N1/1 UTCRCP PERFORMANCE

(RPF November 2011)

G VAN ZYL

Background

- UTCRCP – First Large Scale Experiment (4.3km)
- Construction : Aug 2009 – Feb 2010
- Attention to detail (Design, & Construction)
- First observed failures (2 at Intermediate Joints)
- Two “Pop-outs” (Buckling) after a year
- Monitoring
- Other distress/ small failures
- Temporary repairs

Design

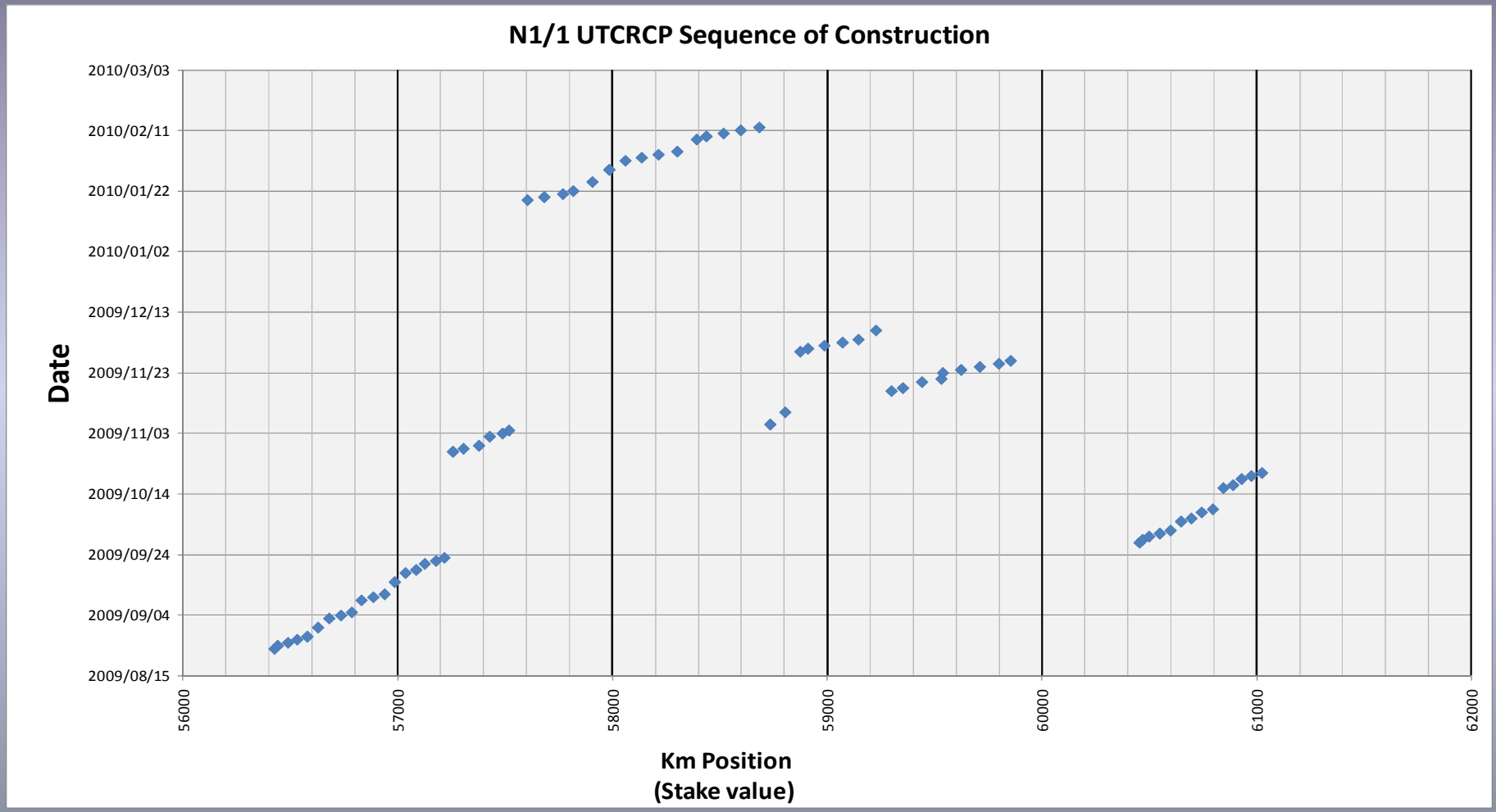
- **Sand – grading selection**
- **Trial mixes (Hornfels aggregate)**
  - Sands
  - W/C
  - Testing
- **Aggregate (Granite)**
  - Flakiness <10%
  - ALD>4mm
  - Testing
- **Trials & Process**

QA

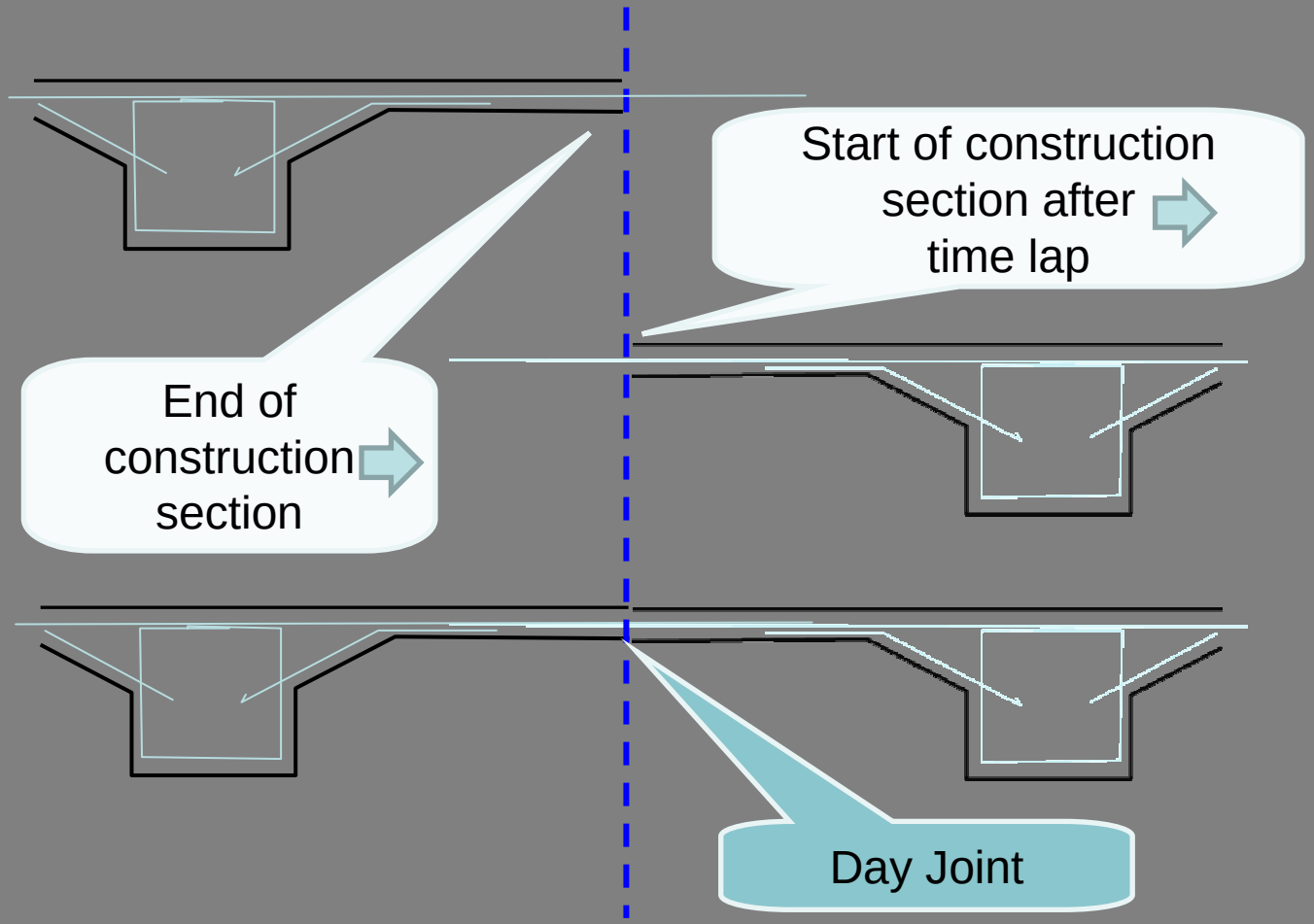
- Dry component mixing
- Dry bagging
- Temp monitoring
- Steel fixing
- Mixing
- Slump
- Cube preparation
- Compaction, finishing, tining & curing
- Compressive strength testing

First observed distress

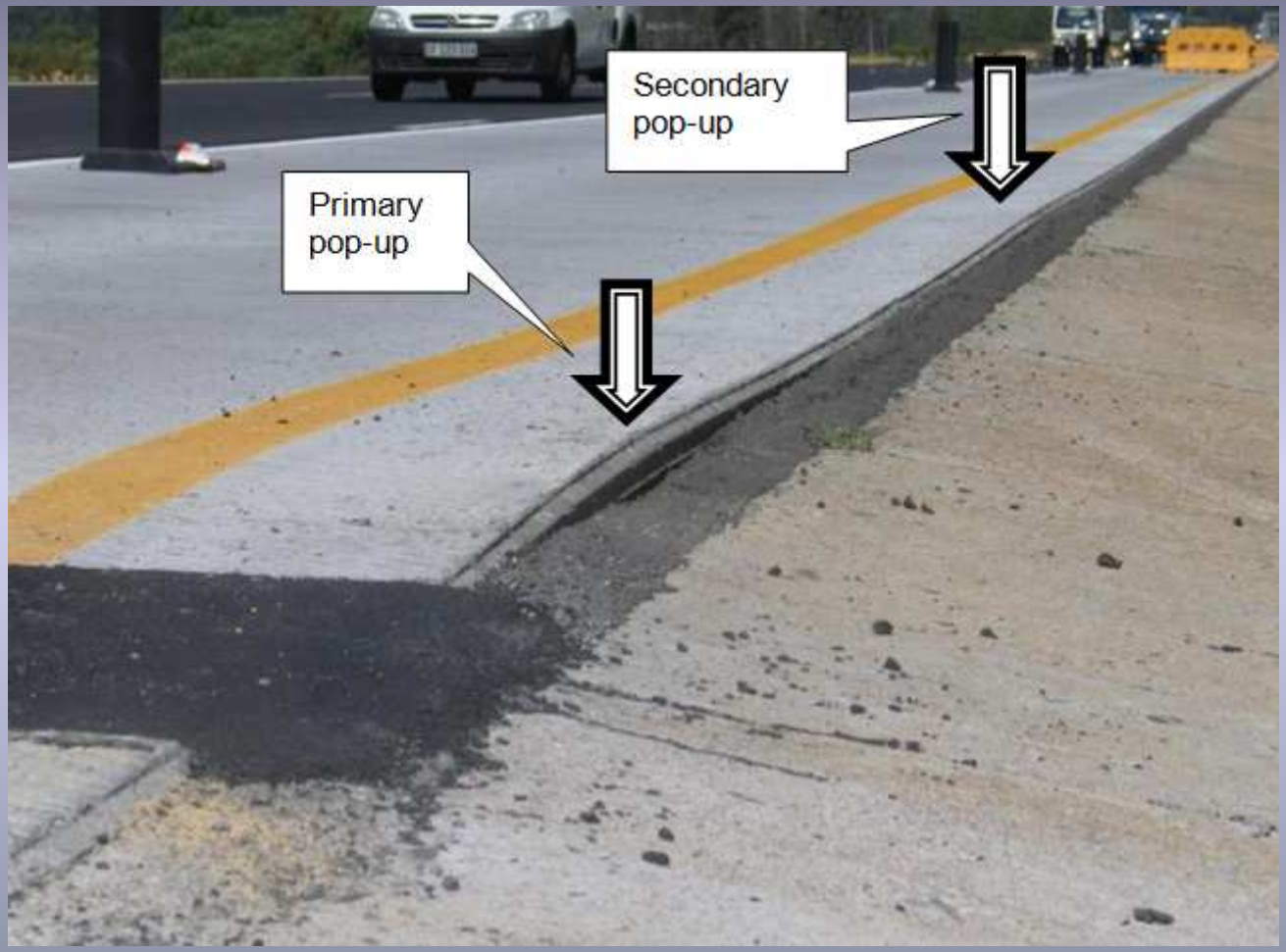
Construction sequence



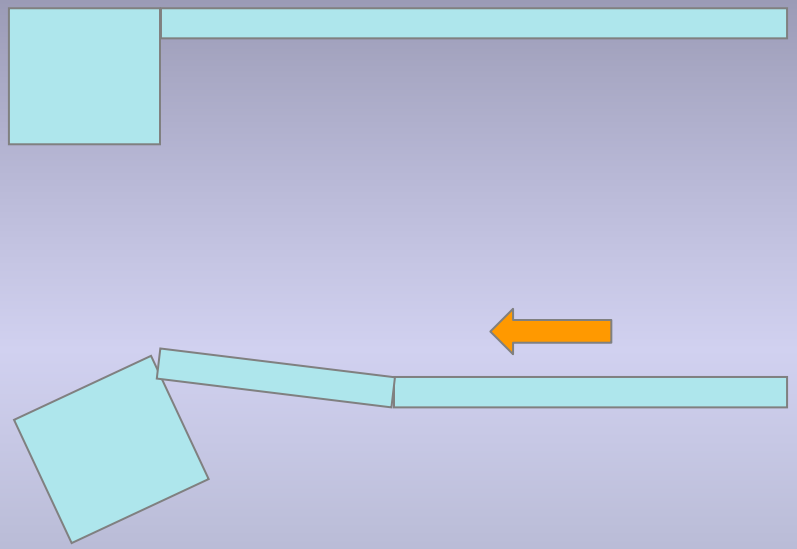
Intermediate beams



Failure & Repair


Secondary
pop-up
Primary
pop-up

After a year (next summer)



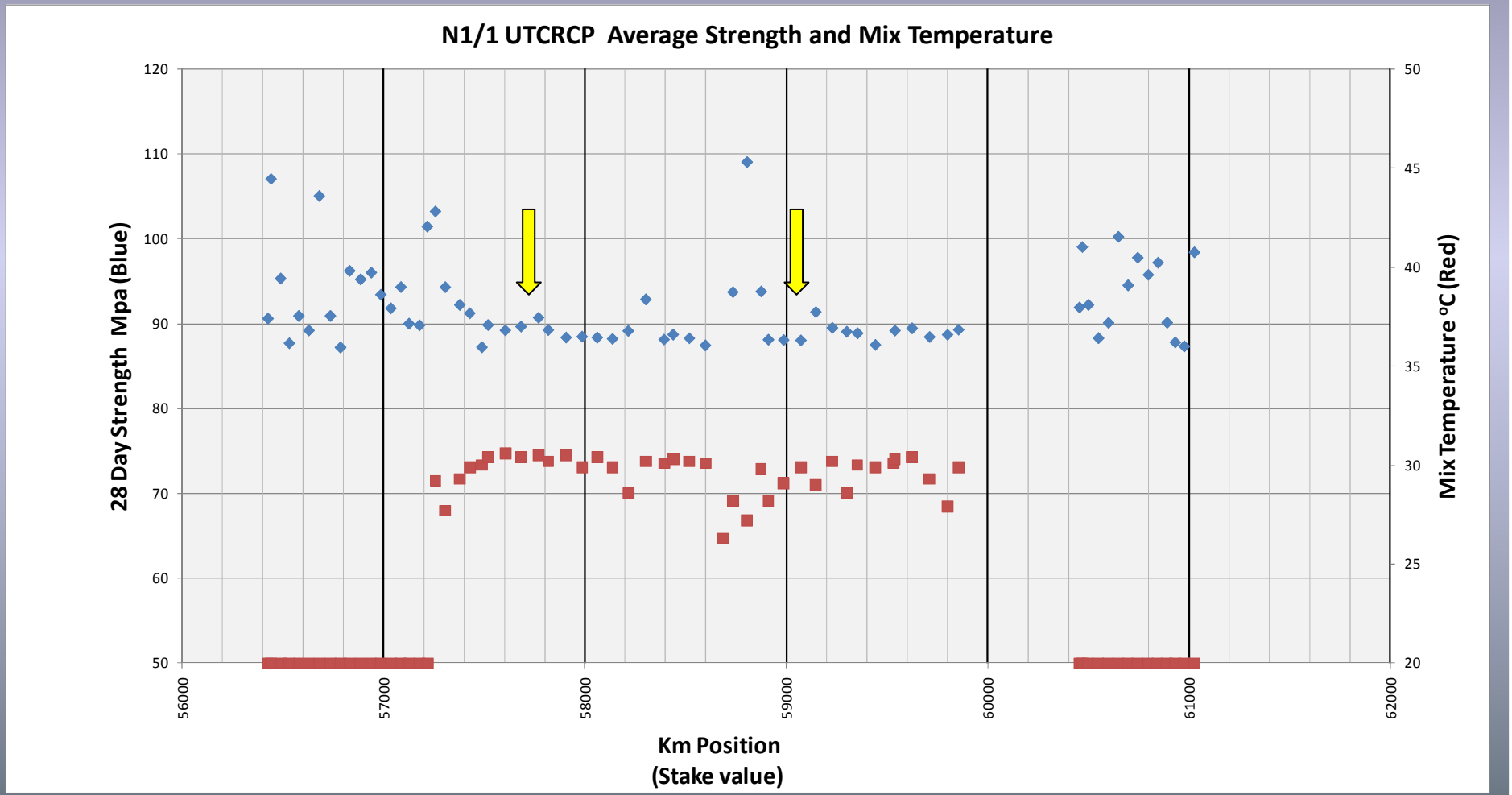
Main Defect: Buckling

- **21/12/2010**

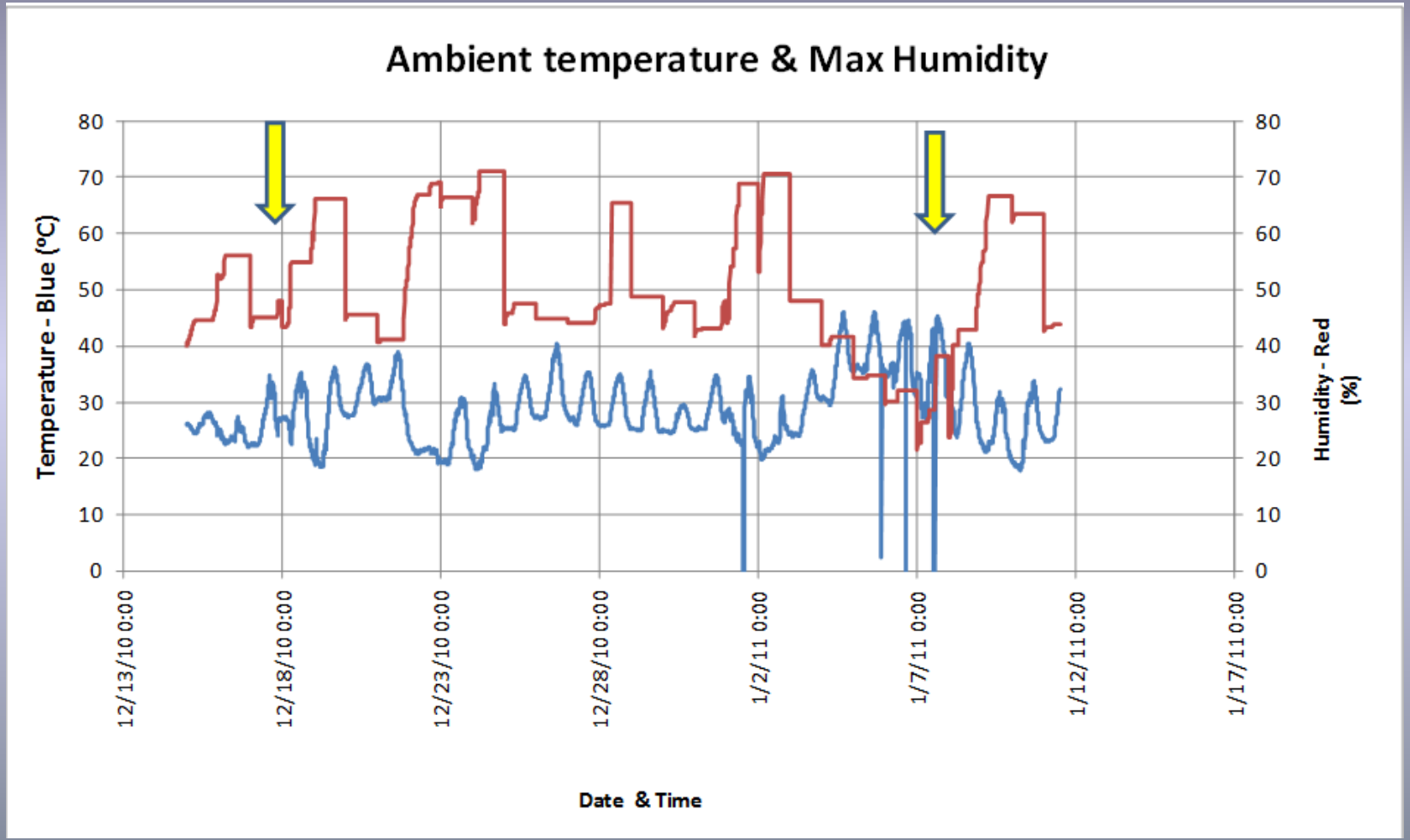
Buckling

- 7/1/2011

Information available



Buckling

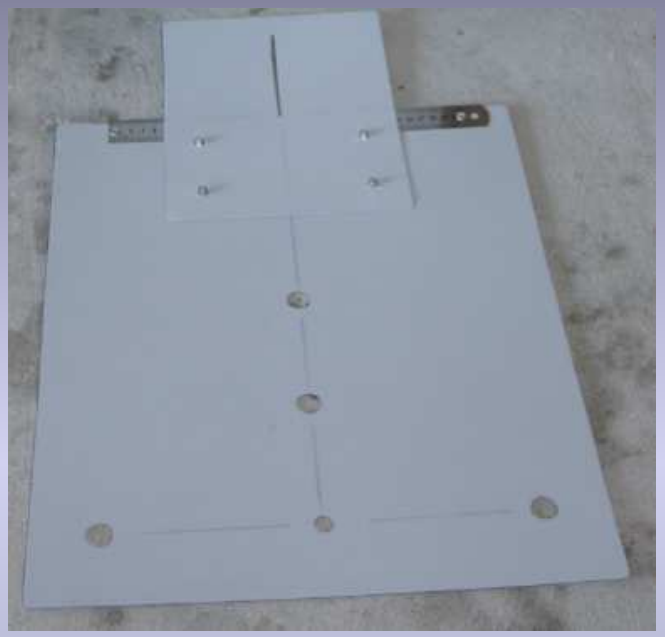

Ambient temperature & Max Humidity
Temperature - Blue (°C)
Humidity - Red (%)
80
70
60
50
40
30
20
10
0
12/13/10 0:00
12/18/10 0:00
12/23/10 0:00
12/28/10 0:00
1/2/11 0:00
1/7/11 0:00
1/12/11 0:00
1/17/11 0:00
Date & Time

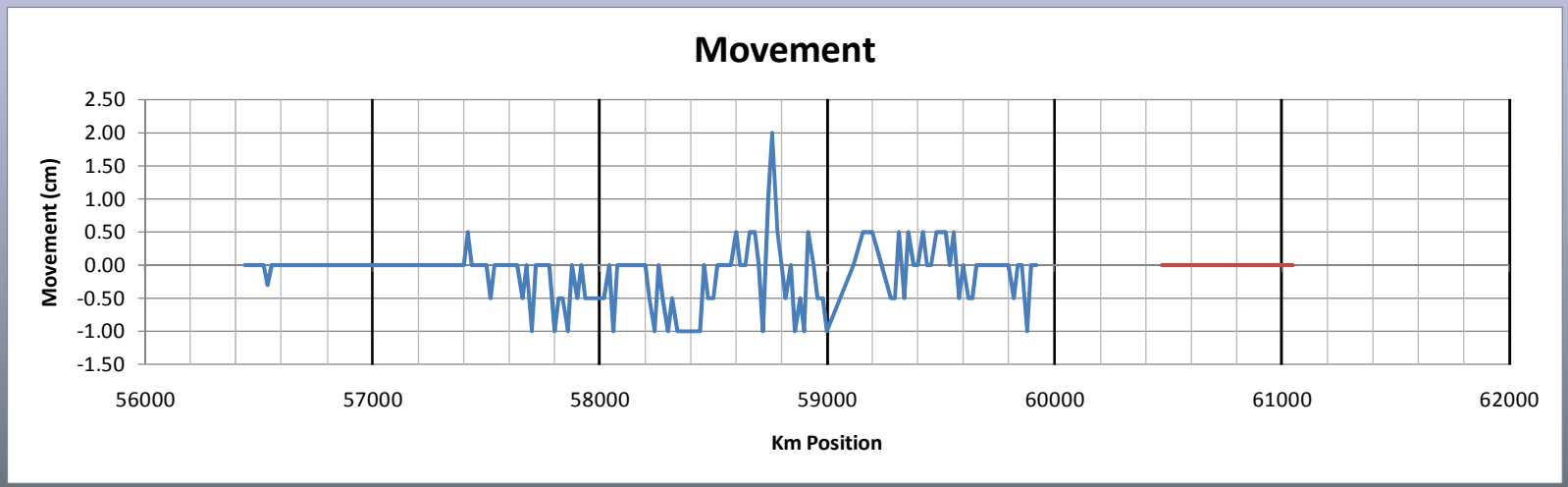
Repair

- Cut
- Mod AC
- 50mm Exp joint
- Fill Viaseal

Monitoring

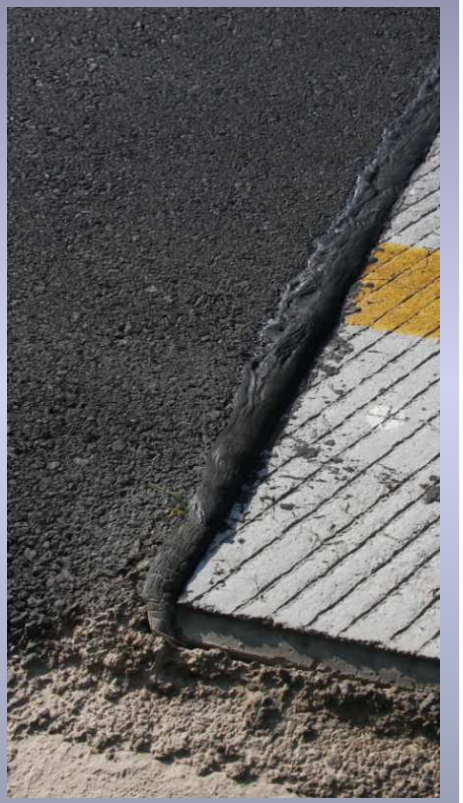
- Continuous (Temperature, Humidity, Wind)
- 24 hour – drive through (Tuncor)
- Horisontal movement study
- Detailed Hor & Vert Movement at “Cut”
- UCT Expansion tests
- Detailed visual assessment
- Profile Measurement

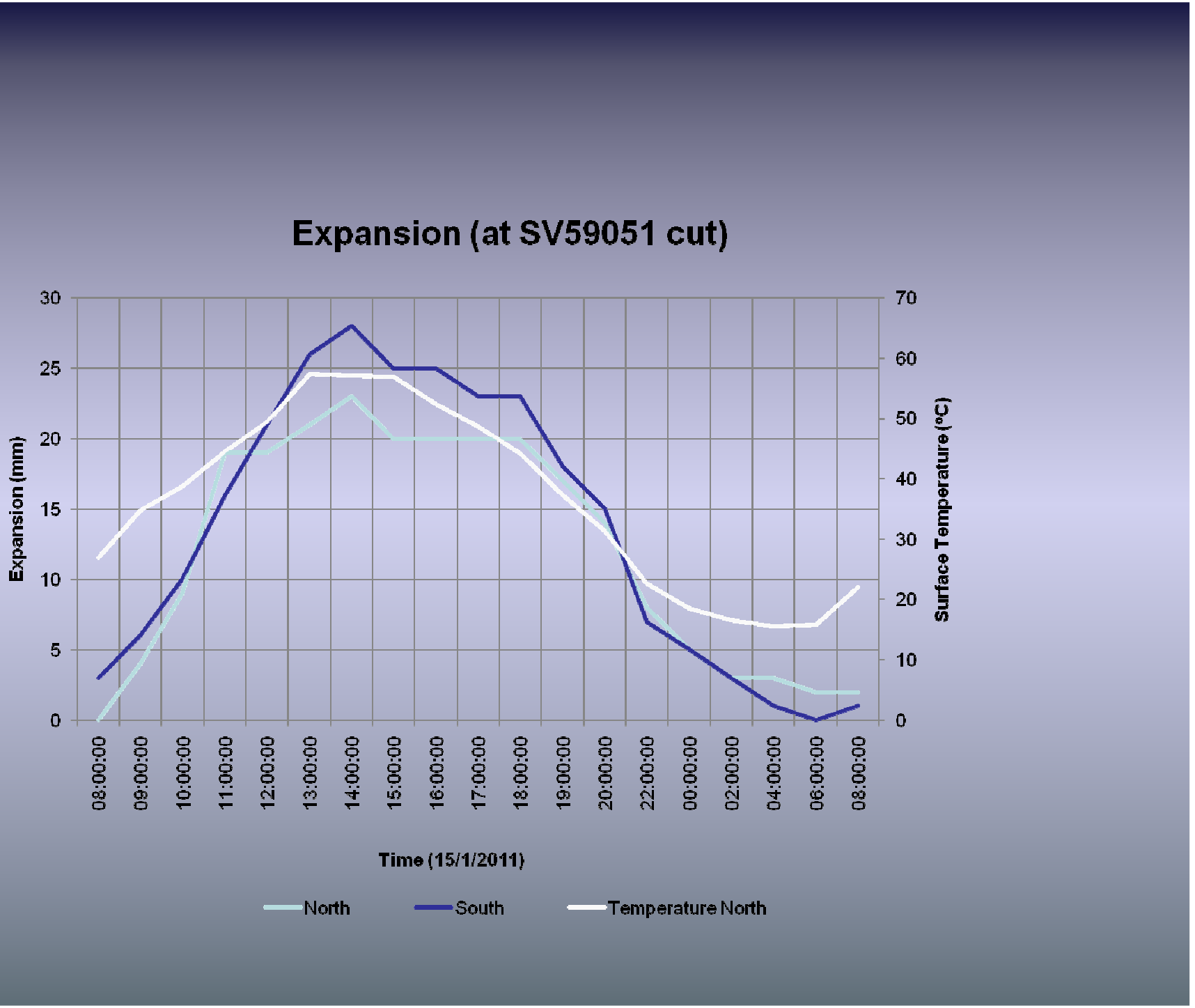



Movement
Movement (cm)
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
56000
57000
58000
59000
60000
61000
62000
Km Position

Temperature/ Expansion

km 59.051						
Time:	Surface Temperature: Concrete North	Surface Temperature: Concrete South	Surface Temperature: WC	Relative Movement: North (mm)	Relative Movement: South (mm)	Relative Movement: Overall (mm)
08:00	22.1	21.9	27.3	20	25	45
09:00	25.8	24.9	29.3	19	23	42
10:00	35.3	33.6	42	17	21	38
11:00	39.6	36.1	45.8	13	15	28
12:00	45.9	44.8	50.4	7	10	17
13:00	48.5	48.5	55.2	3	2	5
14:00	54.6	55.8	62.6	0	0	0
15:00	53.3	51.3	60	0	0	0
16:00	52.3	50.1	55.9	0	1	1
17:00	44.8	44.4	49.8	1	2	3
18:00	42.4	42.1	47.5	5	7	12
19:00	34.7	34.4	37.5	8	9	17
20:00	29.9	29.6	33.1	11	12	23
22:00	24.4	23.3	27.7	15	18	33
00:00	22.3	21.6	26.8	16	22	38
02:00	18.5	17.6	23.6	18	23	41
04:00	17.8	17.5	22.7	20	26	46
06:00	15.8	15.6	20.6	20	26	46
08:00	23.3	22.5	30	19	24	43
			Distance from closest Int beam	249m	13m	



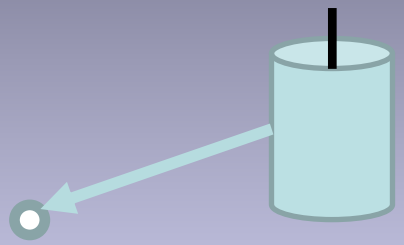

Expansion (at SV59051 cut)
Expansion (mm)
Surface Temperature (°C)
30
25
20
15
10
5
0
70
60
50
40
30
20
10
0
08:00:00
09:00:00
10:00:00
11:00:00
12:00:00
13:00:00
14:00:00
15:00:00
16:00:00
17:00:00
18:00:00
19:00:00
20:00:00
22:00:00
00:00:00
02:00:00
04:00:00
06:00:00
08:00:00
Time (15/1/2011)
North
South
Temperature North

Survey of “Grid pattern” N1/1
(not to scale)

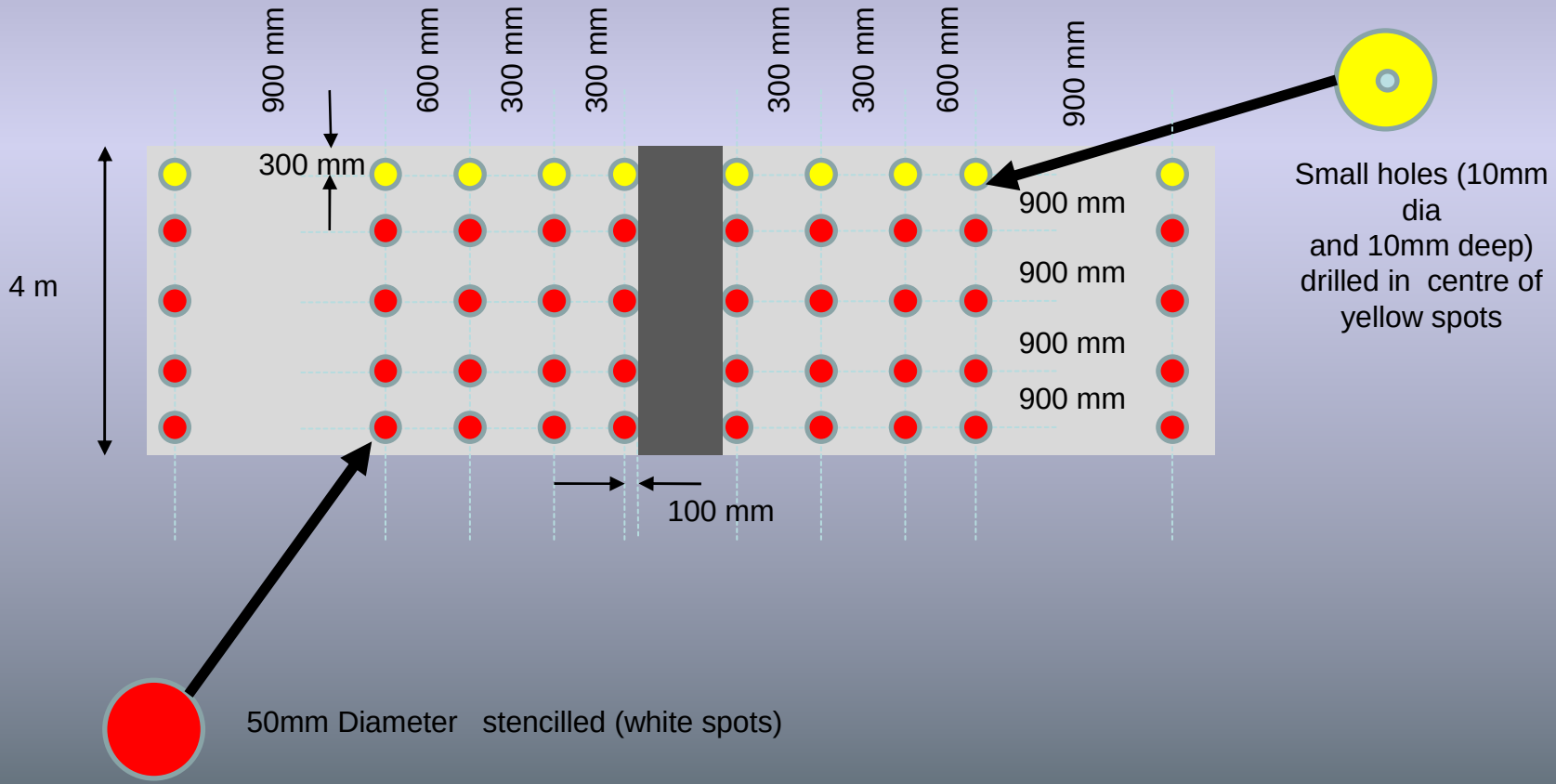
Purpose: Monitor horisontal and vertical movement

Location: At each failure repair

- SV 59051 S
- SV 57717 S
- SV 58735 S
- SV59300 S



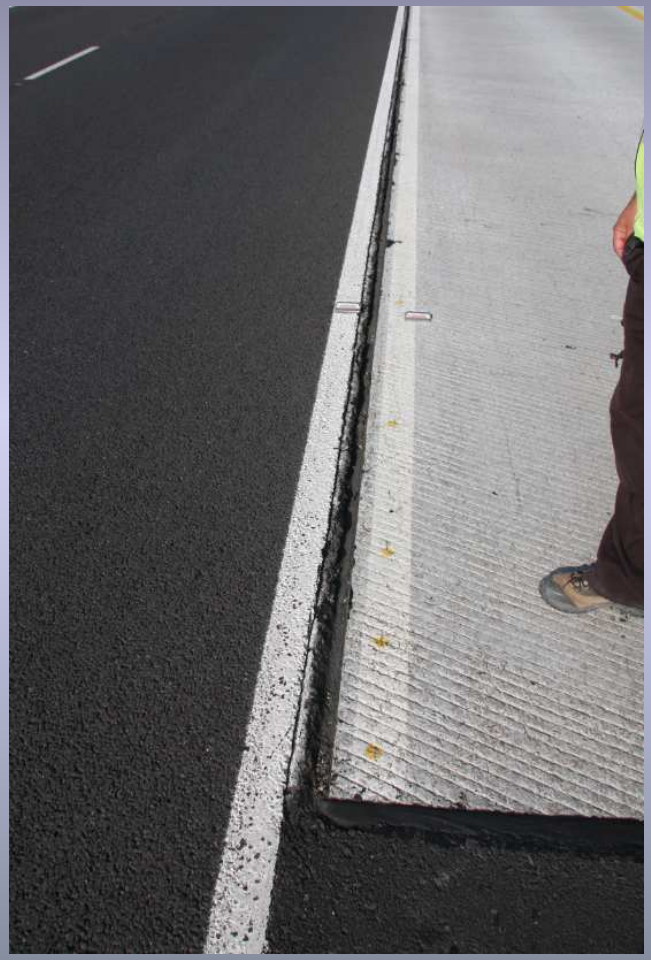
Bench mark (Y12 in concrete)
300mm Diameter 500 mm deep
Outside of concrete side drain



Small holes (10mm dia
and 10mm deep)
drilled in centre of
yellow spots

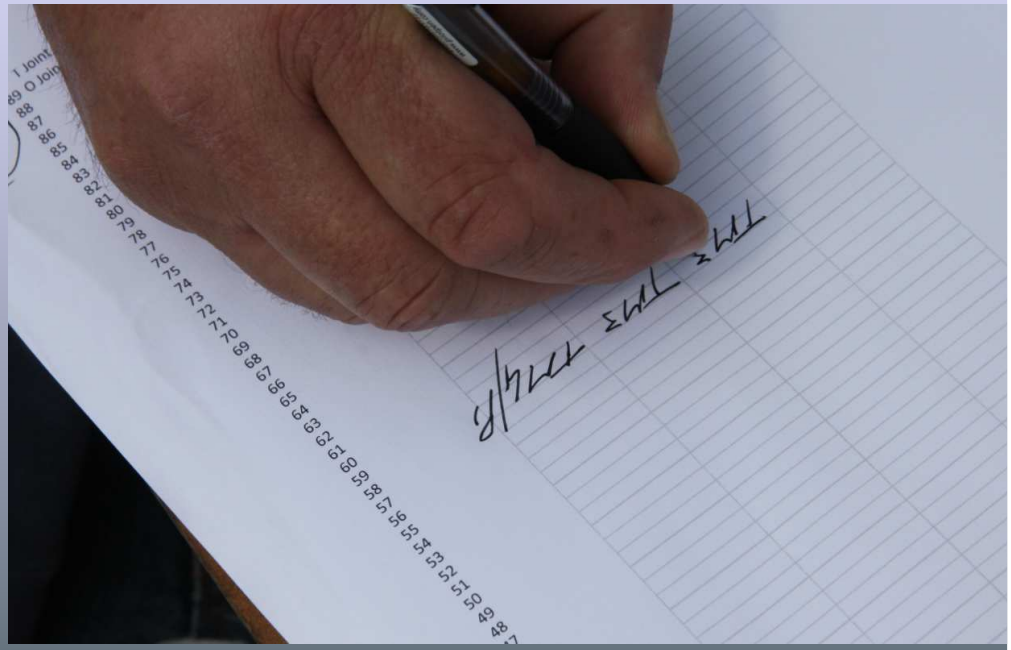
50mm Diameter stencilled (white spots)

Creeping on curve



Visual Assessment

- 9 June 2011
- Different distress types
- Degree 0 – 5
- Record per 1m x 1m (4 m lane)
- Joints separately



UTCRCP DISTRESS

- **Crack Types**
  - Transverse cracking
  - Transverse Mesh cracking
  - Block Mesh cracking
  - Longitudinal cracking
  - Crocodile cracking
- **Pumping of fines**
- **Rust**
- **Transverse Joint Spalling**
- **Longitudinal Joint**
- **Edge breaks**

Transverse Cracking

- **Random pattern (not mesh related)**

Transverse Mesh Cracking

Block Mesh cracking

Longitudinal cracking

- **Not mesh related**

Crocodile cracking

- **Irregular block pattern (not mesh related)**

Pumping of Fines

Rust

Transverse Joint Spalling

Longitudinal joint

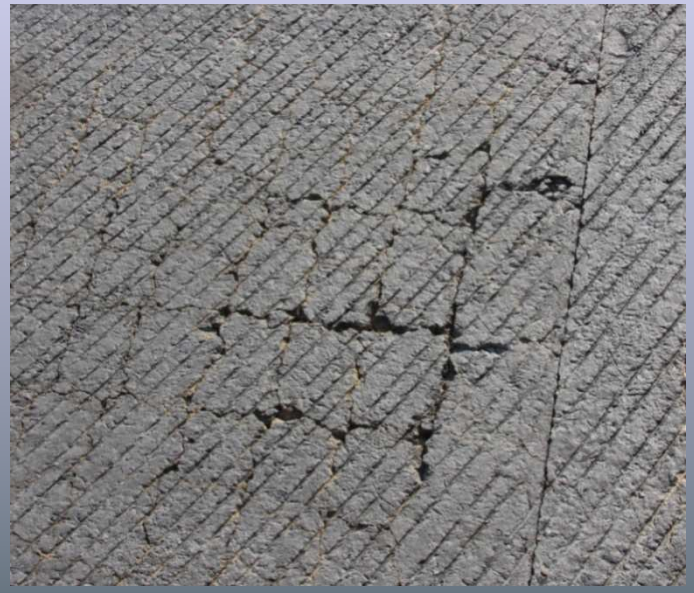
Edge breaks

Step

Repairs

Small Failures

- **Principle**
  - <1/3 of width – Patch Mod AC
  - >1/3 of width – Full-width cut and patch Mod AC



Transverse Joint

Theoretical Analyses to Determine Risk of Buckling

Develop cncBuckle

- Buckling develops because of horizontal compression in the UTCRC
- Risk of buckling = Compression due to expansion (high temp. and humidity) > tensile stress due to shrinkage (high water content, fines, drying out)
- Interaction with support, reinforcement, variable cross section etc. complicates analysis: Finite Element Analysis

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WELCOME | CONTROL | WHAT IF

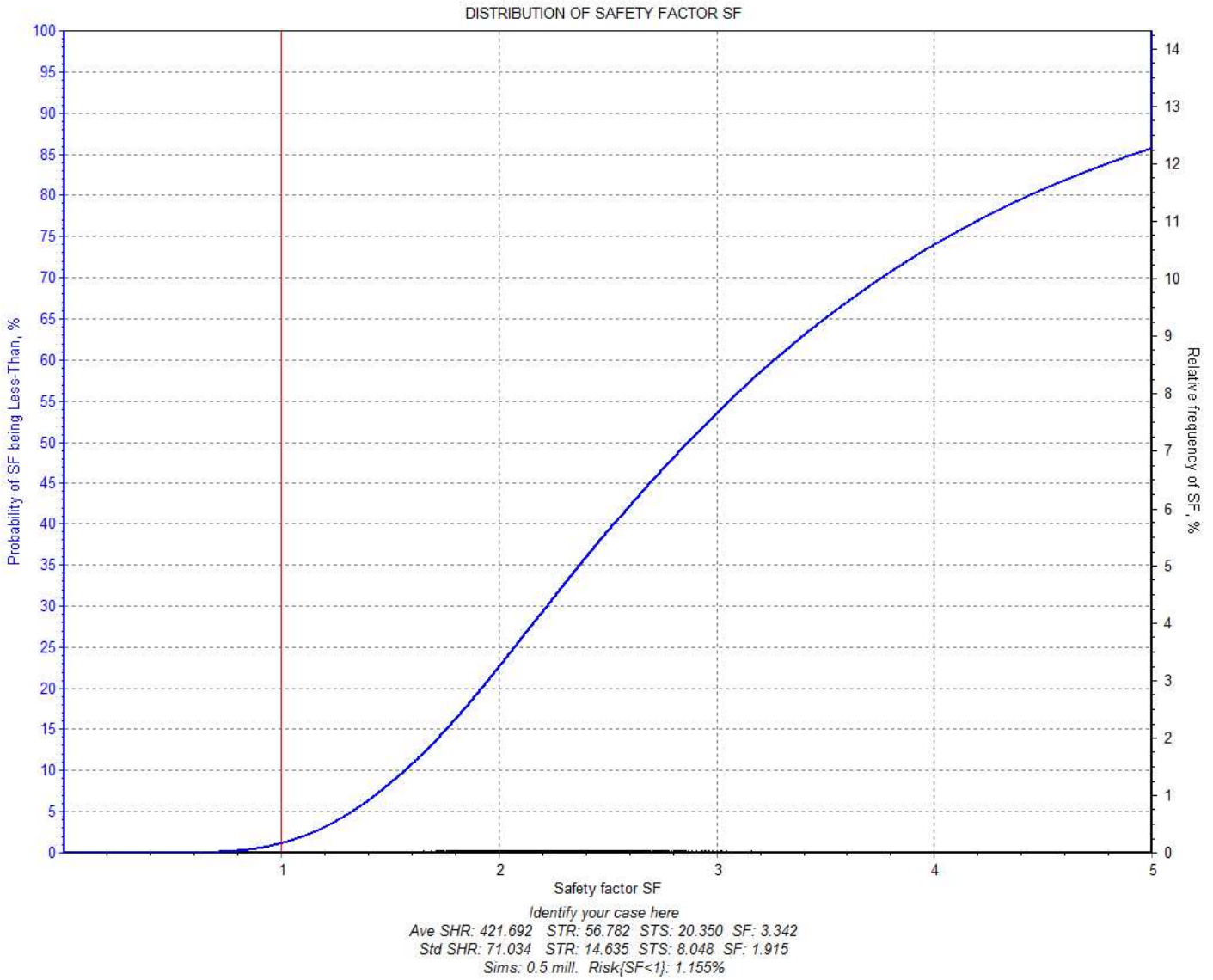
V	Variable	Min	Best	Max
1	wat, l/m3	165	175	185
2	aggc, %	57	60	63
3	f, MPa	9	11	13
4	hum, %	30	55	80
5	T, deg C	15	30	65
6	Unassigned	2	2.5	3
7	h, mm	48	51	56
8	hhoney, mm	0	0	20
9	hhump, mm	0	0	0
10	Bond	1	2	4

C	Constant	Value
1	t, years	1
2	Ls, m	200
3	|Grad|, %	4.5
4	hedge, mm	0
5	alpha	9.0e-6

Risk of SF<1:

1.2 %

Print ...



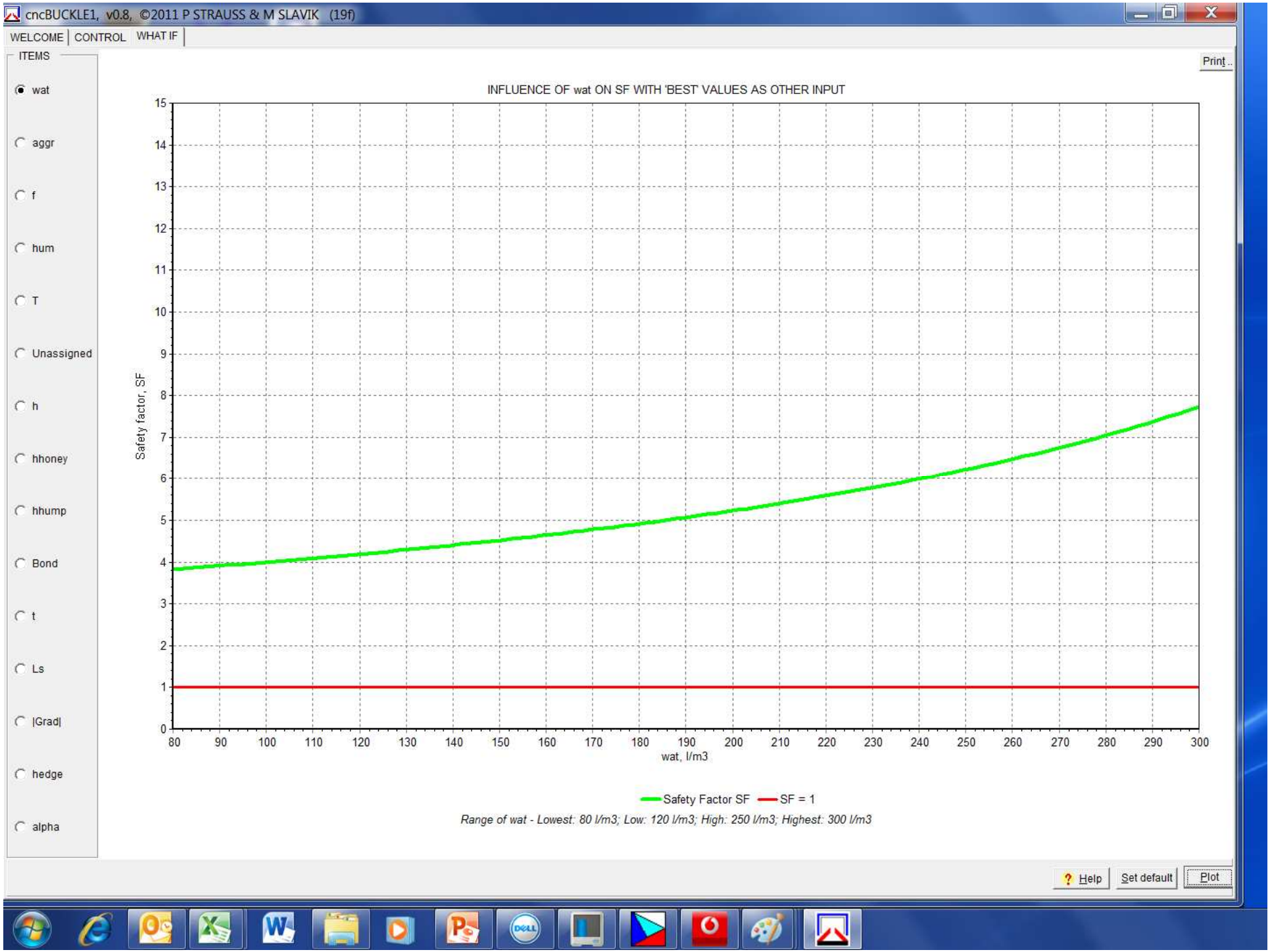
Identify your case here

Ave SHR: 421.692 STR: 56.782 STS: 20.350 SF: 3.342

Std SHR: 71.034 STR: 14.635 STS: 8.048 SF: 1.915

Sims: 0.5 mill. Risk{SF<1}: 1.155%

Identify your case here | Input guide | Help | Set default | 0.86 seconds | Abort | Evaluate


cncBUCKLE1, v0.8, ©2011 P STRAUSS & M SLAVIK (19f)
WELCOME
CONTROL
WHAT IF
ITEMS
wat
aggr
f
hum
T
Unassigned
h
hhoney
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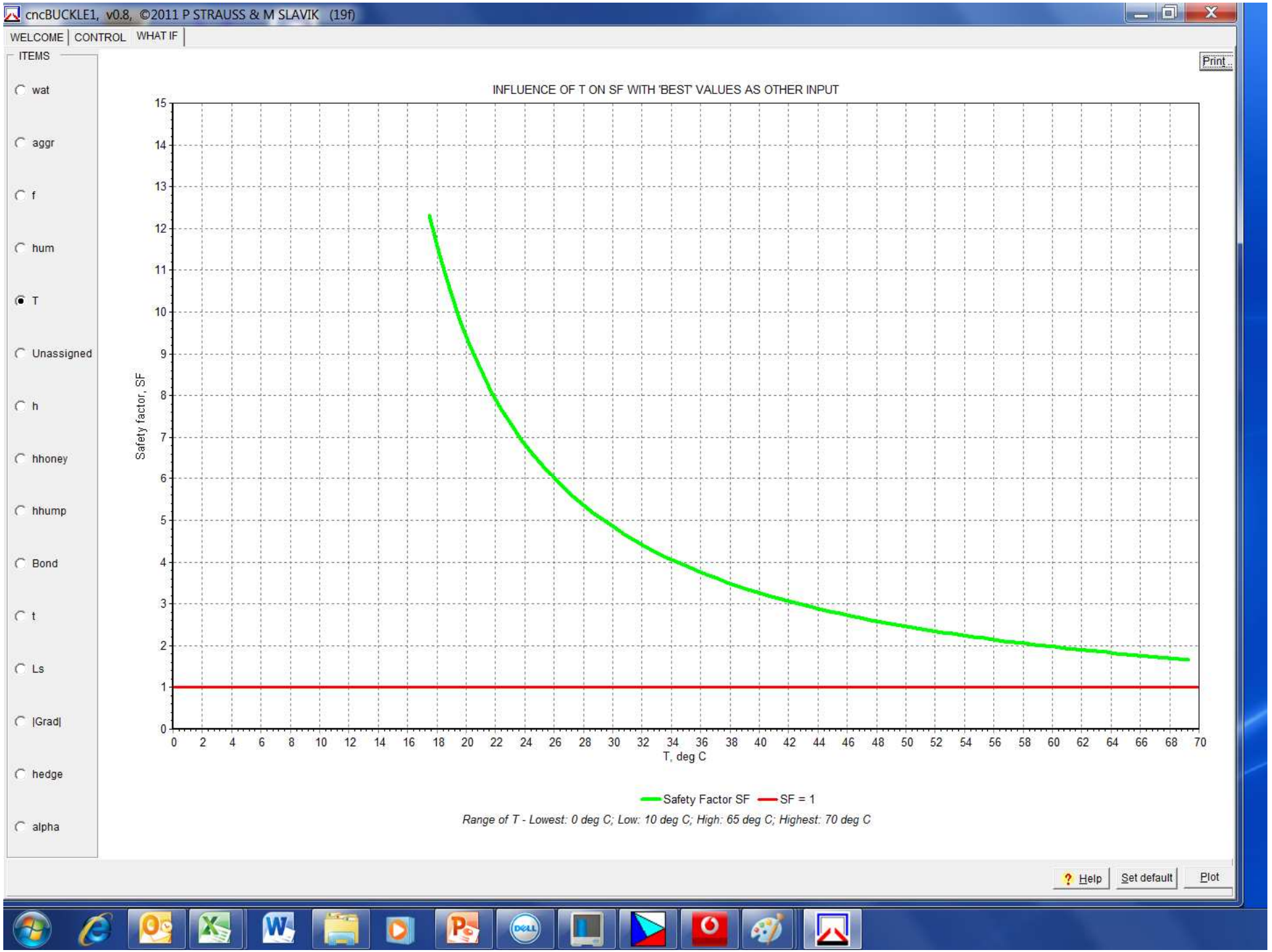
Bond
t
Ls
|Grad|
hedge
alpha
Print ..
INFLUENCE OF wat ON SF WITH 'BEST' VALUES AS OTHER INPUT
Safety factor, SF
wat, l/m3
Safety Factor SF
SF = 1
Range of wat - Lowest: 80 l/m3; Low: 120 l/m3; High: 250 l/m3; Highest: 300 l/m3
Help
Set default
Plot


cncBUCKLE1, v0.8, ©2011 P STRAUSS & M SLAVIK (19f)
WELCOME
CONTROL
WHAT IF
ITEMS
wat
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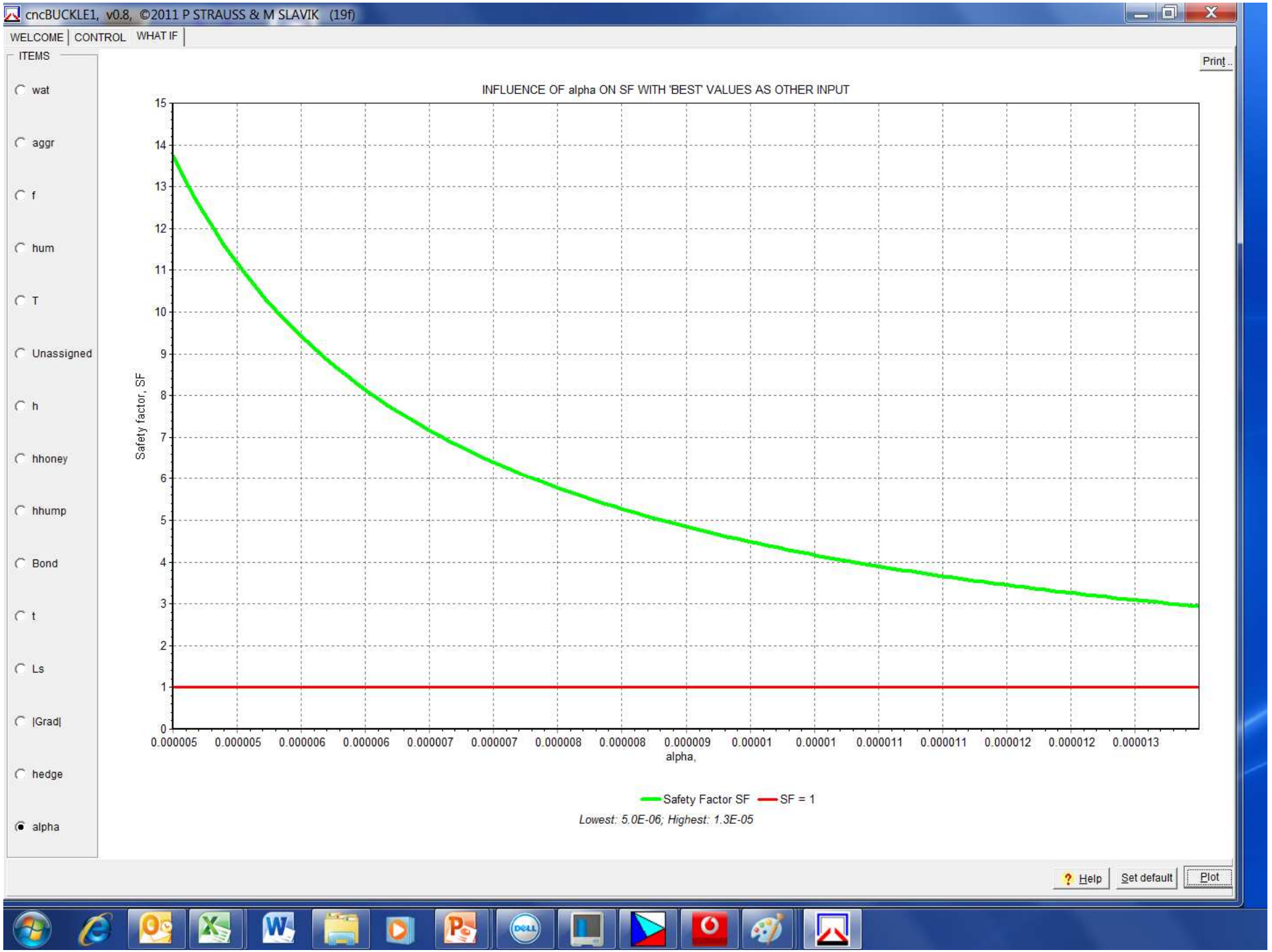
Ls
|Grad|
hedge
alpha
Print...
INFLUENCE OF T ON SF WITH 'BEST' VALUES AS OTHER INPUT
Safety factor, SF
T, deg C
Safety Factor SF
SF = 1
Range of T - Lowest: 0 deg C; Low: 10 deg C; High: 65 deg C; Highest: 70 deg C
Help
Set default
Plot


cncBUCKLE1, v0.8, ©2011 P STRAUSS & M SLAVIK (19f)
WELCOME
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hedge
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Print ..
INFLUENCE OF alpha ON SF WITH 'BEST' VALUES AS OTHER INPUT
Safety factor, SF
0
1
2
3
4
5
6
7
8
9
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11
12
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15
0.000005
0.000005
0.000006
0.000006
0.000007
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0.000008
0.000008
0.000009
0.00001
0.00001
0.000011
0.000011
0.000012
0.000012
0.000013
alpha,
Safety Factor SF
SF = 1
Lowest: 5.0E-06; Highest: 1.3E-05
Help
Set default
Plot


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WELCOME
CONTROL
WHAT IF
ITEMS
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Bond
t
Ls
|Grad|
hedge
alpha
Print ..
INFLUENCE OF hum ON SF WITH 'BEST' VALUES AS OTHER INPUT
Safety factor, SF
hum, %
Safety Factor SF
SF = 1
Range of hum - Lowest: 0 %; Low: 10 %; High: 85 %; Highest: 100 %
Help
Set default
Plot

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WELCOME | CONTROL | WHAT IF

ITEMS

- wat
- aggr
- f
- hum
- T
- Unassigned
- (•) h
- hhoney
- hhump
- Bond
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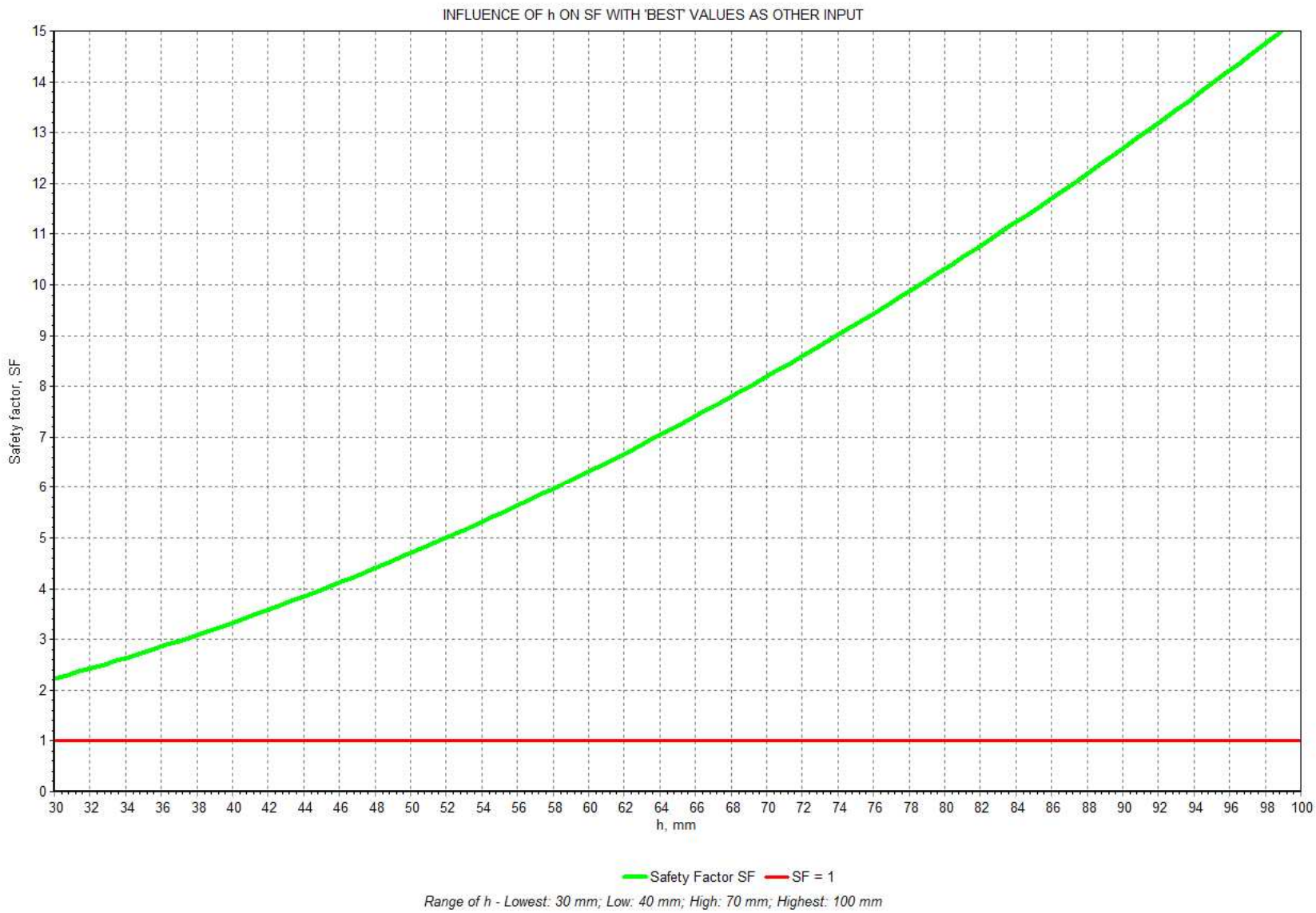
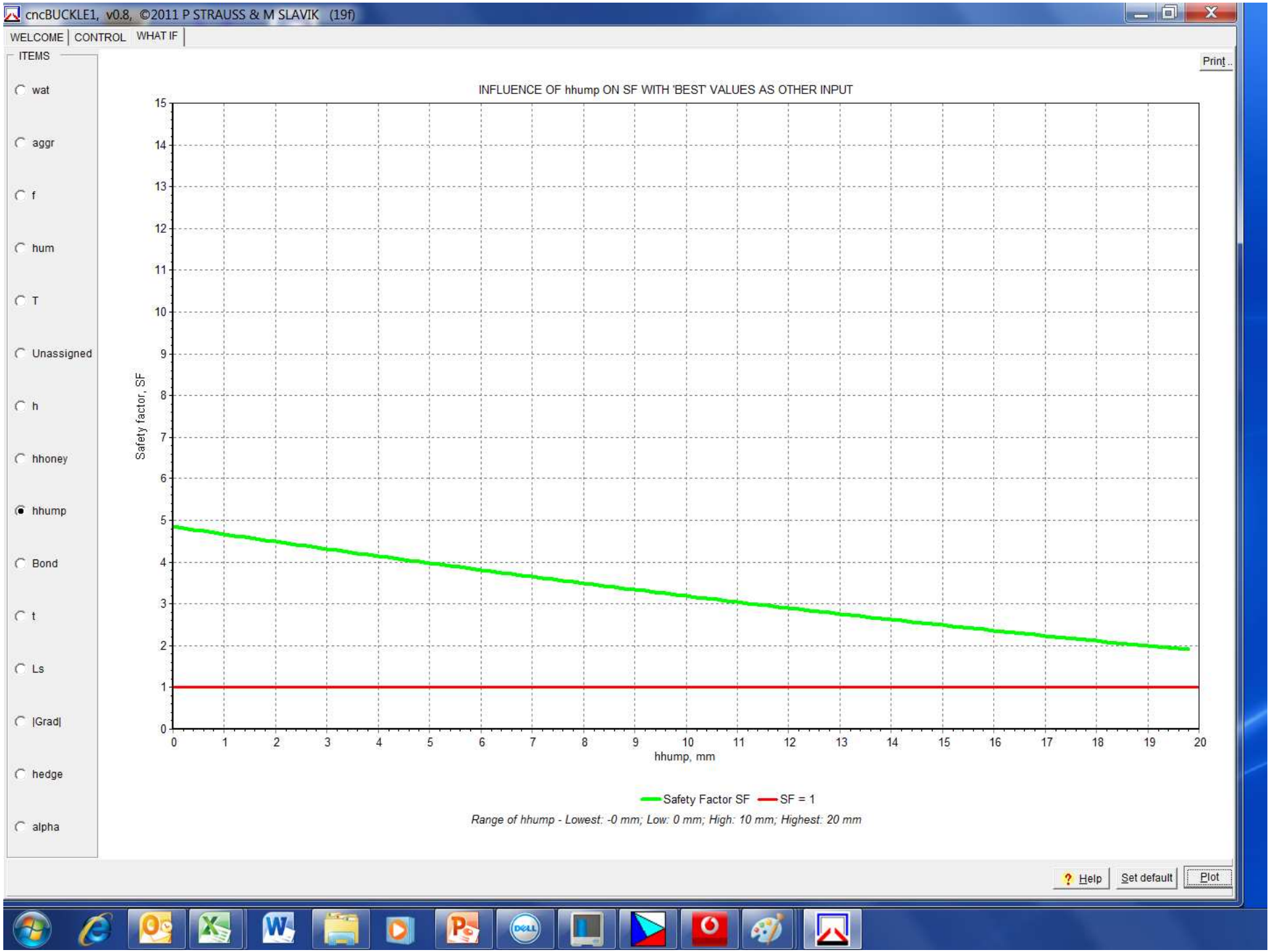
- Ls
- |Grad|
- hedge
- alpha

Print ..



Help | Set default | Plot


cncBUCKLE1, v0.8, ©2011 P STRAUSS & M SLAVIK (19f)
WELCOME
CONTROL
WHAT IF
ITEMS
wat
aggr
f
hum
T
Unassigned
h
hhoney
hhump
Bond
t
Ls
|Grad|
hedge
alpha
Print ..
INFLUENCE OF hhump ON SF WITH 'BEST' VALUES AS OTHER INPUT
Safety factor, SF
hhump, mm
Safety Factor SF
SF = 1
Range of hhump - Lowest: -0 mm; Low: 0 mm; High: 10 mm; Highest: 20 mm
Help
Set default
Plot

cncBUCKLE1, v0.8, ©2011 P STRAUSS & M SLAVIK (19f)

WELCOME | CONTROL | WHAT IF

ITEMS

- wat
- aggr
- f
- hum
- T
- Unassigned
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- (•) hhoney
- hhump
- Bond
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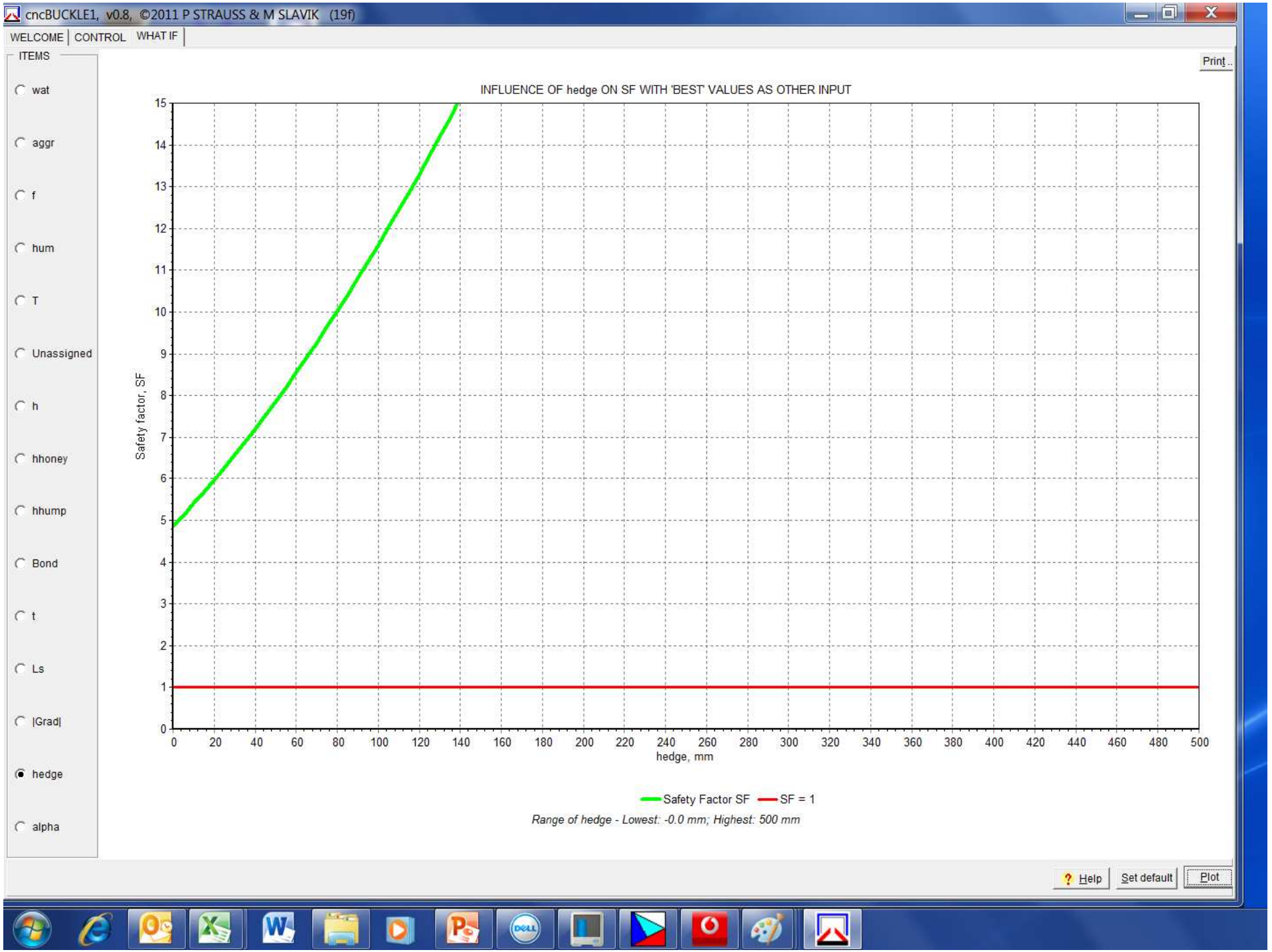
- Ls
- |Grad|
- hedge
- alpha

Print ..

Help | Set default | Plot


cncBUCKLE1, v0.8, ©2011 P STRAUSS & M SLAVIK (19f)
WELCOME
CONTROL
WHAT IF
ITEMS
wat
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Unassigned
h
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Bond
t
Ls
|Grad|
hedge
alpha
Print ..
INFLUENCE OF hedge ON SF WITH 'BEST' VALUES AS OTHER INPUT
Safety factor, SF
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
hedge, mm
Safety Factor SF
SF = 1
Range of hedge - Lowest: -0.0 mm; Highest: 500 mm
Help
Set default
Plot

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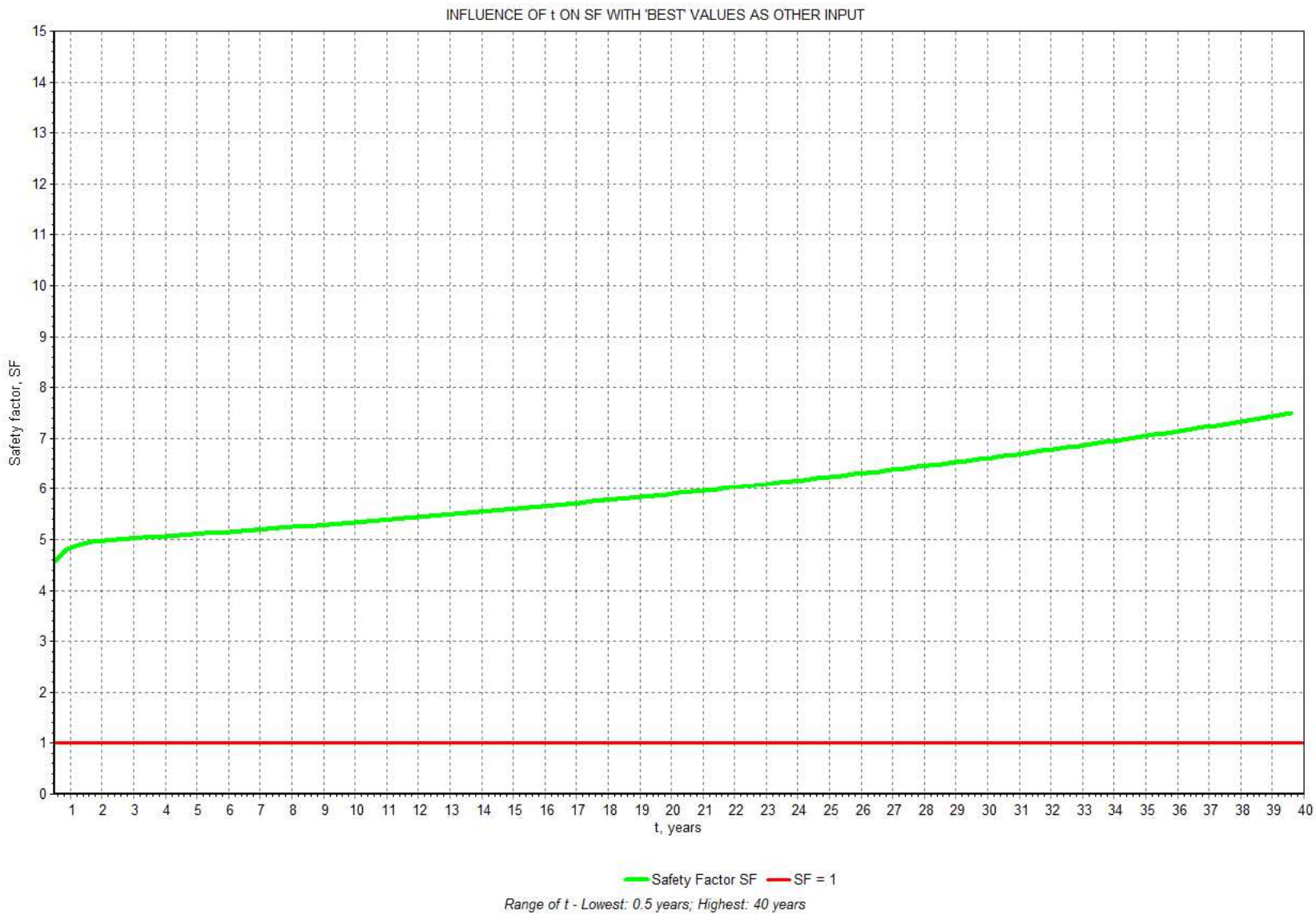
WELCOME | CONTROL | WHAT IF

ITEMS

- wat
- aggr
- f
- hum
- T
- Unassigned
- h
- hhoney
- hhump
- Bond
- t
- Ls
- |Grad|
- hedge
- alpha

Print ..



Help | Set default | Plot

Implications

- FEA indicated that normally shrinkage stress would be high enough to absorb any expansion
- Relaxation of tensile stress must have occurred
- Variation in thickness most critical
- Weakness such as construction joints may act as triggers
- Safety in joining with adjacent lanes (thickened edges), proper compaction, uniform slab thickness and support.

Less critical issues

- Position of the reinforcement in the slab
- Longitudinal slope of the pavement
- Aggregate content and strength of the concrete
- Bond between UTCRC and support
- Distance between construction joints

Thank you for your attention

End