismic modulus, indirect tensile strength, and black pixels, and change in fracture energy is effective in the identification of all the poor performing mixes
- Analyze the data from several tests as classification problems
- Utilize Artificial Neural networks (ANN) to classify mixes according to their moisture damage potential
- Improve the ANN over time with laboratory and field performance data


Thank you!