COLD IN-PLACE RECYCLING OF MARGINAL MATERIALS IN MALAYSIA

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ROADCARE (M) SDN BHD

JKR

Kumpulan IKRAM Sdn Bhd

Introduction

- **CIPR technique was first introduced in Malaysia in mid 1980's.**
  - **1985: FT002 Kuala Lumpur - Kuantan, Pahang**
  - **1988: FT008 Pagar Sasak - Merapoh, Pahang**
- **Approximately 10% of Federal Roads* in Malaysia have been treated using CIPR.**
- **Involves all the asphalt layers and part of underlying pavement layers with addition of stabilizing agents to produce stabilized base course.**

***Total length = 18,580.73 km (Malaysian Road Statistics 2010)**

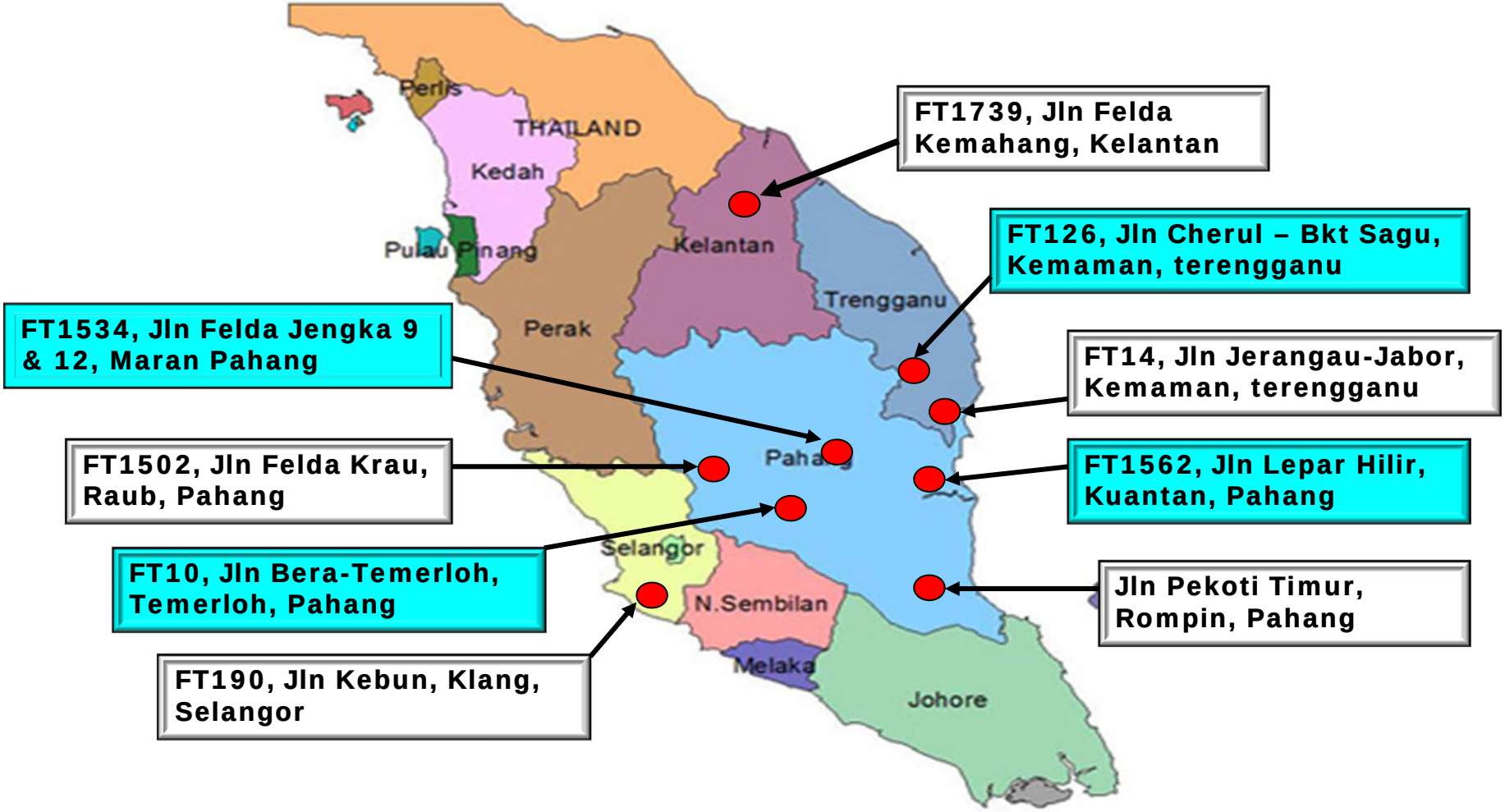
Collaborative Research

- Collaborative research between the Government (PWD) and private sector (IKRAM & Roadcare).
- Title: “Research on Fundamental Characteristics of Stabilised Full Depth Reclaimed (FDR) Pavement Layers in Malaysia”
- Sites: Nine (9)
- Period: 5 years 2004 – 2009 (extended to 2012)
- Cost: RM13.2m (US$3.8m)

Objective of Research

- To study the fundamental engineering parameters of stabilized FDR layers.
- To investigate the properties of aggregates from reclaimed pavements.
- To investigate the effect of moisture saturation levels on stabilized FDR layers.
- To investigate the effect of various stabilizing agents on FDR layers.
- To study the performance of FDR pavements in Malaysia.
- To provide design & construction manual on FDR for Malaysia.

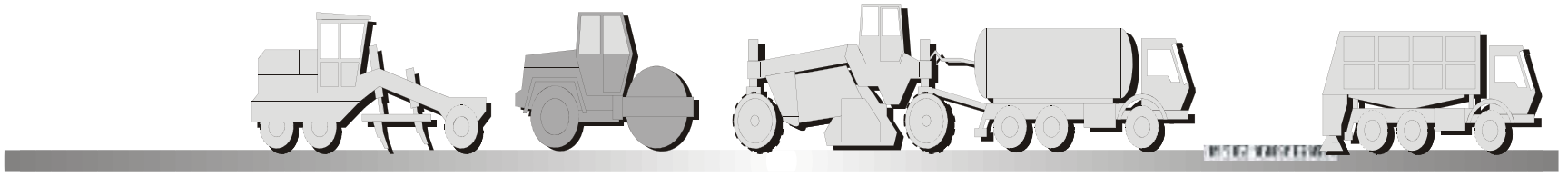
Research Sites



Types of Stabilizing Agent

- **Four types of stabilizing agent were used – cement, lime, foamed bitumen and bitumen emulsion.**

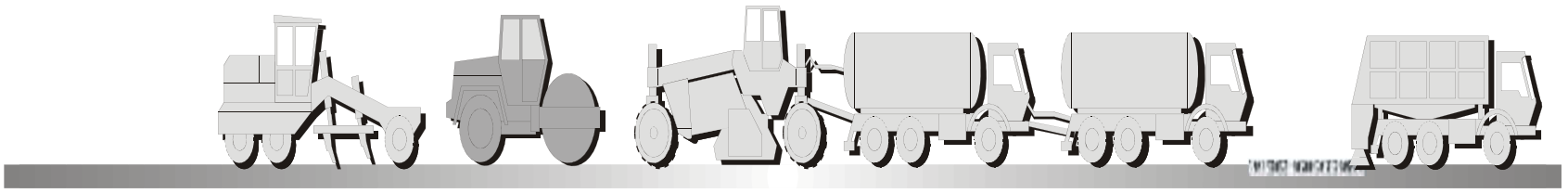
- **Control section constructed using conventional method (either mill & pave, partial or full reconstruction).**



Test Sections

- **Length 1 km, uniform in terrain, geometric, level of traffic, pavement type and surface condition.**

- **Each site is divided to five 200m sections for four different types of stabilizing agent, and a control section.**



Background

- **Marginal Materials**
  - **Naturally occuring road making materials or locally available materials.**
  - **Gravel/laterite/earth roads.**

Background

- **Demand of Marginal Materials**

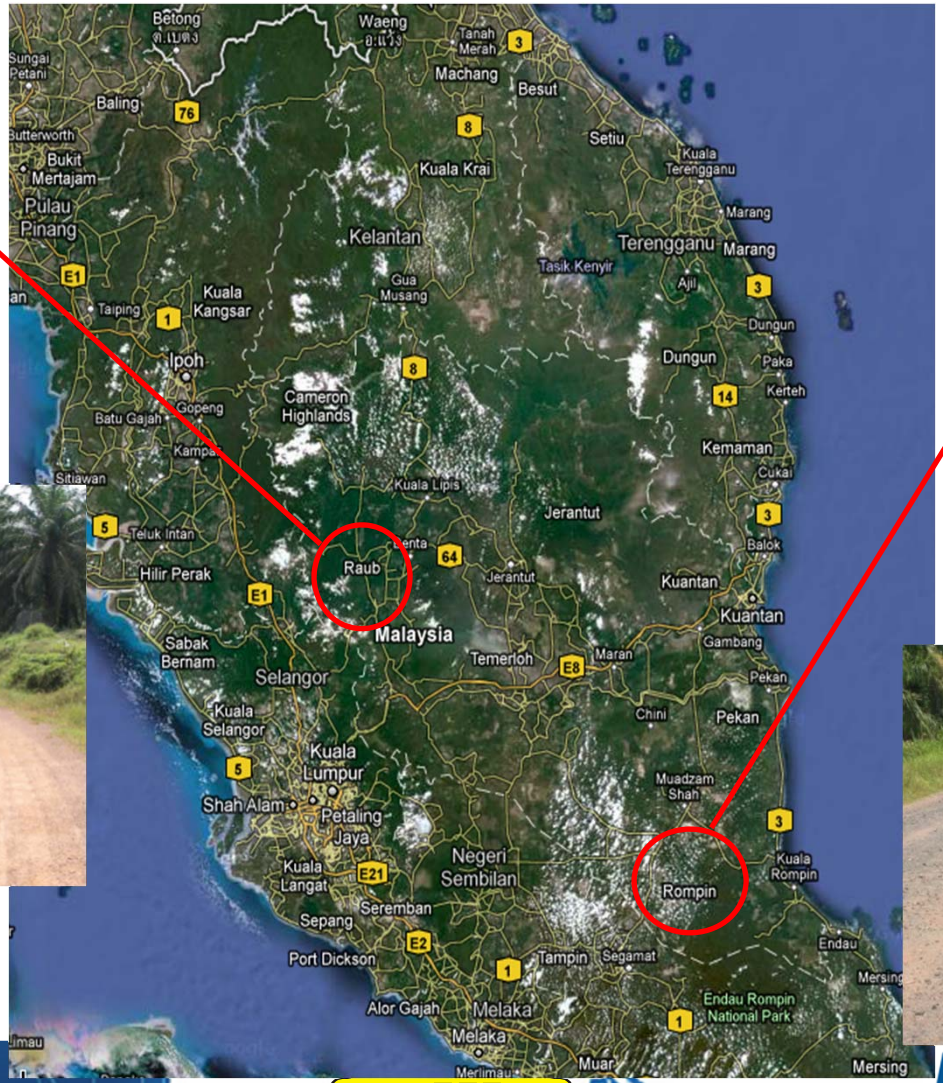
- **Malaysia consists of 14 states, which are linked by;**

  - **100,000 km of paved road,**
  - **16,000 km of gravel roads*, and**
  - **8,000 km of laterite/earth* roads.**

- ***Gravel/laterite/earth roads are mostly found in plantation areas.**

Research Sites

Site 2 – FT 1502, Jalan Felda Krau, Raub



Site 1 – Federal Route Felda Pekoti Timur, Rompin

Research Sites – Existing Conditions

1. **Site 1 and Site 2 were constructed in August 2006 and October 2007 respectively.**

2. **Average Daily Traffic (ADT) < 1,000 vehicles (heavy commercial vehicles 45%).**

3. **Several localised sections recorded depression > 40mm.**

4. **Subgrade's California Bearing Ratio (CBR) 6% - 16% (dry season), may drop below 5% during rainy season.**

Research Sites – Treatment Details

- Divided into four 200m sections for four different types of stabilizer:
  - Cement
  - Lime
  - Foamed bitumen
  - Bitumen emulsion
- A control section of 200m constructed using conventional pavement rehabilitation method.

Treatment Details

Site	Site 1: Felda Pekoti Timur	Site 2: Felda Krau
Section	Design Loading = 1 msa	Design Loading = 2 msa
1	**CIPR Cement** CIPR 200mm + Overlay 60mm AC	**CIPR Cement** Top up 100mm C/run + CIPR 200mm + Overlay 80mm AC
2	**CIPR Foamed Bitumen** CIPR 150mm + Overlay 60mm AC	**CIPR Foamed Bitumen** Top up 100mm C/run + CIPR 200mm + Overlay 80mm AC
3	**CIPR Lime** CIPR 200mm + Overlay 60mm AC	**CIPR Lime** Top up 100mm C/run + CIPR 200mm + Overlay 80mm AC
4	**CIPR Emulsion** CIPR 150mm + Overlay 60mm AC	**CIPR Emulsion** Top up 100mm C/run + CIPR 200mm + Overlay 80mm AC
5	**Control** Top up 100mm C/run + Overlay 60mm AC	**Control** Top up 150mm C/run + Overlay 80mm AC

Construction

- The percentages of stabilizing agents and/or water contents were first determined during mix design stage.
- The required quantity of cement or lime was spread manually.
- Recycle using recycling machine to a depth of 150mm or 200mm according to the specified treatment.

Construction

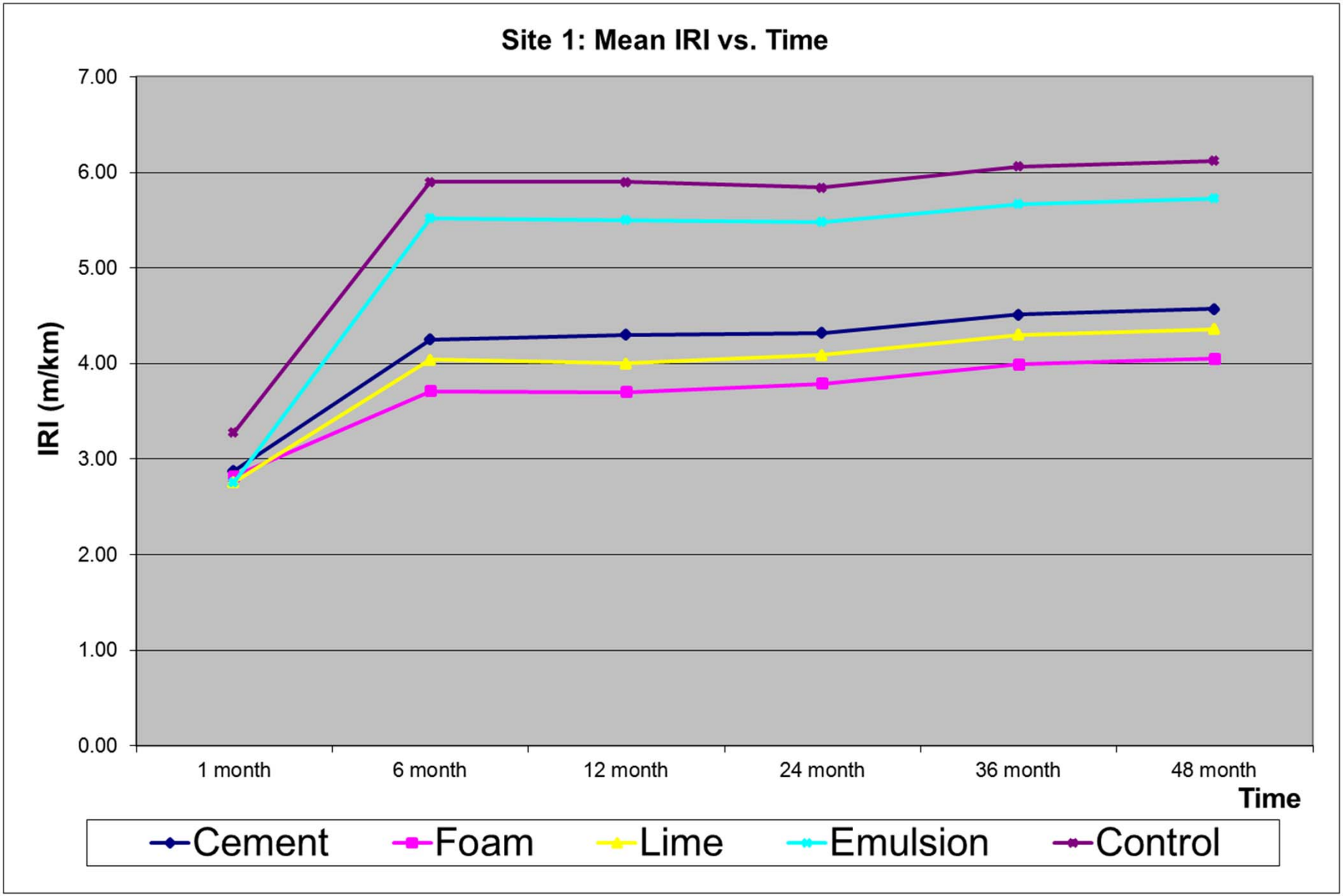
- Breakdown rolling using smooth drum roller immediately after recycling.
- A grader was used to re-profile the finished recycled layer.
- Further compaction by vibratory roller.
- Open to traffic immediately after compaction.
- Curing by spraying water three times/day.

Construction

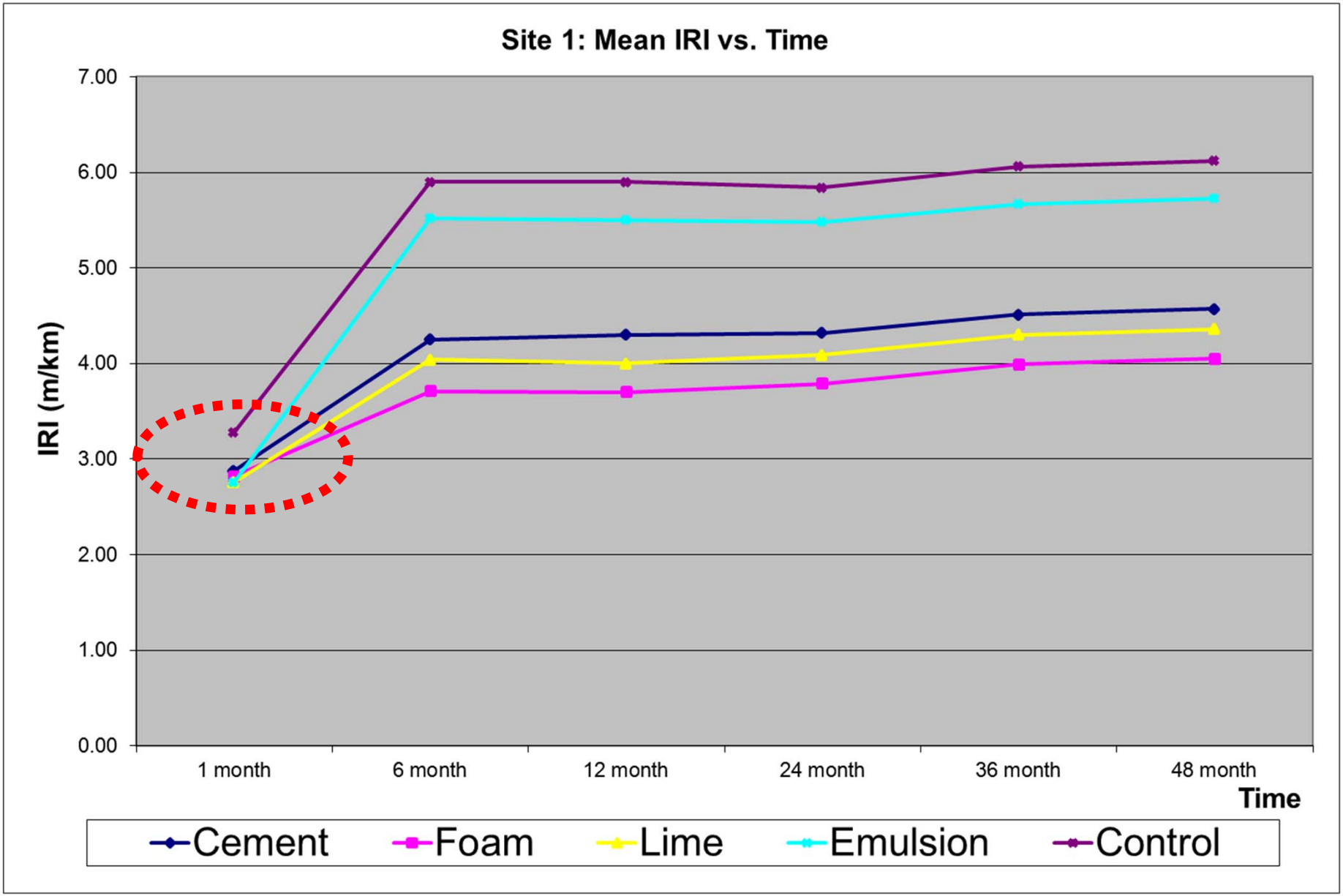
- After three days of curing, a layer of prime coat was applied and allowed for curing overnight.

- Asphalt wearing course was laid as per specified thickness and specifications.

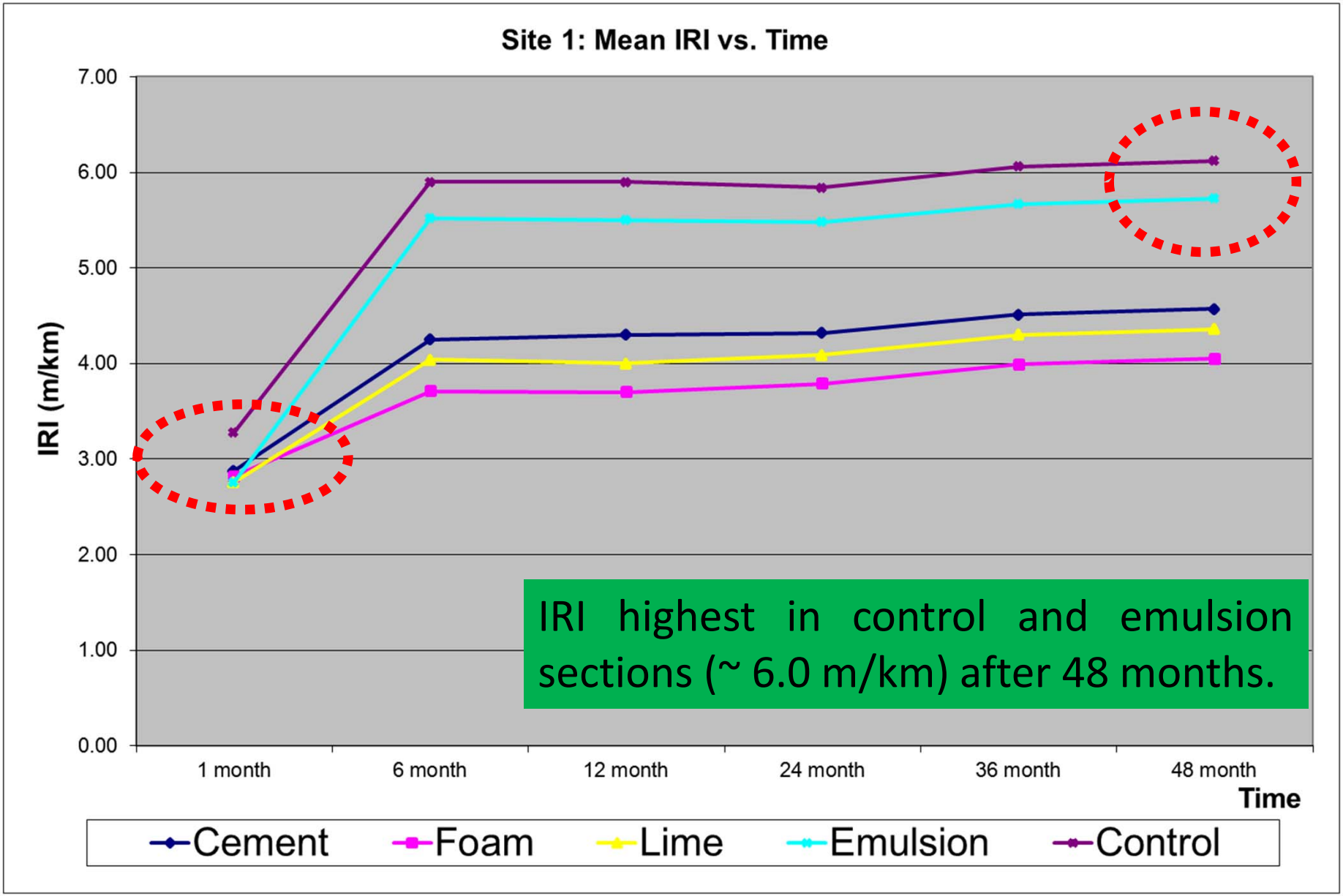
International Roughness Index (IRI) – Site 1



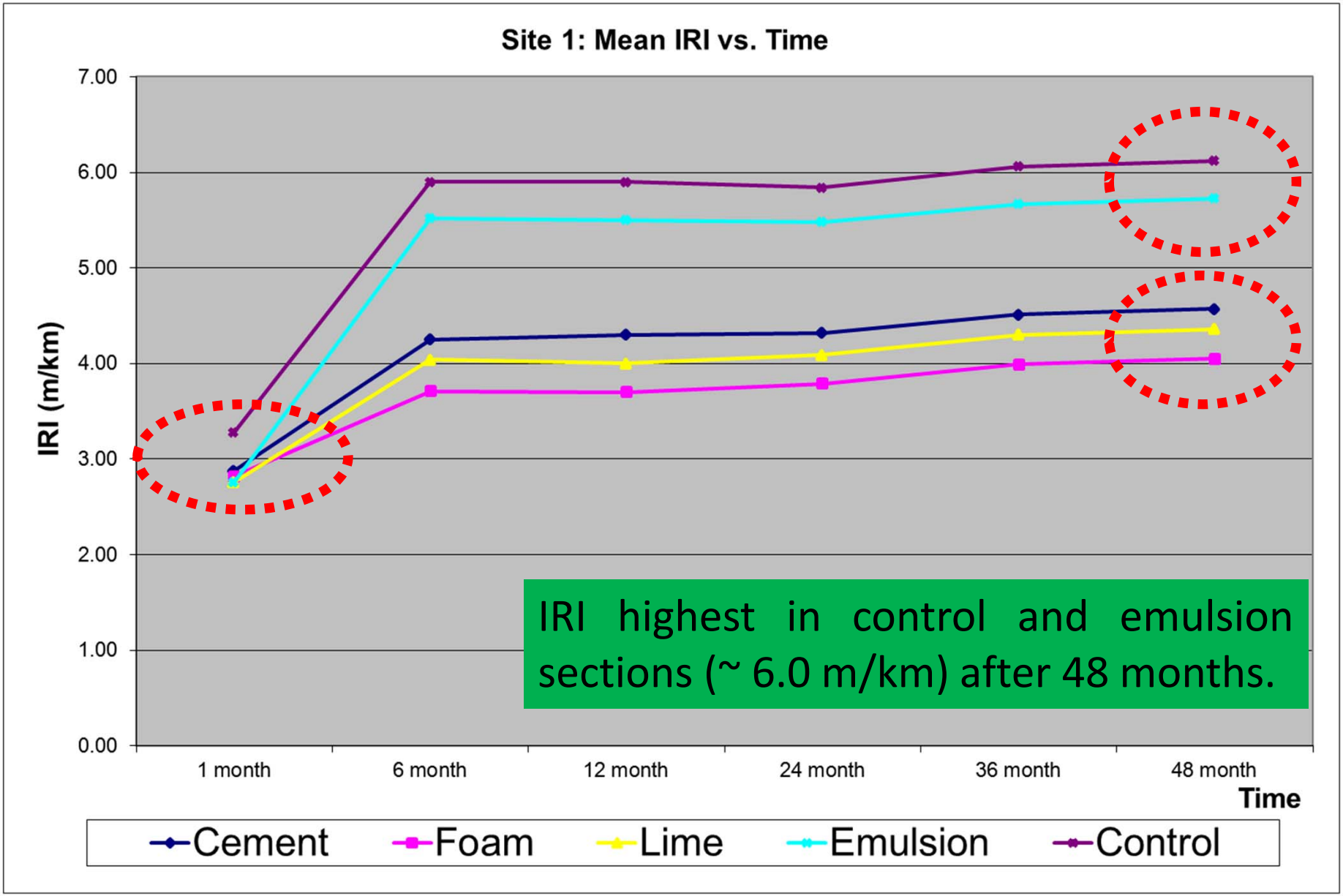
International Roughness Index (IRI) – Site 1



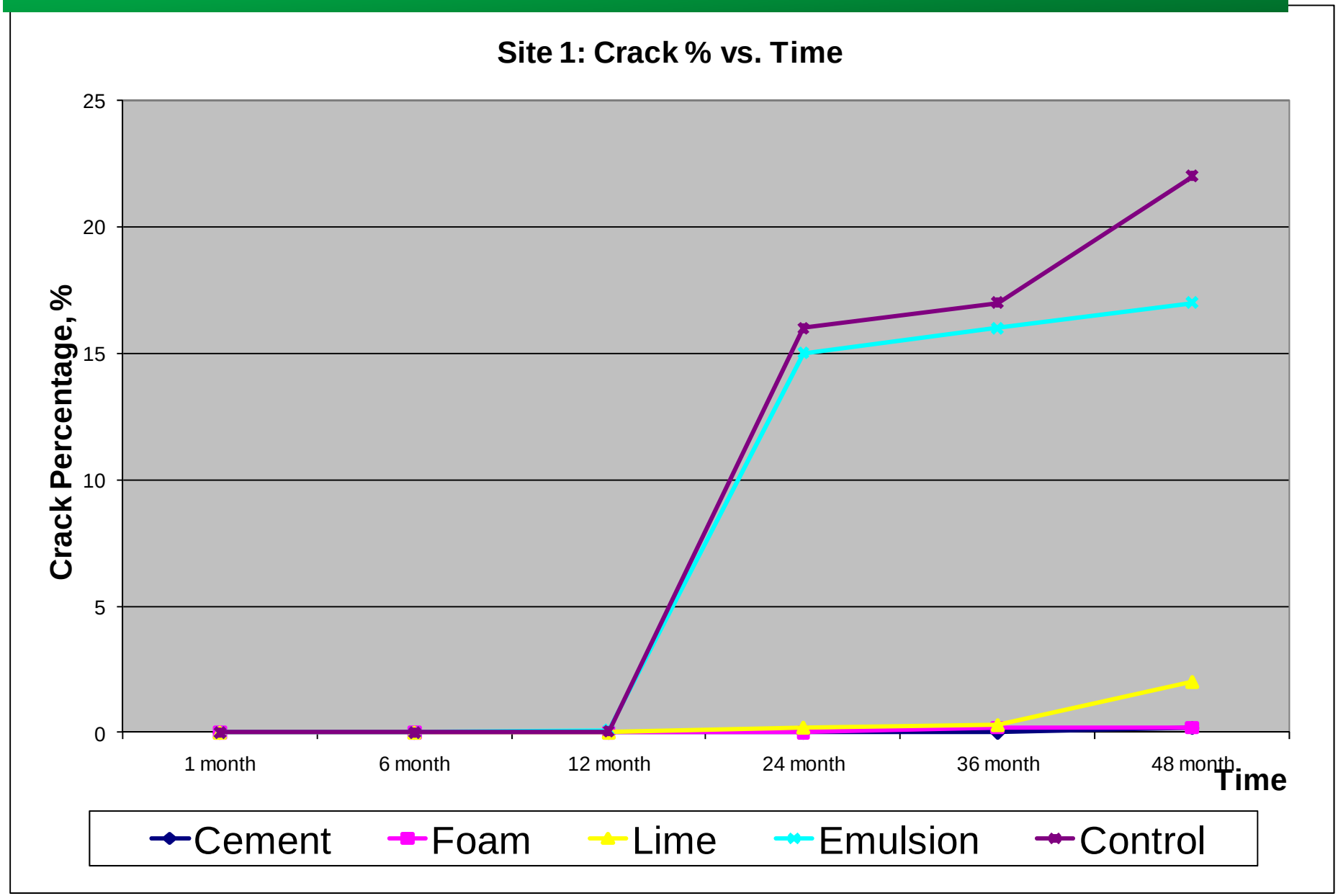
International Roughness Index (IRI) – Site 1



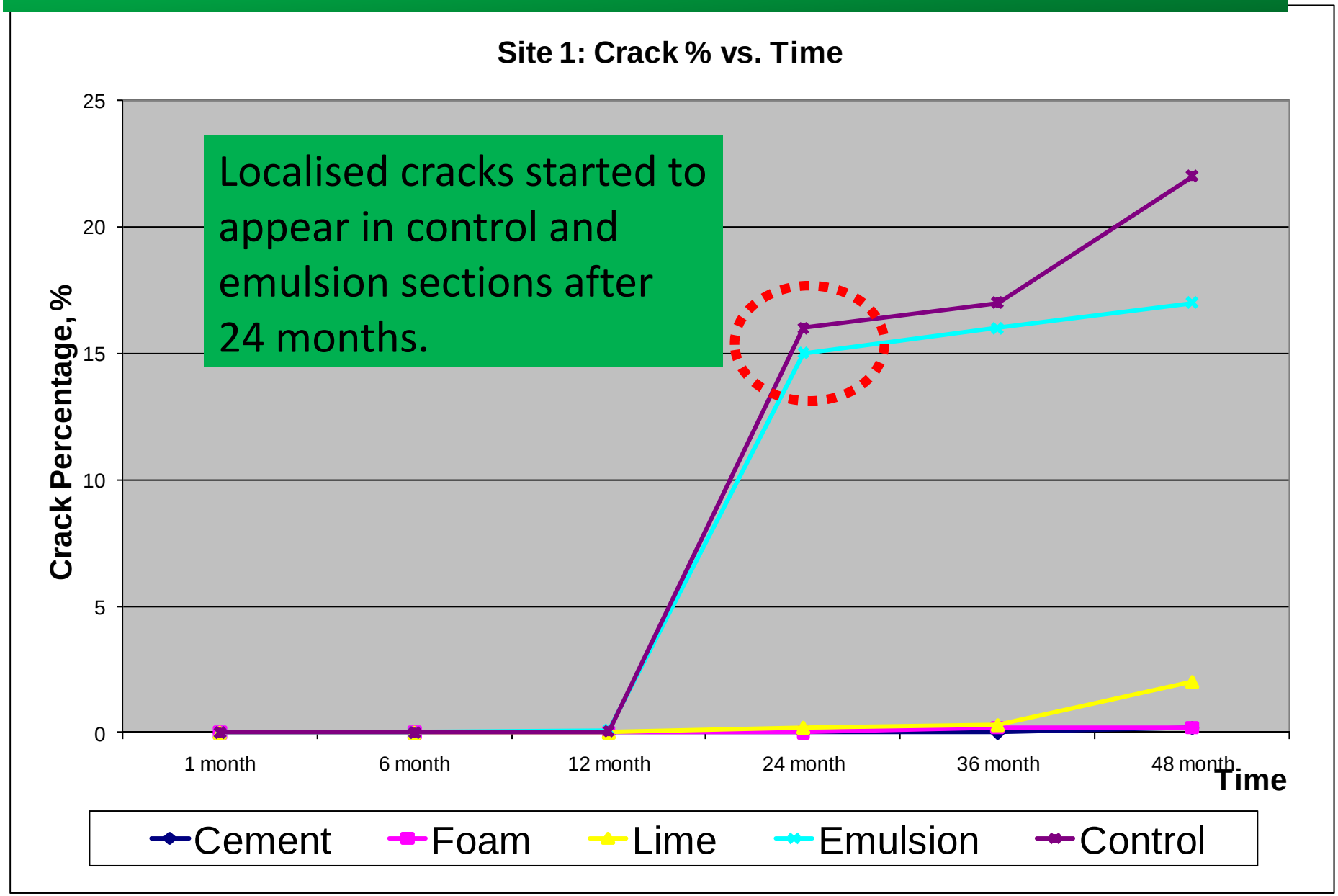
International Roughness Index (IRI) – Site 1



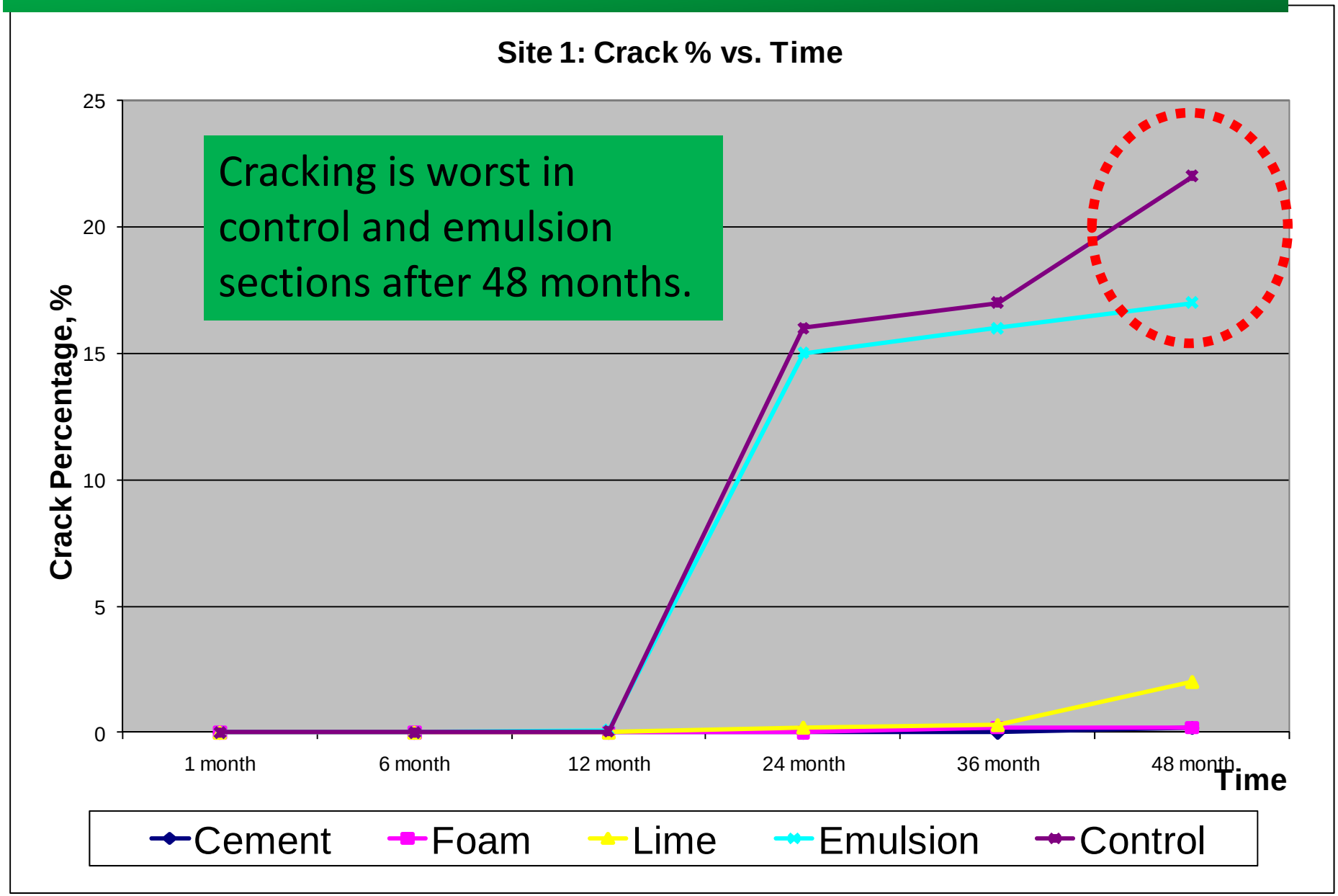
Crack – Site 1


Site 1: Crack % vs. Time
Crack Percentage, %
25
20
15
10
5
0
1 month
6 month
12 month
24 month
36 month
48 month
Time
Cement
Foam
Lime
Emulsion
Control

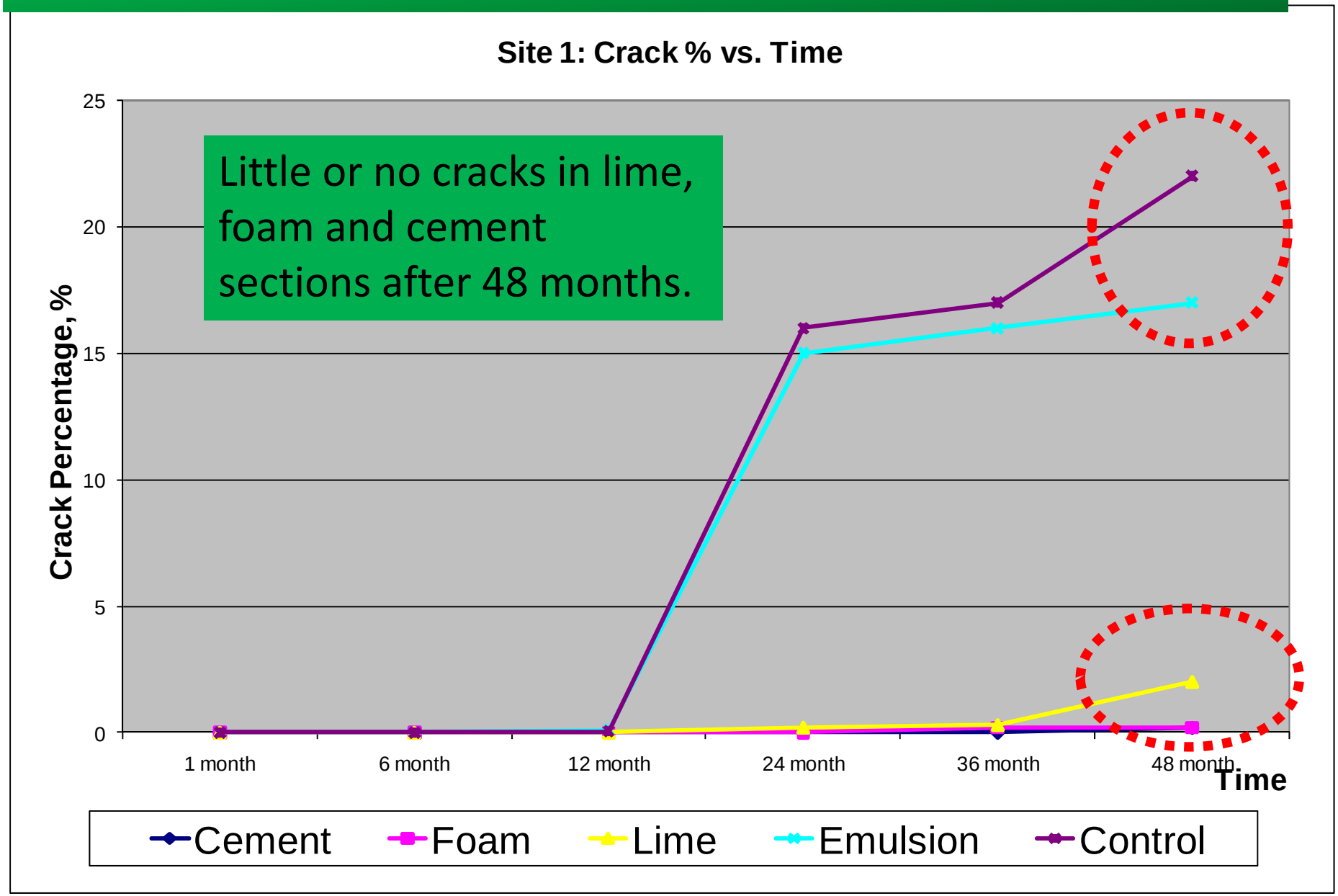
Crack – Site 1


Site 1: Crack % vs. Time
Localised cracks started to appear in control and emulsion sections after 24 months.
Crack Percentage, %
25
20
15
10
5
0
1 month
6 month
12 month
24 month
36 month
48 month
Time
Cement
Foam
Lime
Emulsion
Control

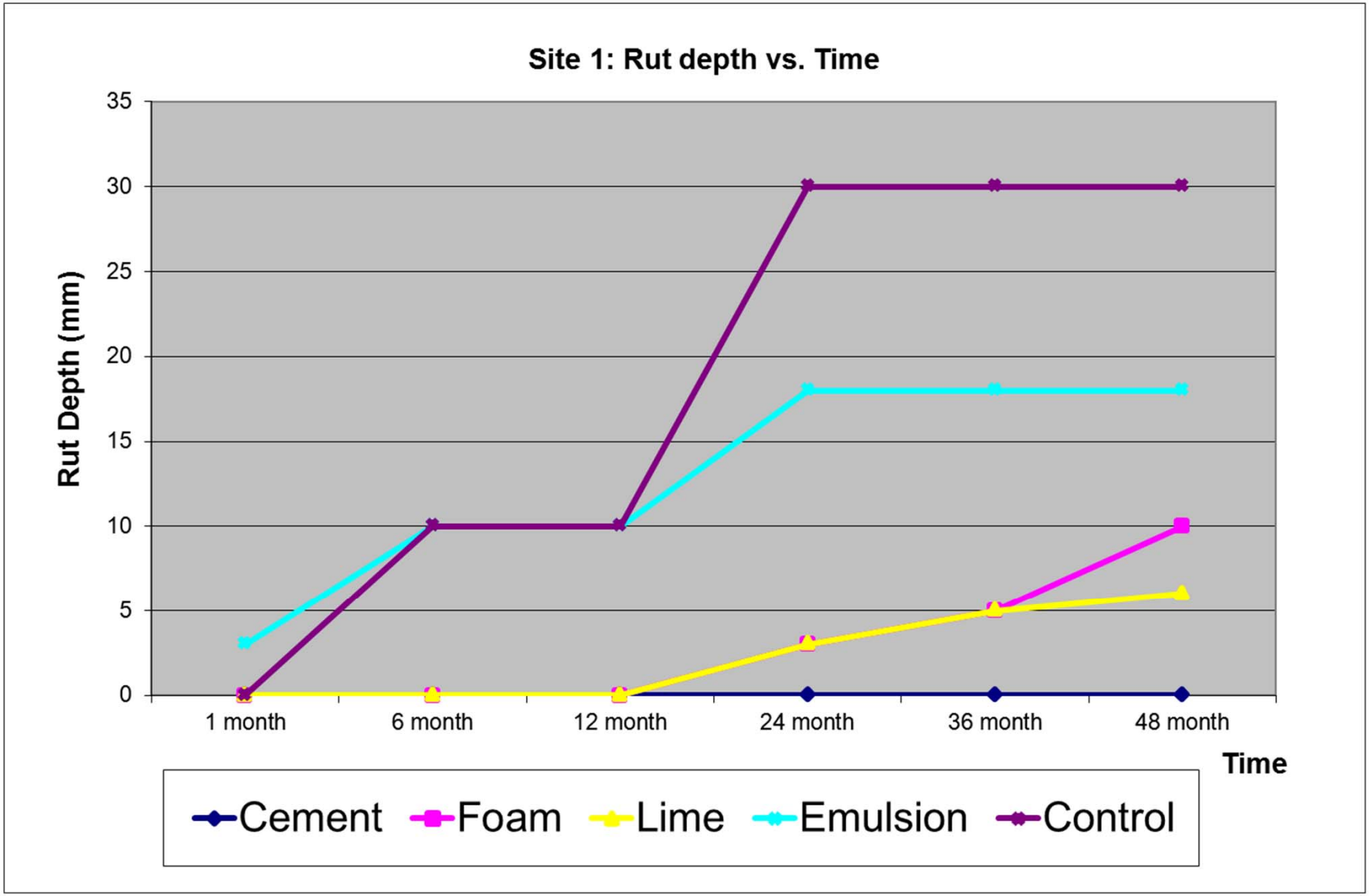
Crack – Site 1


Site 1: Crack % vs. Time
Cracking is worst in control and emulsion sections after 48 months.
Crack Percentage, %
25
20
15
10
5
0
1 month
6 month
12 month
24 month
36 month
48 month
Time
Cement
Foam
Lime
Emulsion
Control

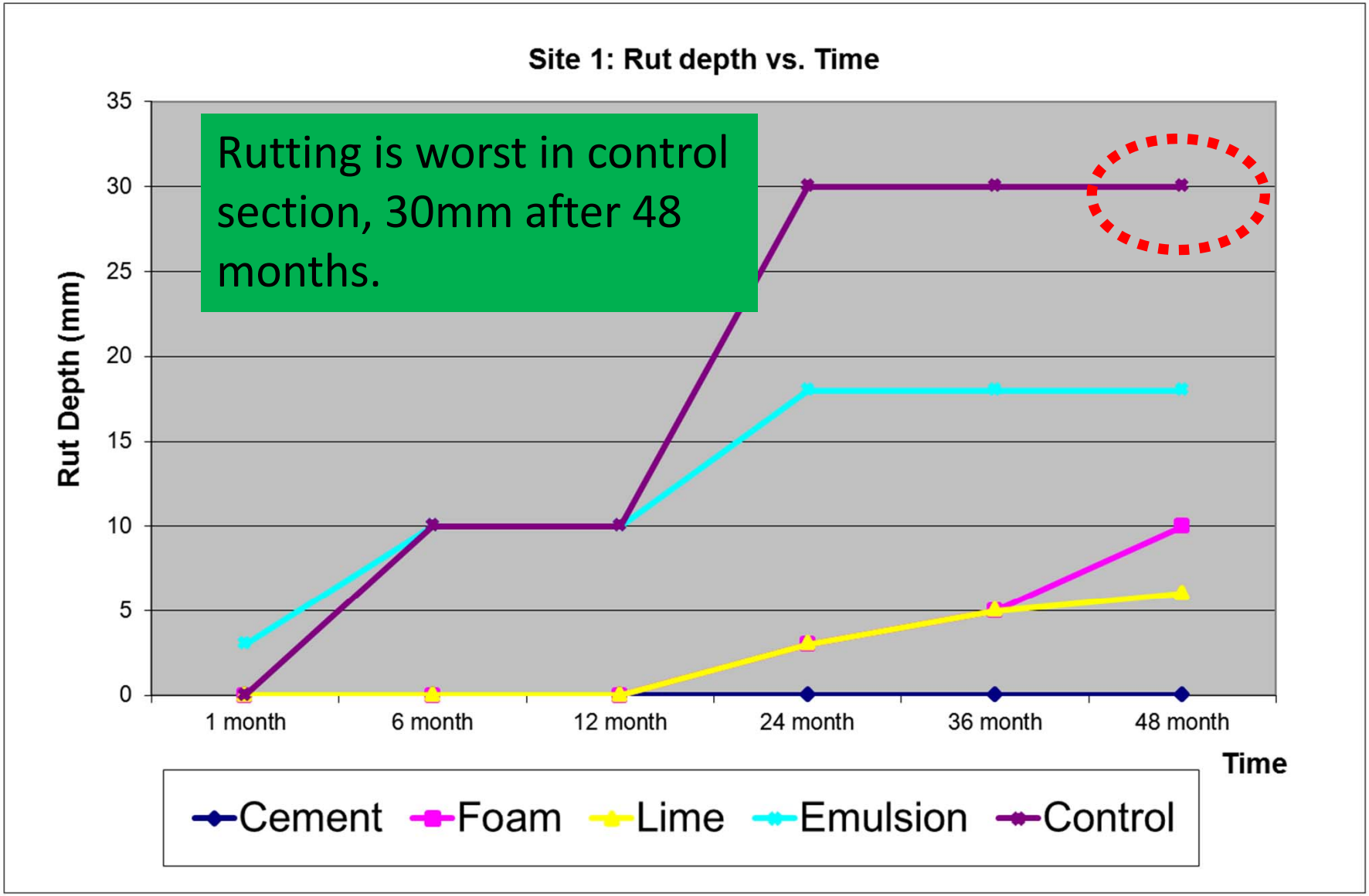
Crack – Site 1


Site 1: Crack % vs. Time
Little or no cracks in lime, foam and cement sections after 48 months.
Crack Percentage, %
25
20
15
10
5
0
1 month
6 month
12 month
24 month
36 month
48 month
Time
Cement
Foam
Lime
Emulsion
Control

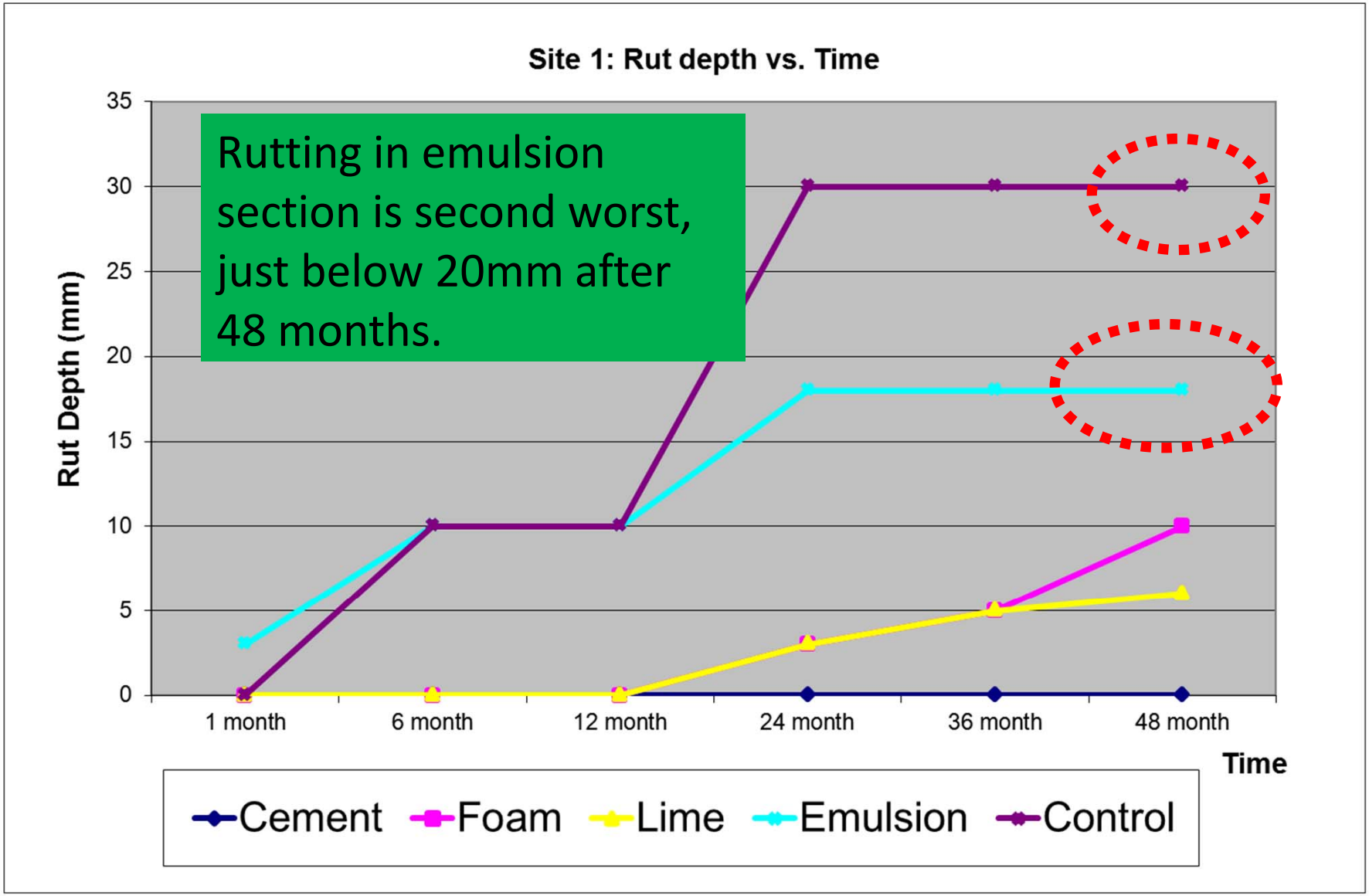
Rut – Site 1


Site 1: Rut depth vs. Time
Rut Depth (mm)
35
30
25
20
15
10
5
0
1 month
6 month
12 month
24 month
36 month
48 month
Time
Cement
Foam
Lime
Emulsion
Control

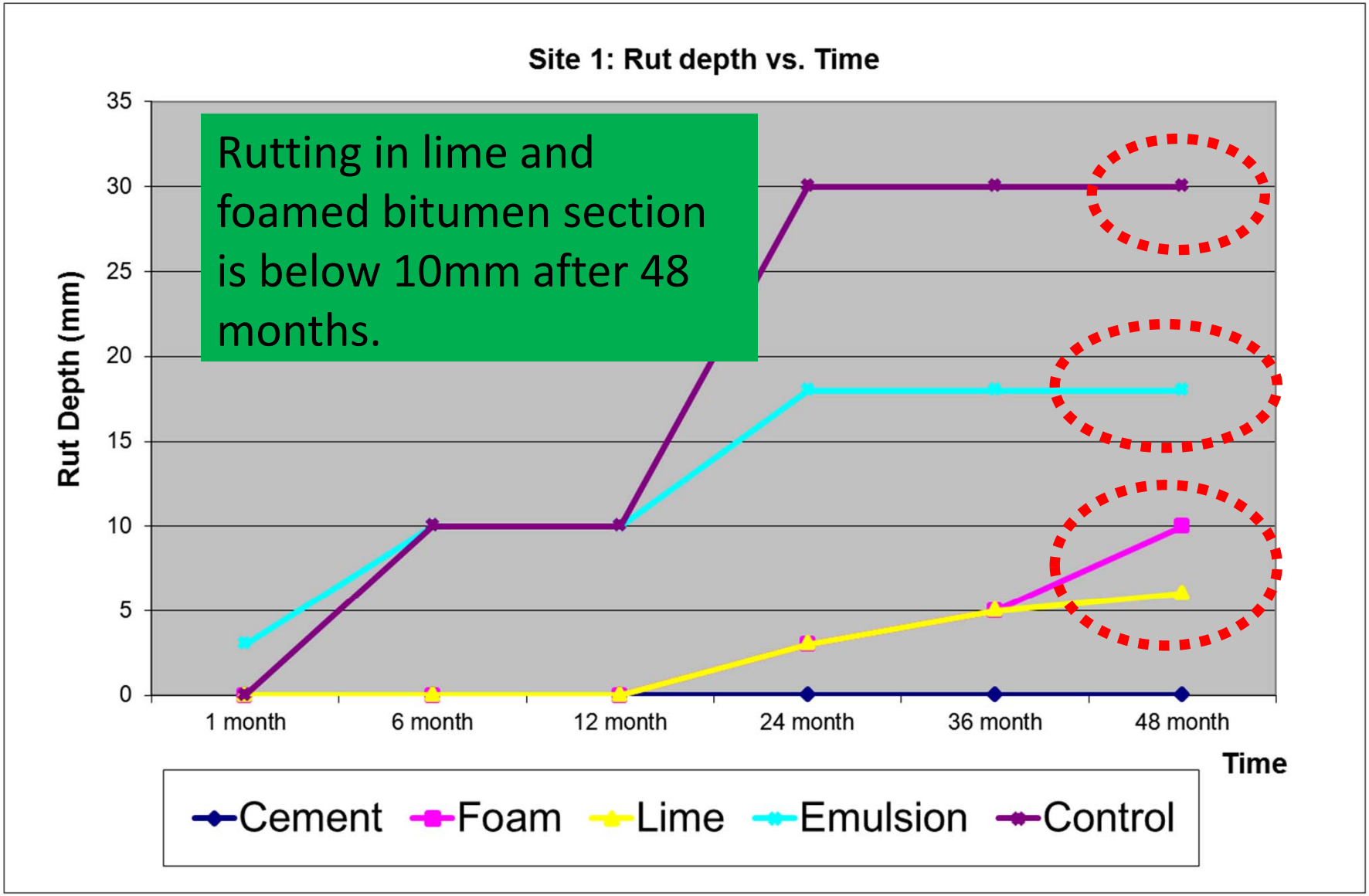
Rut – Site 1


Site 1: Rut depth vs. Time
Rutting is worst in control section, 30mm after 48 months.
Rut Depth (mm)
35
30
25
20
15
10
5
0
1 month
6 month
12 month
24 month
36 month
48 month
Time
Cement
Foam
Lime
Emulsion
Control

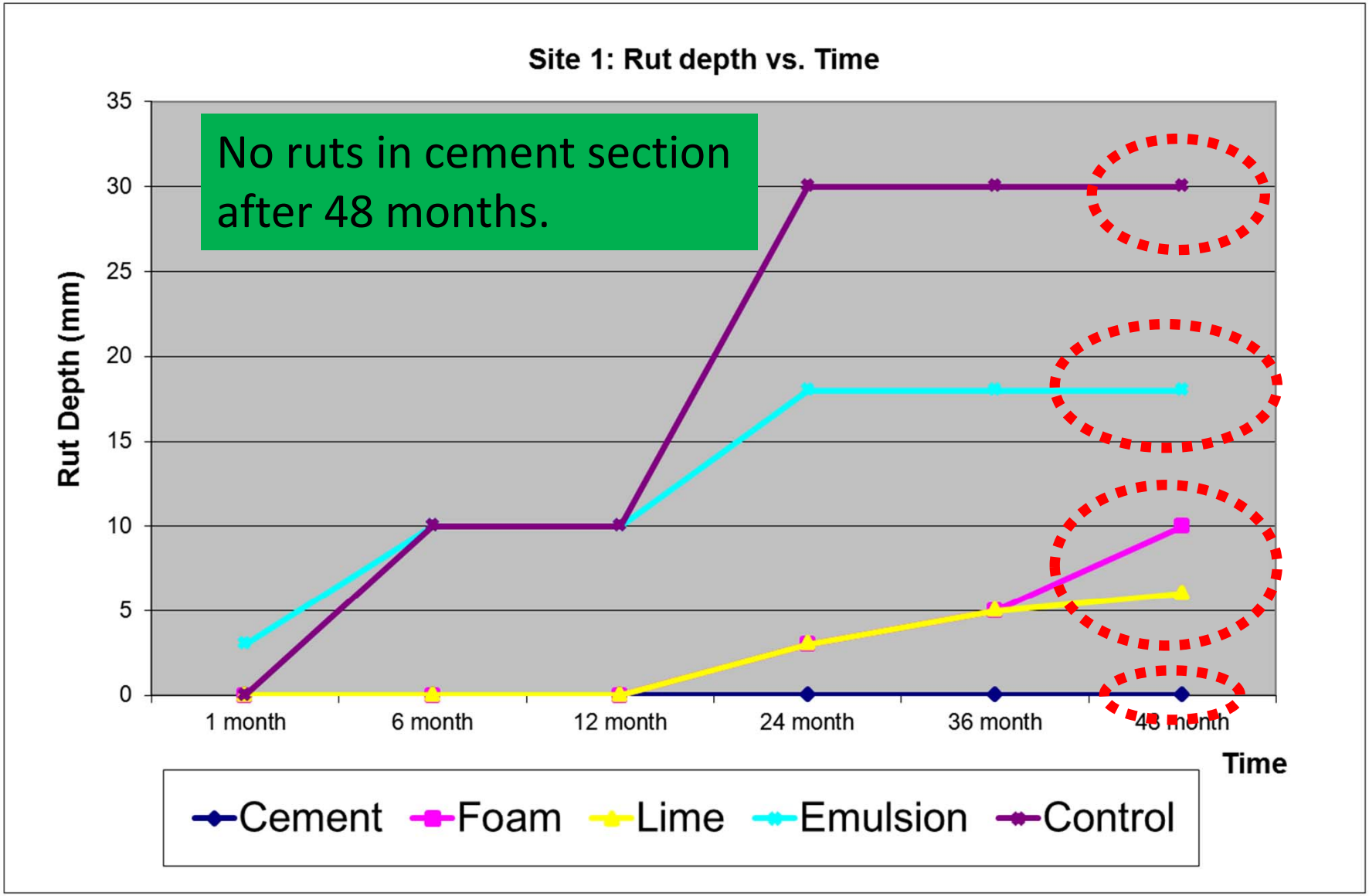
Rut – Site 1


Site 1: Rut depth vs. Time
Rutting in emulsion section is second worst, just below 20mm after 48 months.
Rut Depth (mm)
35
30
25
20
15
10
5
0
1 month
6 month
12 month
24 month
36 month
48 month
Time
Cement
Foam
Lime
Emulsion
Control

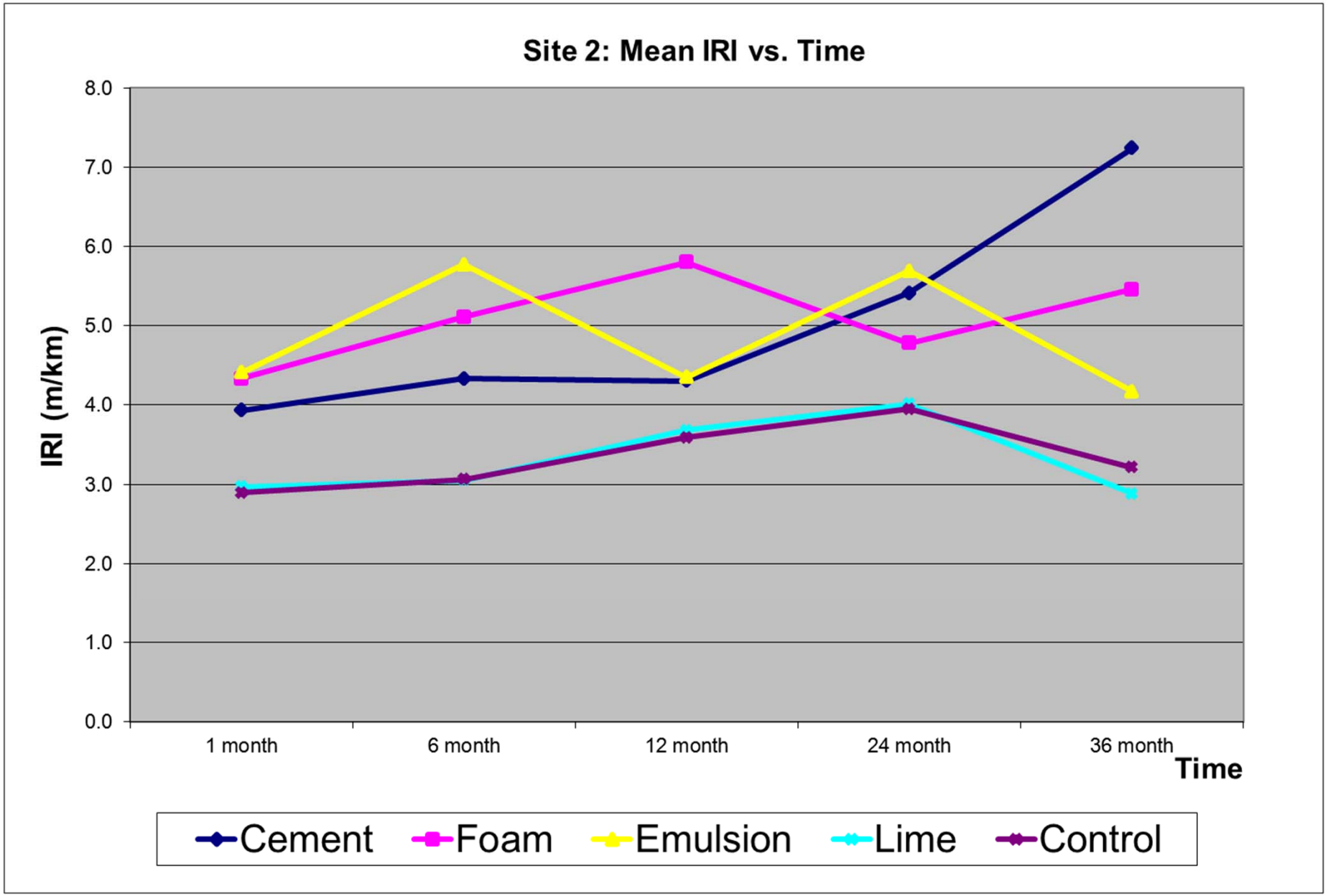
Rut – Site 1


Site 1: Rut depth vs. Time
Rutting in lime and foamed bitumen section is below 10mm after 48 months.
Rut Depth (mm)
35
30
25
20
15
10
5
0
1 month
6 month
12 month
24 month
36 month
48 month
Time
Cement
Foam
Lime
Emulsion
Control

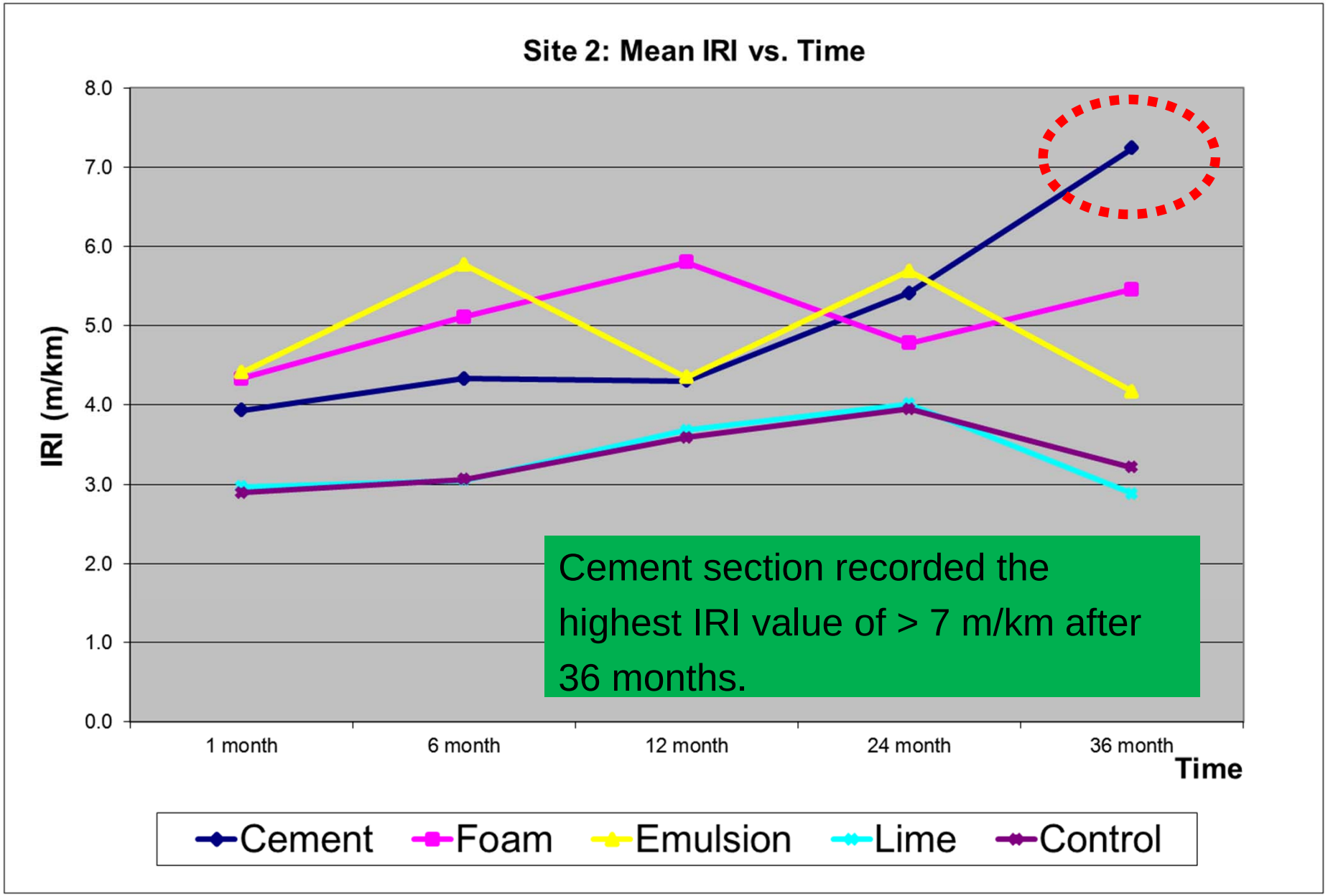
Rut – Site 1


Site 1: Rut depth vs. Time
No ruts in cement section after 48 months.
Rut Depth (mm)
35
30
25
20
15
10
5
0
1 month
6 month
12 month
24 month
36 month
48 month
Time
Cement
Foam
Lime
Emulsion
Control

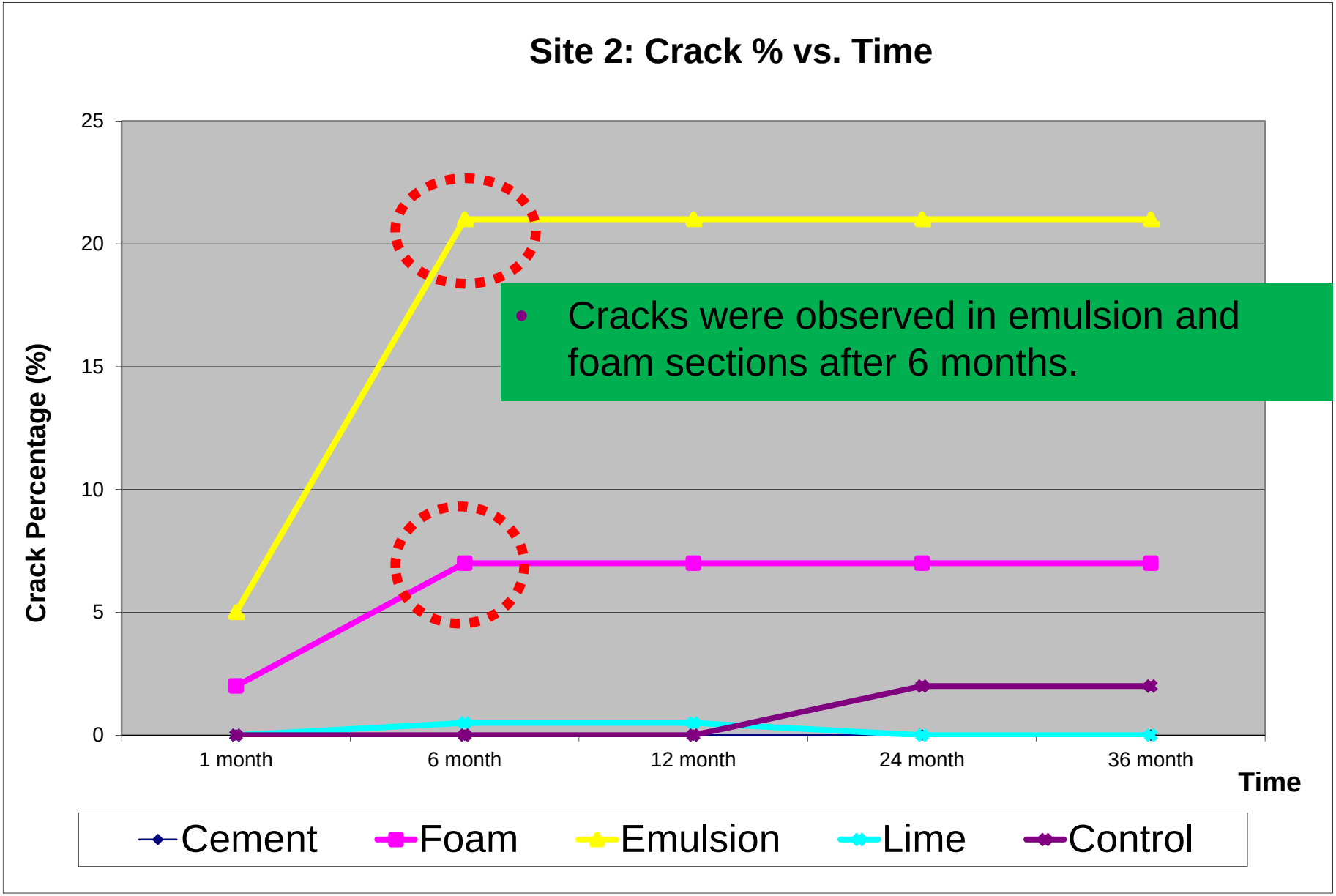
International Roughness Index (IRI) – Site 2



International Roughness Index (IRI) – Site 2

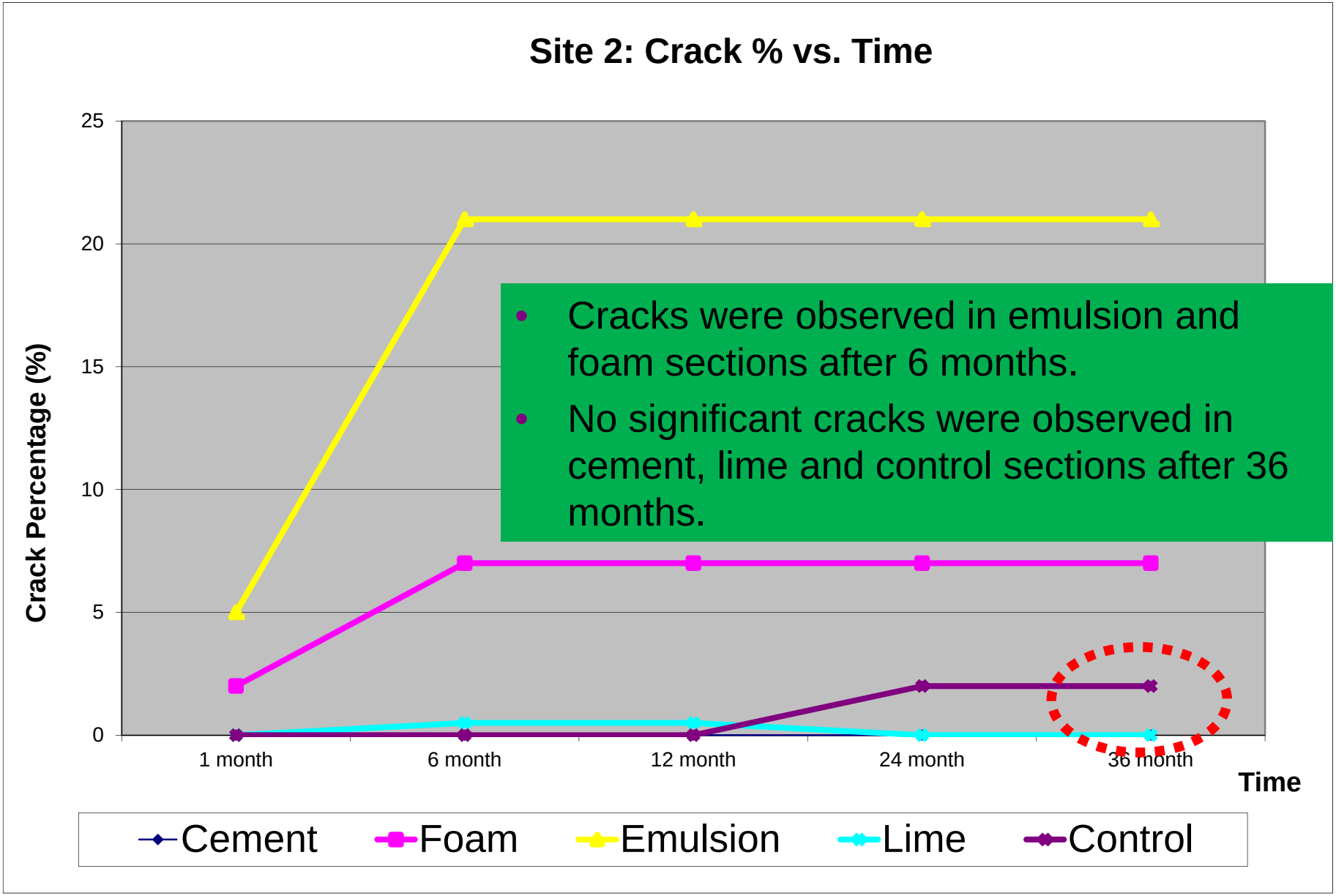


Crack – Site 2



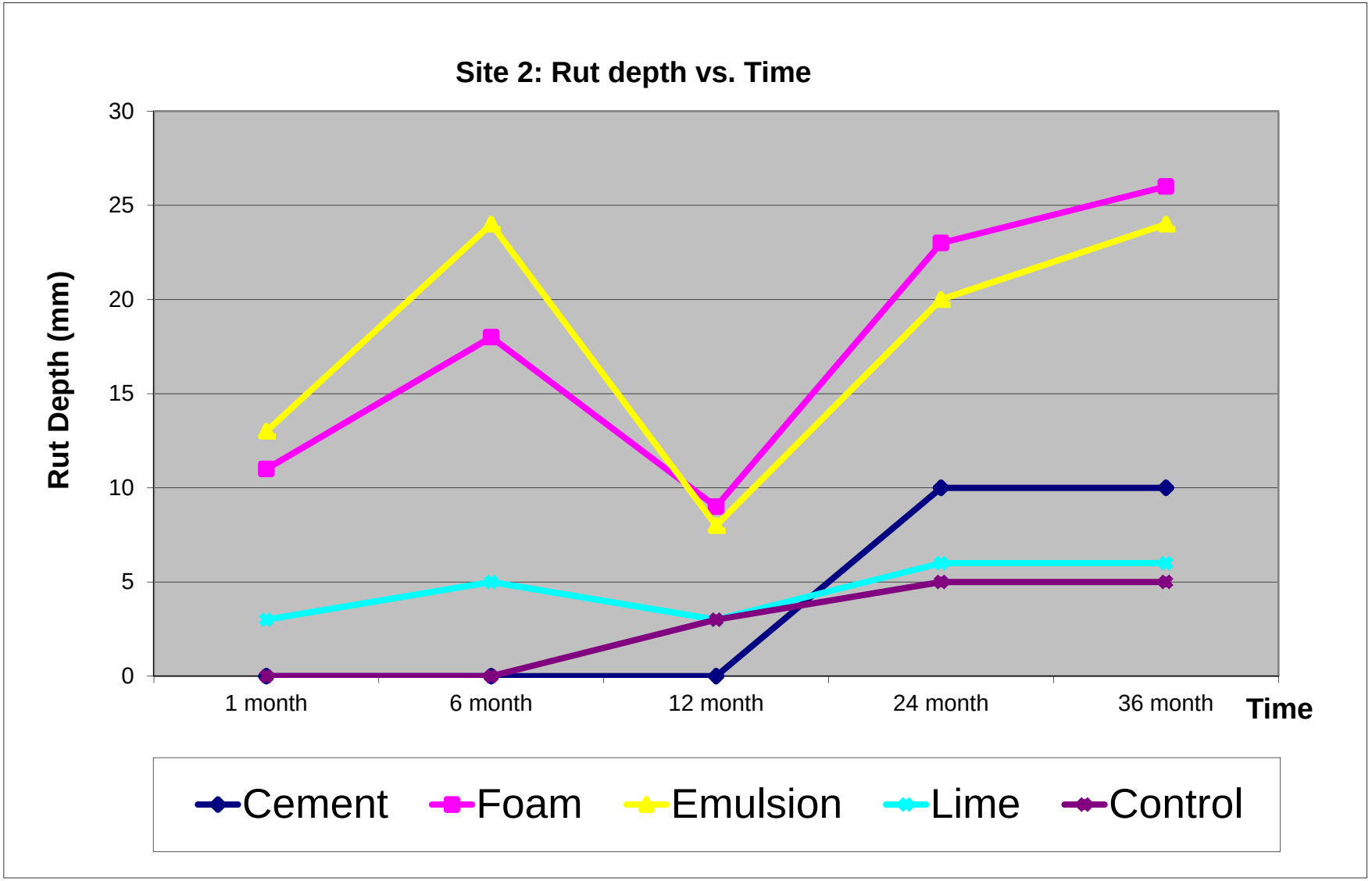
- Cracks were observed in emulsion and foam sections after 6 months.

Crack – Site 2

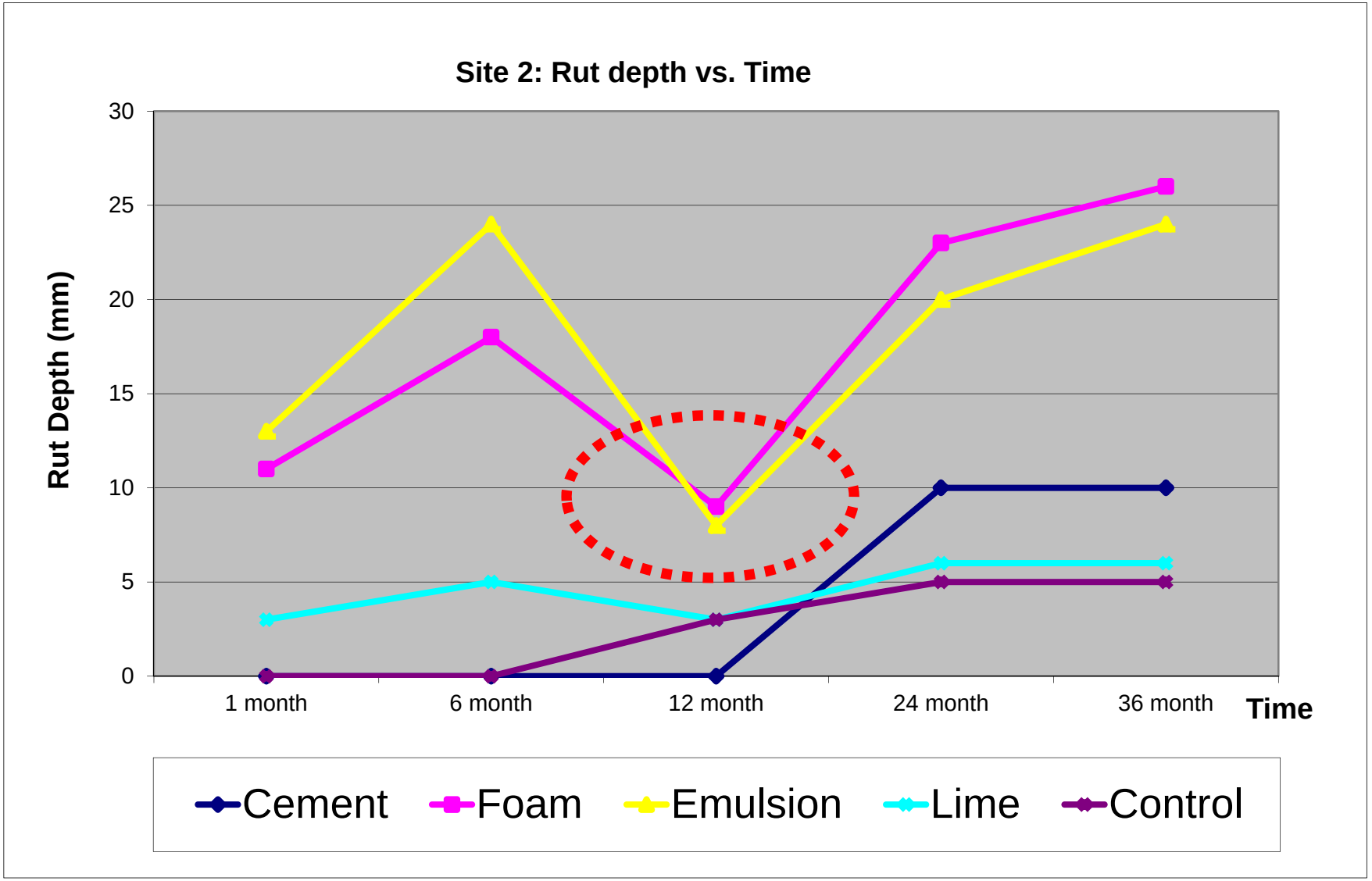


- Cracks were observed in emulsion and foam sections after 6 months.
- No significant cracks were observed in cement, lime and control sections after 36 months.

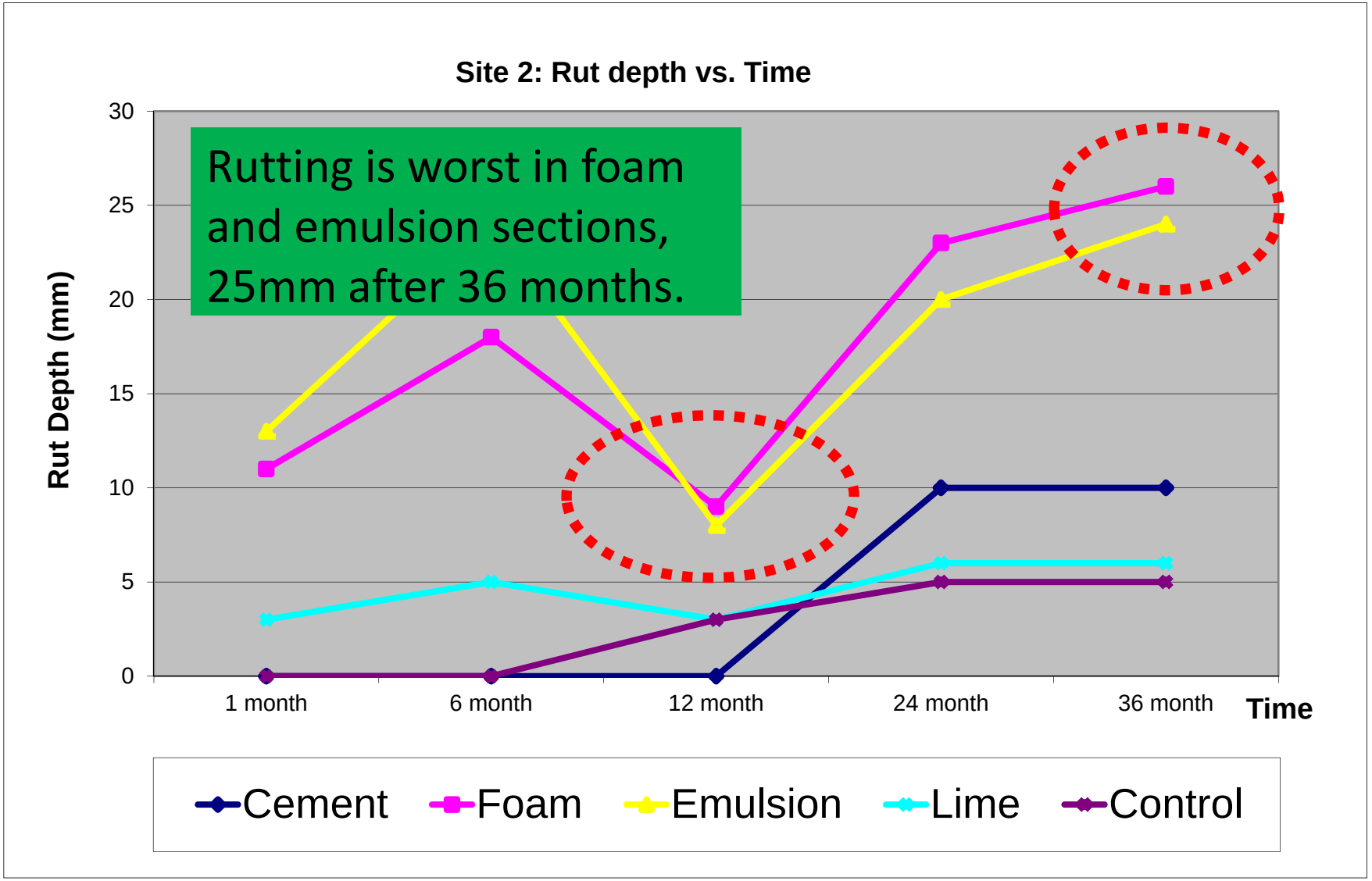
Rut – Site 2


Site 2: Rut depth vs. Time
Rut Depth (mm)
30
25
20
15
10
5
0
1 month
6 month
12 month
24 month
36 month
Time
Cement
Foam
Emulsion
Lime
Control

Rut – Site 2


Site 2: Rut depth vs. Time
Rut Depth (mm)
30
25
20
15
10
5
0
1 month
6 month
12 month
24 month
36 month
Time
Cement
Foam
Emulsion
Lime
Control

Rut – Site 2


Site 2: Rut depth vs. Time
Rutting is worst in foam and emulsion sections, 25mm after 36 months.
Rut Depth (mm)
30
25
20
15
10
5
0
1 month
6 month
12 month
24 month
36 month
Time
Cement
Foam
Emulsion
Lime
Control

Site 2: After 6 months

Cement section

Emulsion section

Foam section

Lime section

Control section

Control section

Site 2: After 6 months - Defects

Foam section

Foam section

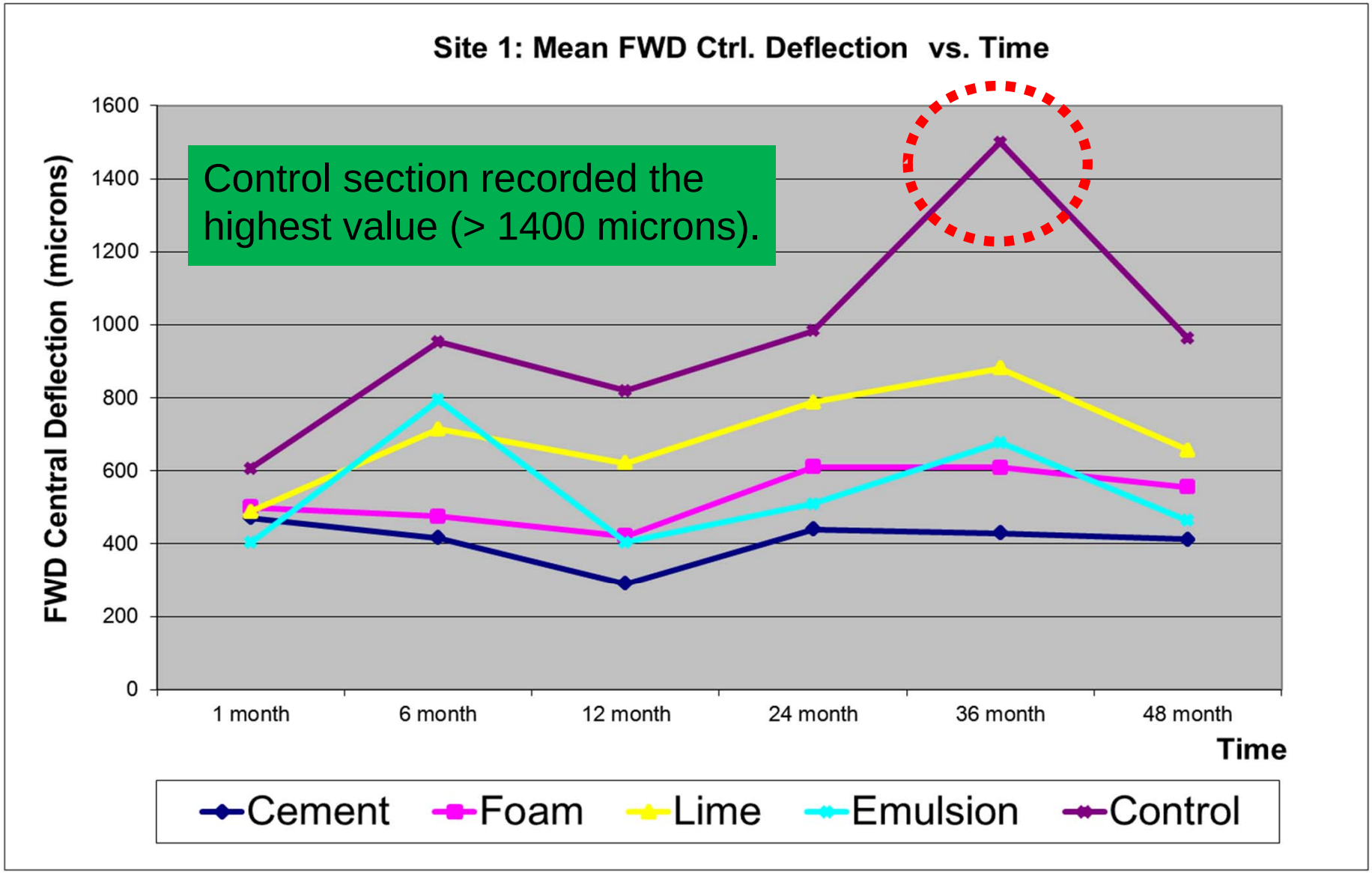
Emulsion section

Lime section

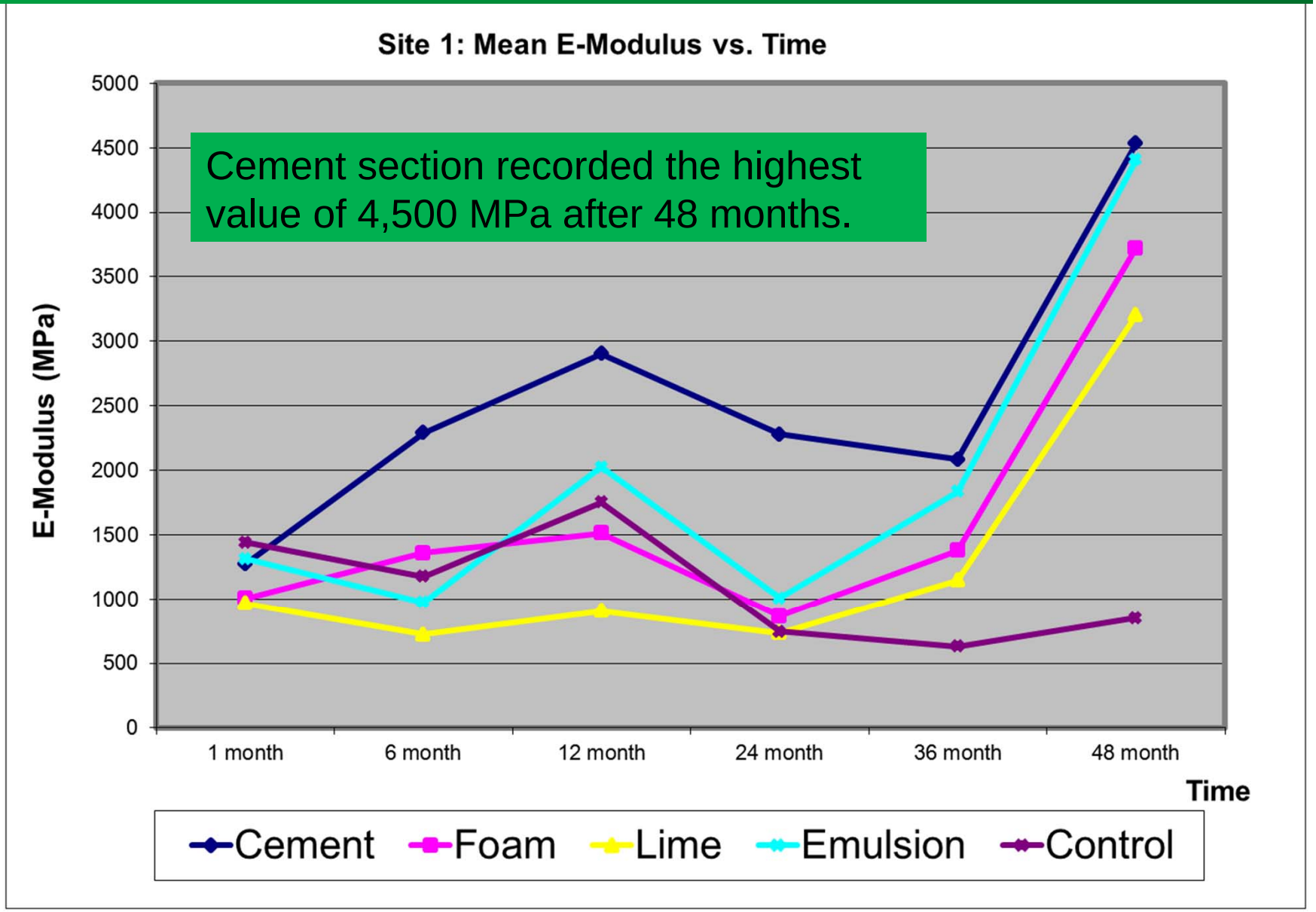
Lime section

Emulsion section

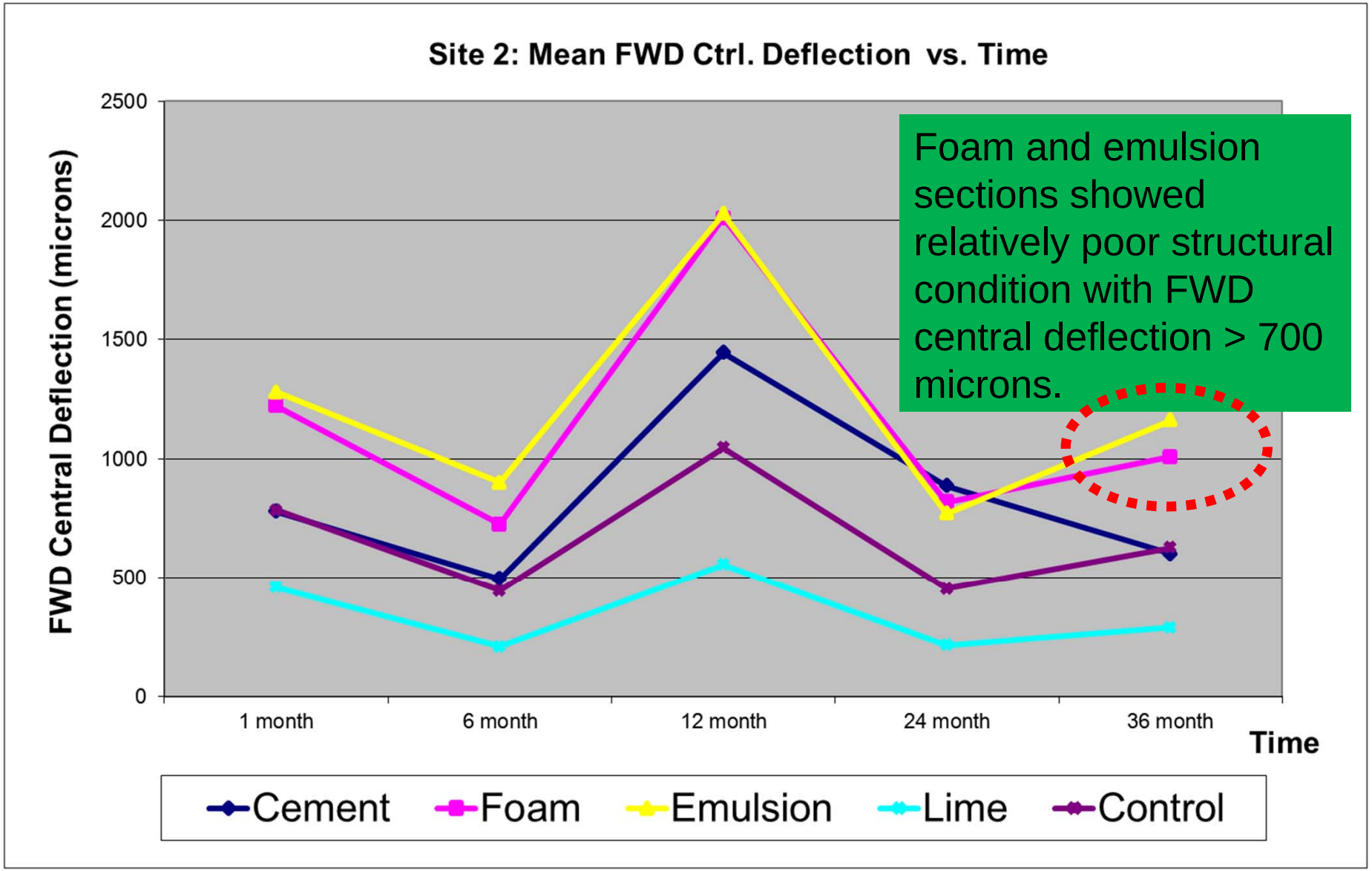
FWD Central Deflection – Site 1



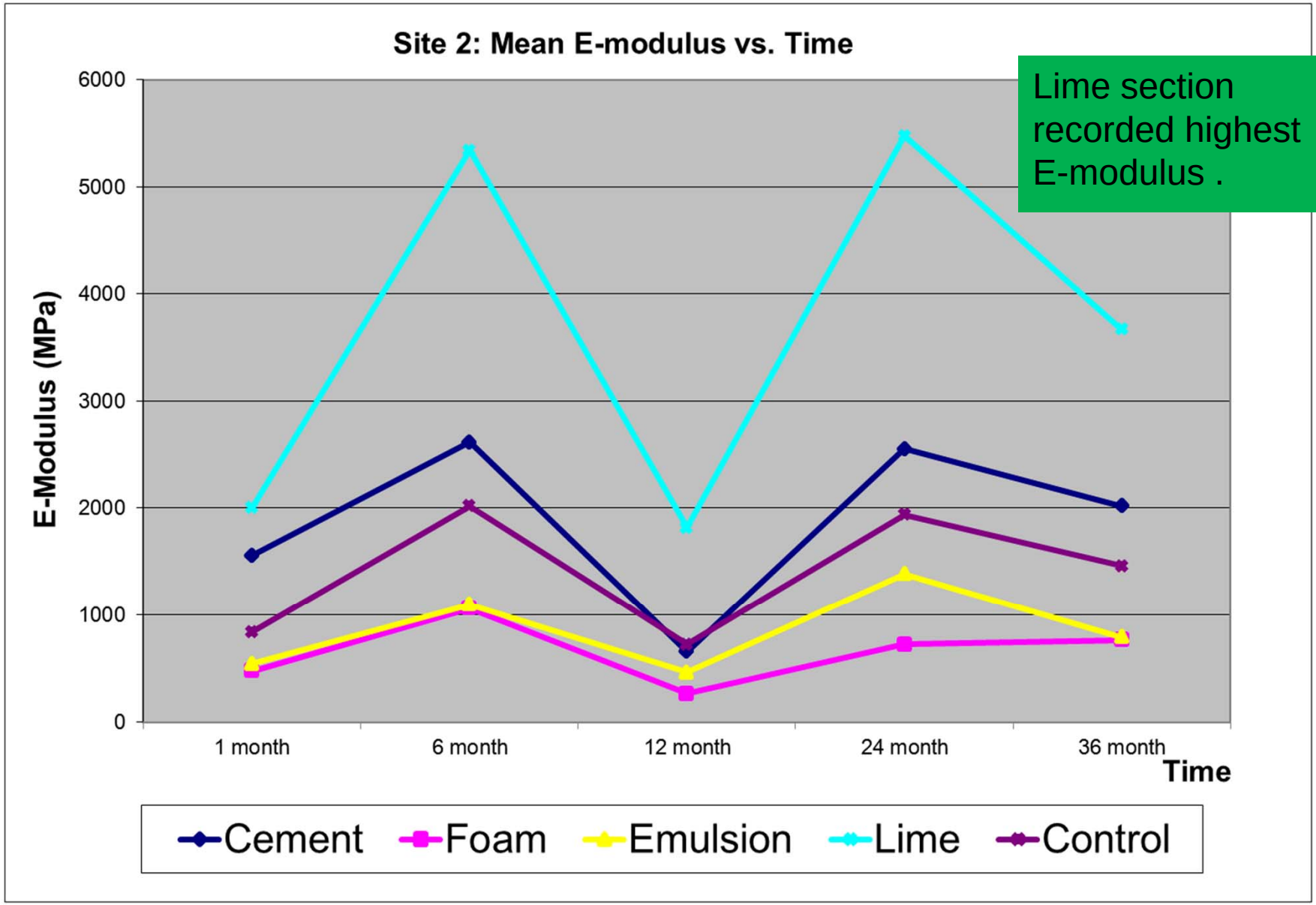
E-Modulus – Site 1



FWD Central Deflection – Site 2

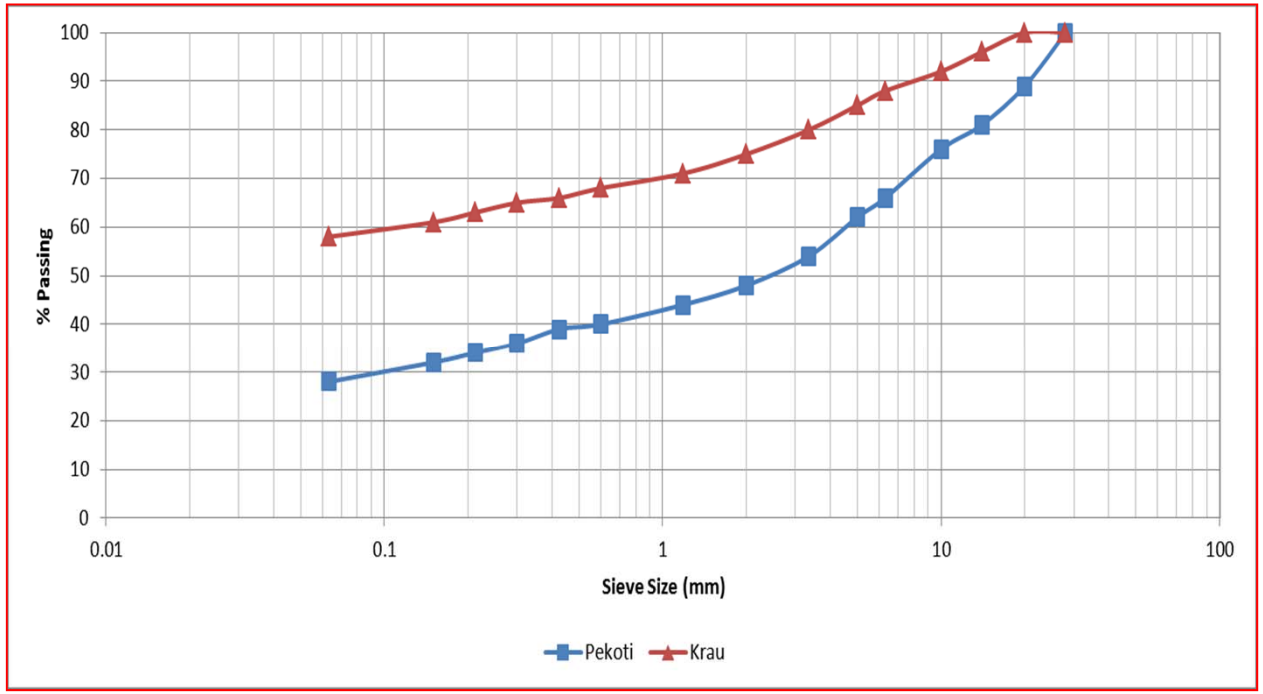


E-Modulus – Site 2



Lime section recorded highest E-modulus .

Grading & Atterberg Limits



Clay/silt content > 55% for Site 2.

Site	Atterberg Limits			Sieve Analysis (%)			
	LL	PL	PI	Clay	Silt	Sand	Gravel
1	42	22	20	28		20	52
2	43	23	20	58		17	25

PI = 20 for both sites (clayey soils susceptible to moisture).

Comparison between designed mix & field samples

SITE 1 - PEKOTI

Stabilizer	OBC/BC (%)	
	Lab	Field
Cement	-	-
Foamed	3.5	2.2
Lime	-	-
Emulsion	6.0	5.3

SITE 2 - KRAU

Stabilizer	OBC/BC (%)	
	Lab	Field
Cement	-	-
Foamed	4.0	3.0
Lime	-	-
Emulsion	6.0	6.6

Comparison between designed mix & field samples

SITE 1 - PEKOTI

Stabilizer	OMC/MC (%)	
	Lab	Field
Cement	5.5	8.4
Foamed	5.6	9.2
Lime	5.3	9.3
Emulsion	5.3	9.6

SITE 2 - KRAU

Stabilizer	OMC/MC (%)	
	Lab	Field
Cement	8.5	10.2
Foamed	8.5	8.6
Lime	8.5	7.6
Emulsion	8.5	6.7

Comparison between designed mix & field samples

SITE 1 - PEKOTI

Stabilizer	ITS (kPa)	
	Lab	Field
Cement	-	-
Foamed	582	315
Lime	-	-
Emulsion	372	350

SITE 2 - KRAU

Stabilizer	ITS (kPa)	
	Lab	Field
Cement	-	-
Foamed	218	238
Lime	-	-
Emulsion	269	188

Comparison between designed mix & field samples

SITE 1 - PEKOTI

Stabilizer	ITS (kPa)	
	Lab	Field
Cement	-	-
Foamed	582	315
Lime	-	-
Emulsion	372	350

SITE 2 - KRAU

Stabilizer	ITS (kPa)	
	Lab	Field
Cement	-	-
Foamed	218	238
Lime	-	-
Emulsion	269	188

> 200 kPa (cured @ 40 ºC for 72 hours)

Comparison between designed mix & field samples

SITE 1 - PEKOTI

Stabilizer	UCS (MPa)	
	Lab	Field
Cement	3.7	3.9
Foamed	3.6	5.7
Lime	2.3	2.4
Emulsion	2.0	2.4

SITE 2 - KRAU

Stabilizer	UCS (MPa)	
	Lab	Field
Cement	2.2	2.3
Foamed	1.1	1.3
Lime	2.0	2.2
Emulsion	1.1	0.9

Comparison between designed mix & field samples

SITE 1 - PEKOTI

Stabilizer	UCS (MPa)	
	Lab	Field
Cement	3.7	3.9
Foamed	3.6	5.7
Lime	2.3	2.4
Emulsion	2.0	2.4

SITE 2 - KRAU

Stabilizer	UCS (MPa)	
	Lab	Field
Cement	2.2	2.3
Foamed	1.1	1.3
Lime	2.0	2.2
Emulsion	1.1	0.9

2 – 5 MPa (7 day strength, moist curing @ 25 ºC)

Comparison between designed mix & field samples

SITE 1 - PEKOTI

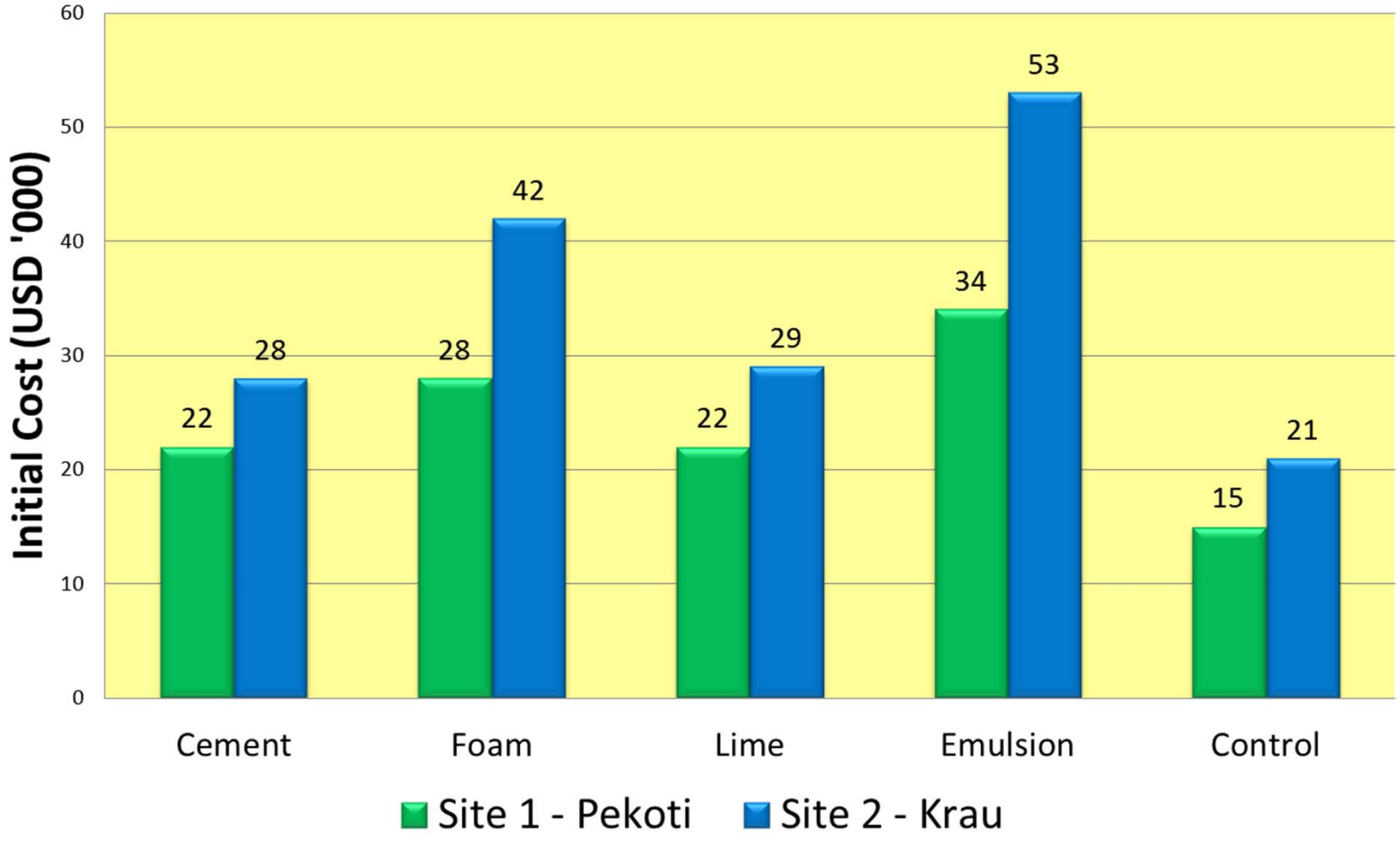
Stabilizer	UCS (MPa)	
	Lab	Field
Cement	3.7	3.9
Foamed	3.6	5.7
Lime	2.3	2.4
Emulsion	2.0	2.4

SITE 2 - KRAU

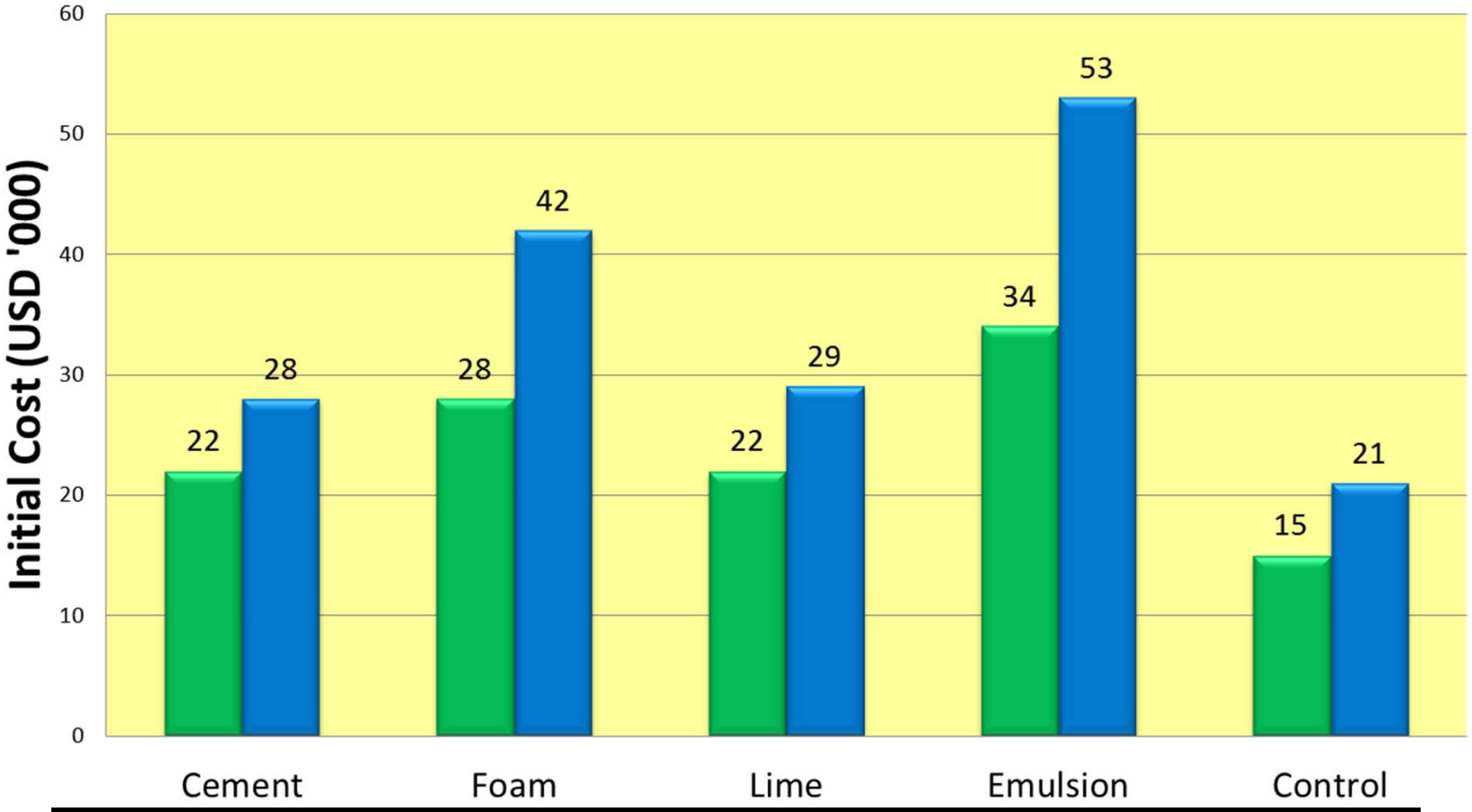
Stabilizer	UCS (MPa)	
	Lab	Field
Cement	2.2	2.3
Foamed	1.1	1.3
Lime	2.0	2.2
Emulsion	1.1	0.9

> 0.7 MPa (7 day strength, moist curing @ 25 °C)

Comparison of initial construction cost

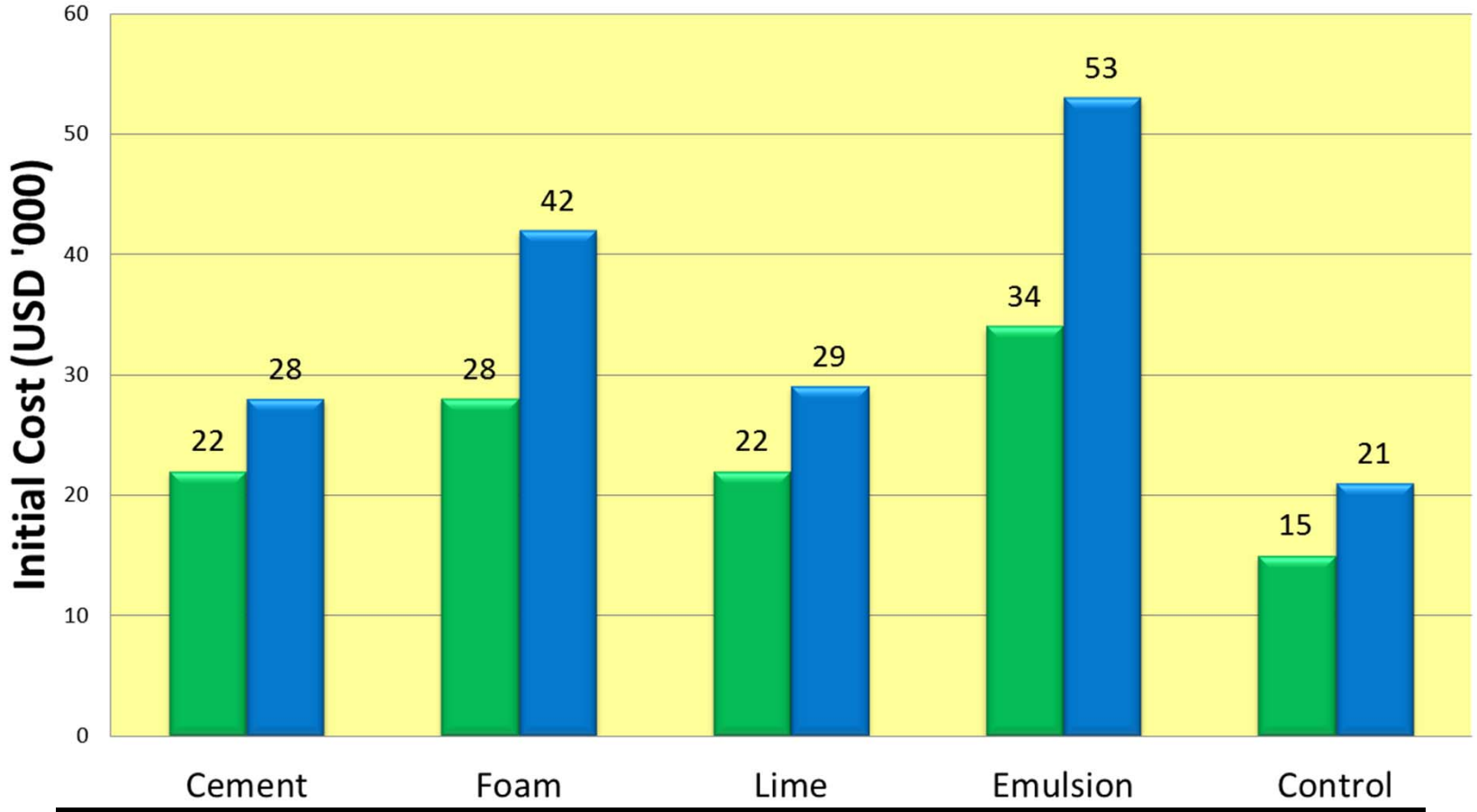


Comparison of initial construction cost



Foam and emulsion are 100% more expensive

Comparison of initial construction cost



Cement and lime are 40% more expensive

Conclusion

1) The functional and structural performances of **cement** and **lime** sections are satisfactory or better than that of the conventionally rehabilitated pavements.

2) **Foamed bitumen** and **emulsion** sections are the weakest CIPR pavements on marginal materials based on functional and structural conditions. More thorough studies are proposed to gain understanding of the impact on the performance of bituminous stabilizers on marginal materials.

Conclusion

3) The need to conduct standard material laboratory test is crucial to prove the effectiveness of the stabilizing agents/treatment options on a particular soil/gravel type.

4) The adoption of best construction quality practice is important if optimum performance of the in-situ stabilized marginal material is to be achieved. Controlled curing and monitoring the level of moisture/bitumen contents is vital to ensure the pavement performed satisfactorily.

5) Good drainage is vital to ensure satisfactory performance of pavement structures.

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THANK YOU