Sustaining reinforced concrete buildings in public rental housing estates

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Presentation outline

- Putting the issue into context
- Describing what we do
- Illustrated by an example

A historical perspective

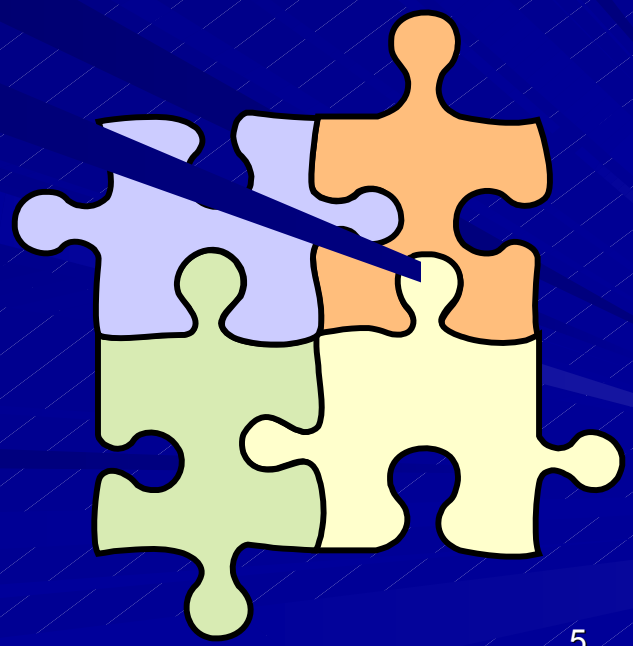
- 2500 BC - major concrete users
- 1200 BC - iron age began
- Around 3000 years later…. Steel reinforced concrete

Reinforced concrete is quite 'new'

- 1854 WB Wilkinson of England erected a [illegible] rc servants cottage
- 1902 rc [illegible] up to 6 stories high
- 1906 [illegible] Building Ohio - the first rc high[illegible] building (16 stories), still there!

Codes are quite new

- 1948 CP114, CP110, BS8110, EN206
- …2 BS EN 1504 (10 parts) ‘products and system for protection and repairs of concrete structures’



Problem is quite serious...

"If indirect costs are included, the annual cost (of steel corrosion to the US economy) is conservatively estimated at $552 billion. Some estimates indicate that up to 30% of this total is related to corrosion in concrete structures."

Concrete International, Dec 2004

"There are approximately 583,000 bridges in the US…Approximately

[illegible] of these bridges are structurally deficient because of corroded steel and steel reinforcement."

Source: FWHA

"Corrosion of the reinforcing steel in concrete structures such as motorways, bridges, buildings and marine installations is costing the UK an estimated 550m GBP per year"

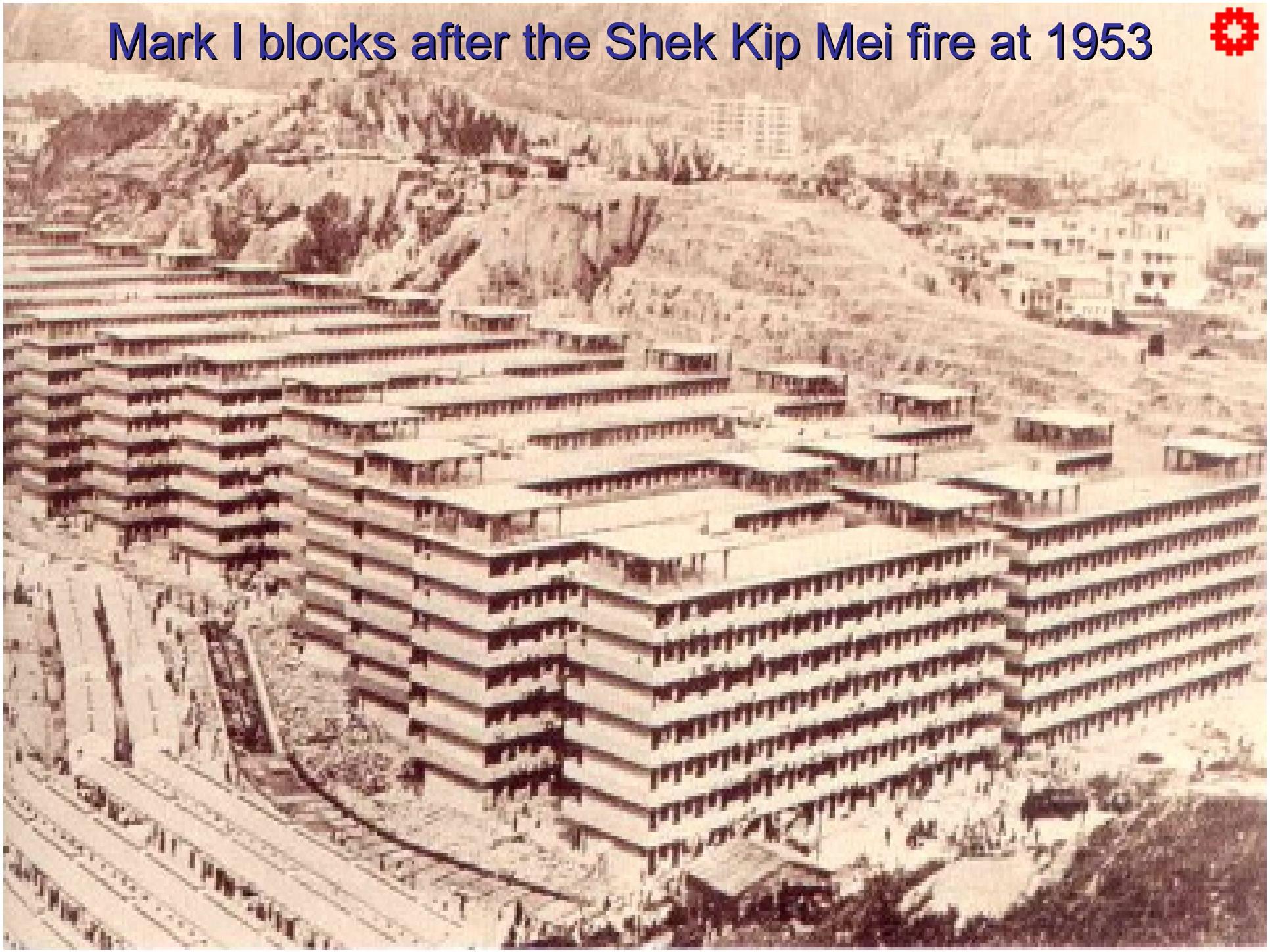
BRE website March 2007

‘…majority of significant deterioration of [illegible] bridges (in Japan) built before the 1984 gu[illegible]es occurred within 15 years of [illegible]truction.’

Mar/Apr 2006 PCI Journal

Our story….

Mark I blocks after the Shek Kip Mei fire at 1953



Redevelopment programmes

- 70's – cleared 250 resettlement blocks
- 80's – extended to another 26 blocks
- 1988 - Comprehensive Redevelopment Programme (CRP) targeting at 566 blocks (completion 2000)

Long Term Housing strategy 1998

- No large scale redevelopment programme [illegible] the CRP.
- Clearance [illegible] be considered only if
  - [illegible] is structurally unsafe, or
  - Beyond economical repair
- (2005 – comprehensive structural investigation programme; initially 10 estates, extended to another 32 estates in a 10 year programme)

Methodology for Investigation

Rele[illegible] documents

- Appraisal [illegible] Existing Structures by IStructE
  and [illegible] TR No. [illegible] Concrete Society
  BRE Digest [illegible]
- UK Highways Agency [illegible] BD5[illegible] BD44/95 and BA44/96

thodology for Investigation

Dev[illegible] our [illegible] methodology
[illegible]ing into a[illegible]ount [illegible]f our
particula[illegible] [illegible]umsta[illegible]ces

Methodology for Investigation

- Aim – not just a snap-shot, but what needs to be done to sustain the buildings for at least [illegible] years
- [illegible] have computerized repair history for over 10 years
- Deterioration inside [illegible] (especially toilet) is often more significant than common areas
- Presence of sitting tenants

Methodology Framework

- formation Searching
- Visual rvey
- Structural Ass ment
- Develop Solution

Maintenance Record in last 10 years

Example : for XX Estate, toilet

Estate	Block	Total No. of Flats	No. of Toilet Spalling Cases	No. of Toilet Seepage Cases	No. of Toilet Spalling & Seepage Cases	No of Toilet Spalling & Seepage Cases per 100 Flats	No. of Repaired at Toilet	No. of Toilet with Repair Cost more than [illegible]
		(A)	(B)	(C)	(B)+(C)	[B+C]/(A)*100		
XXXX	A	753	185	91	276	37	246	75
	B	770	383	127	510	66	454	130
	C	498	166	155	321	64	281	70
	D	457	124	151	275	60	241	71
	E	771	231	138	369	48	330	90
	F	735	243	184	427	58	360	111
	G	771	229	107	336	44	296	77
	H	771	357	222	579	75	470	199
	I	770	327	207	534	69	431	176
	J	381	144	132	276	72	236	69
	K	771	355	248	603	78	481	199

Visual Survey

- Where, how (serious), why?
- [illegible]vide information for planning tesu[illegible]rk
- [illegible]tions
- Represent[illegible]ess
  - In flat, at least : 5%
  - Common area : all

Key Tests

- Open up and reinforcement survey
- Concrete core compression test
- Chloride content
- Carbonation front measurement
- Moisture meter measurement

Opening-ups

- Steel bar size and spacing
- Concrete cover
- Carbonation depth

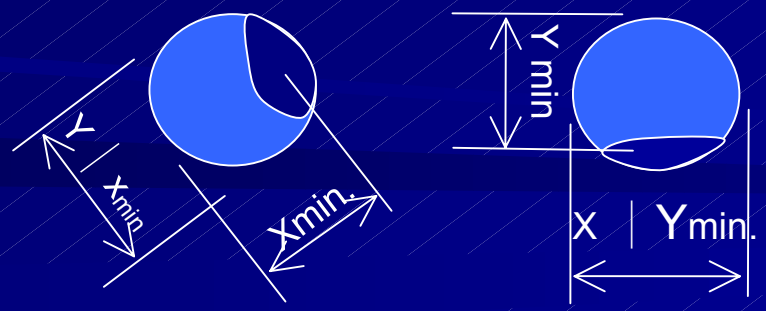
Steel Bar Measurement

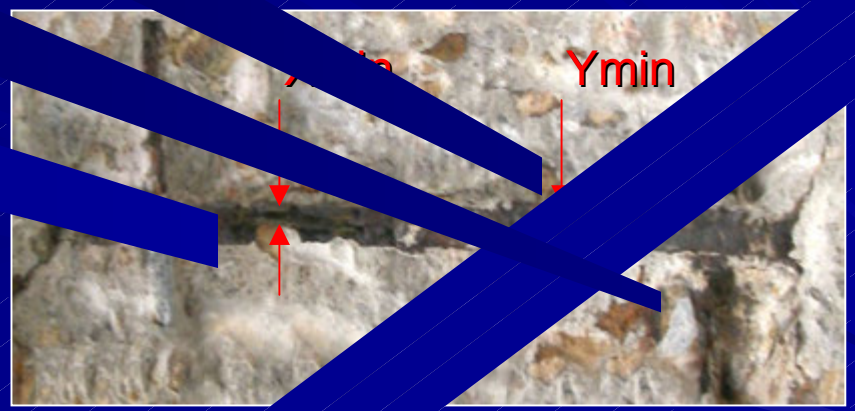
Based on [illegible] 38/93

[illegible] Sectional [illegible]ea of Steel Bar is the minimum [illegible]

$\Pi/4$ [illegible] Y | x_{min}

$\Pi/4 \times Y\ min \times X$ | y_{min}





Chloride Content Test

Av[illegible] chloride content and profile

[illegible]ling to ex[illegible] concrete
powder [illegible]ride diag[illegible]is

Moisture Meter Measurement

- Calibration against actual moisture content in concrete
- Regulations and profile

Structural Assessment

- Statistical approach in strength assessment
- Global vs local considerations

Develop Repair Solution

- BS EN 1504 - first comprehensive concrete repair standard
- Guides on product performance
- Principles and repair methods for concrete defects and reinforcement corrosion

Develop Repair Solution

- Varying extent of defects
- Tailor-made solutions

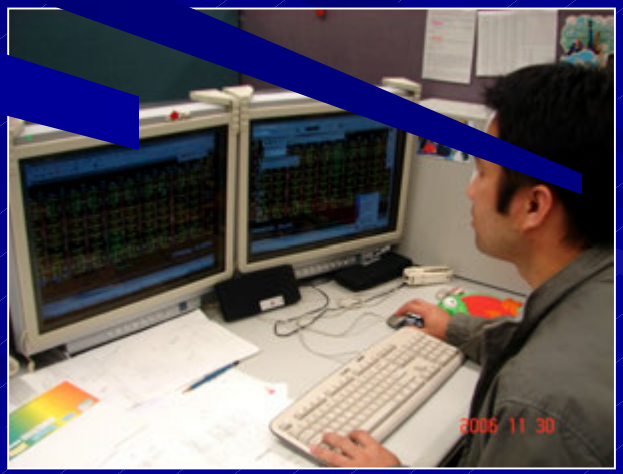
Comprehensive Structural Investigation on Toilets at Wo Lok Estate

Desk Study

Re ings

Design

Reports



Repair Records

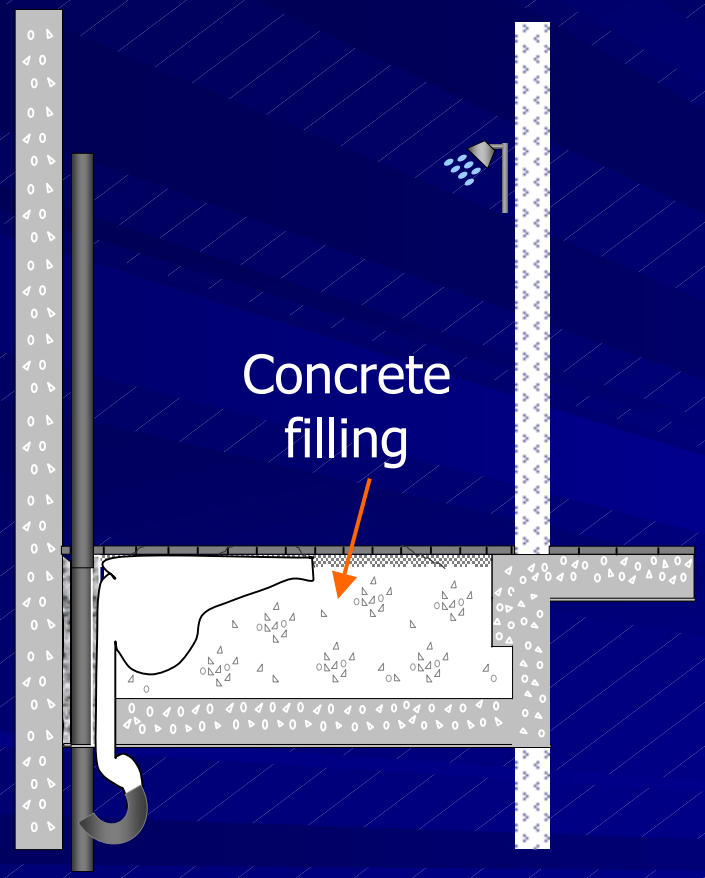
Desk Study
(Information Collected)

a) [illegible] improve[illegible] was carried out during 199[illegible]07

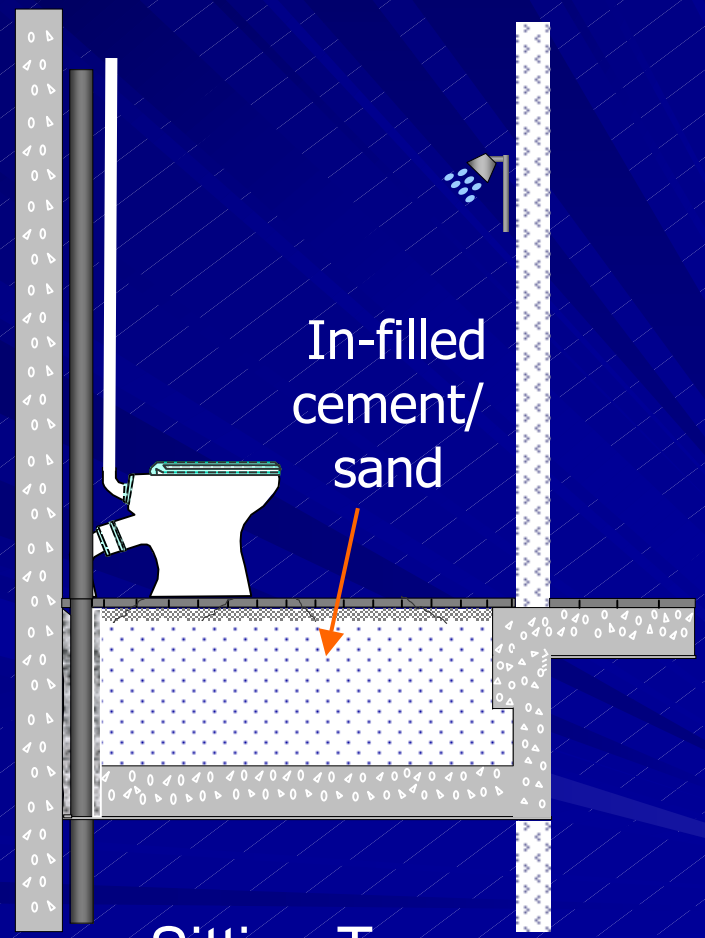
b) For [illegible] 10 years [illegible] about [illegible]lf toilets received seep[illegible] or concre[illegible] repa[illegible] about 1/3 of which were repaired [illegible]re than once

c) Toilets were converted from squatting type to sitting type

Desk Study

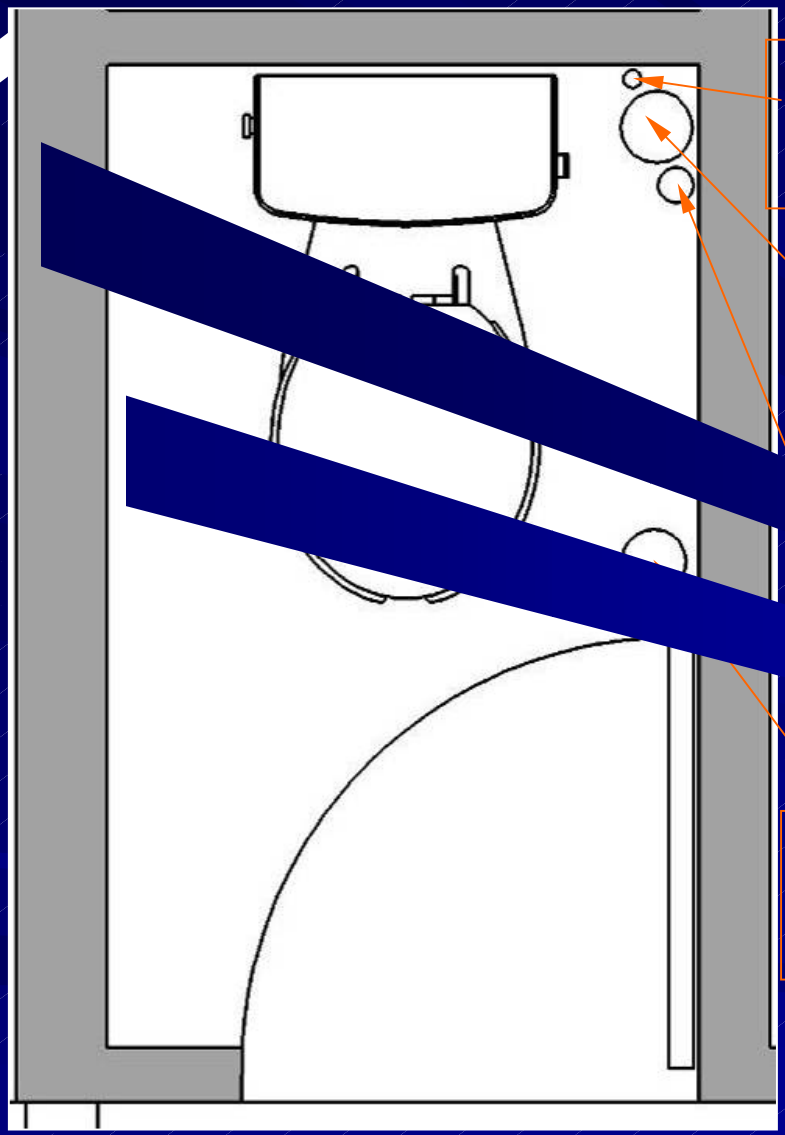


Squatting Type Toilet



Sitting Type Toilet

Visual Survey



Flushing Pipe

Soil Pipe

Pipe

Floor drain

Visual Survey

Moisture Survey

Taking Photo

Tapping Test

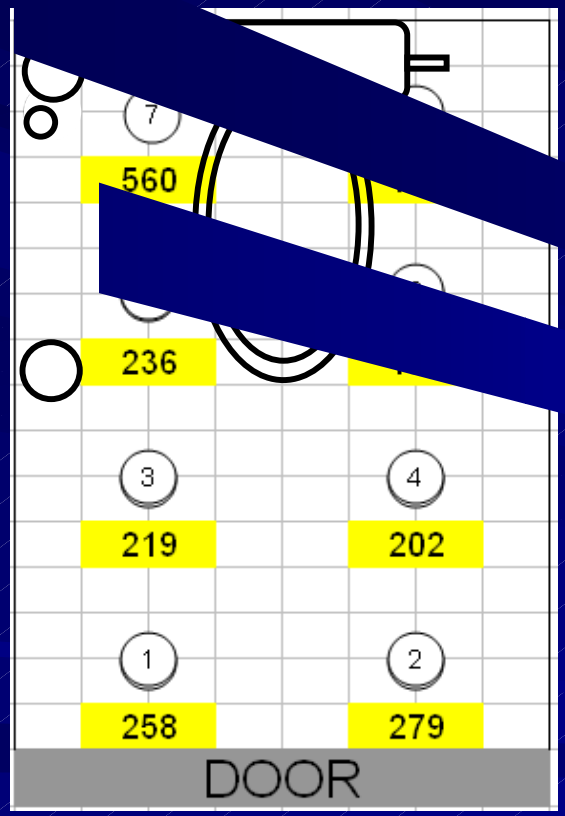
Visual Conditions of Toilet Ceiling

Fair

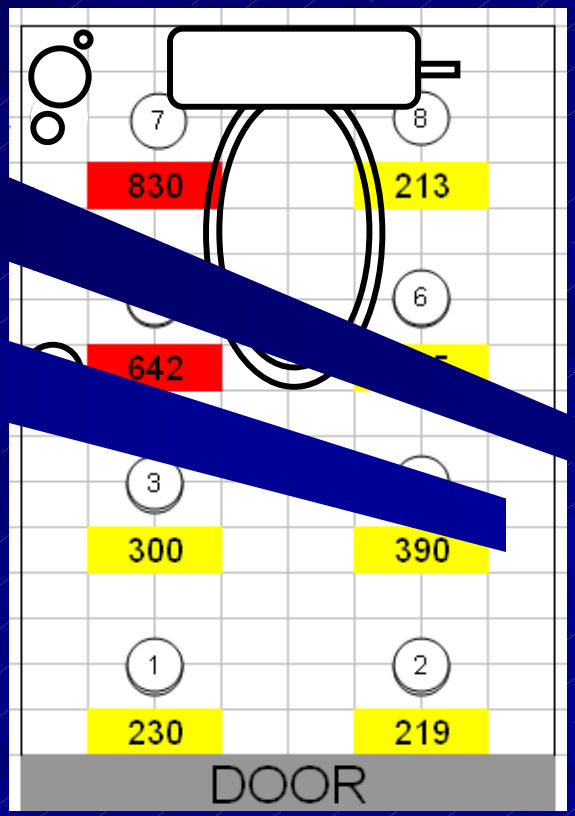
Moderate

Poor

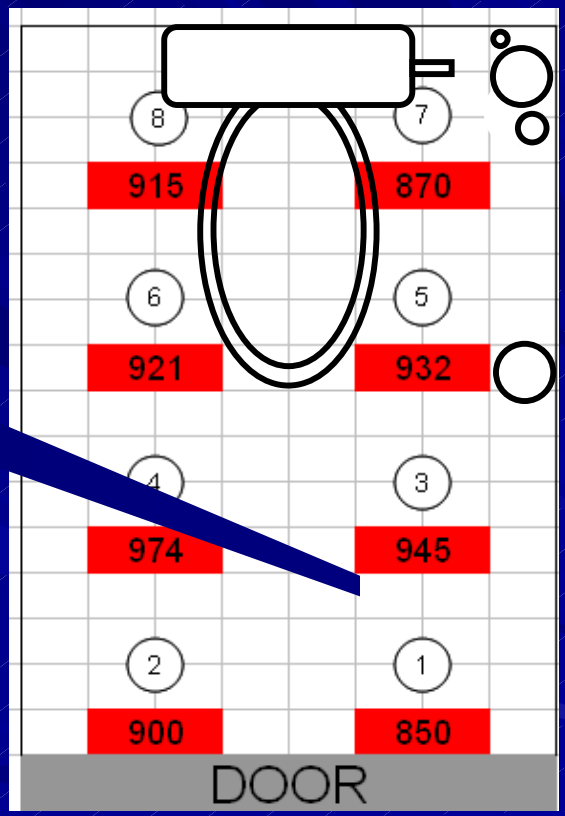
Moisture Condition of Toilet Slabs



Dry

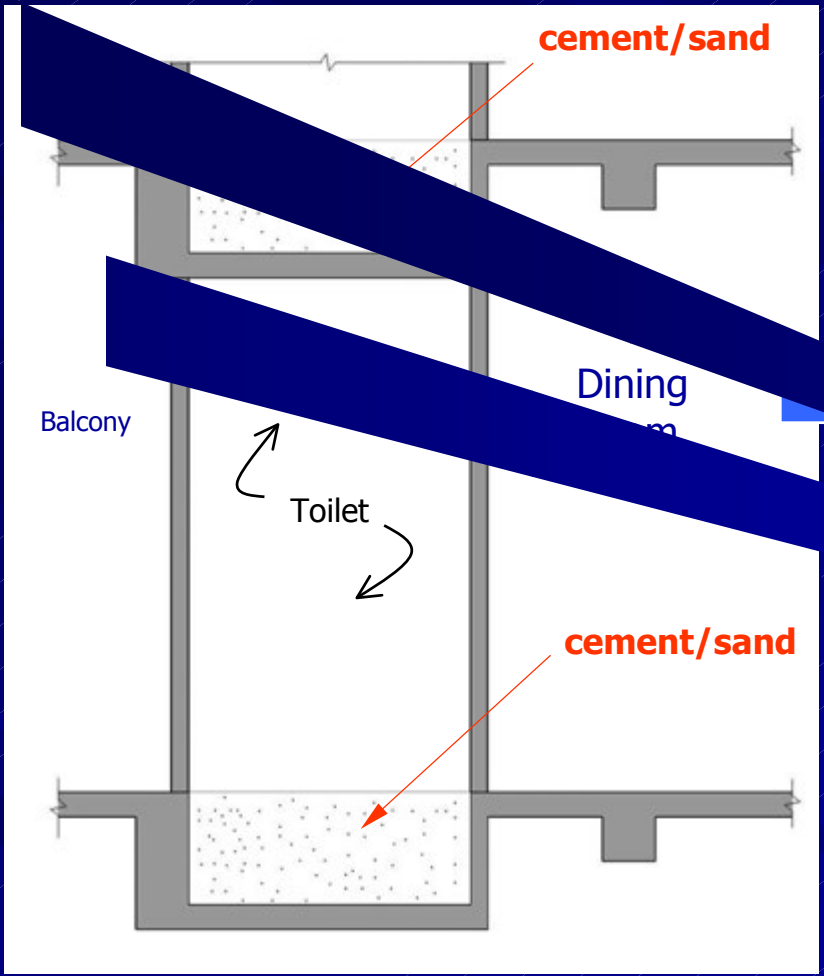


Locally Wet



Wet

Visual Survey
(Dinning Room adjoining Toilet)



Testing and Measurement

Testing and Measurement

Testing and Measurement

Core Test

Steel Bar Measurement

Carbonation Test

Laboratory Test

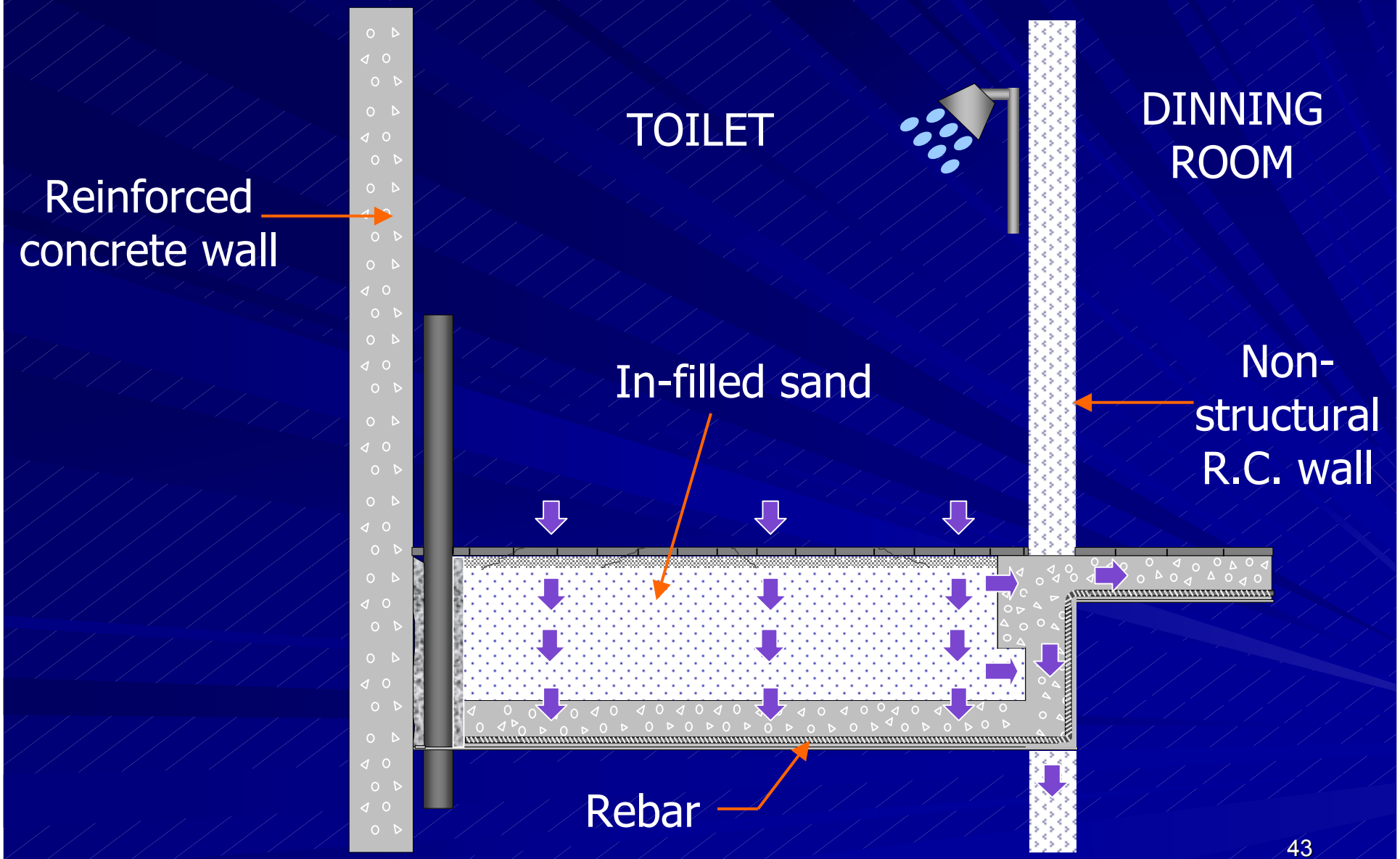
Corrosion of Rebars

Pitting Corrosion

General Corrosion

Pitting Corrosion

Cause of Defects

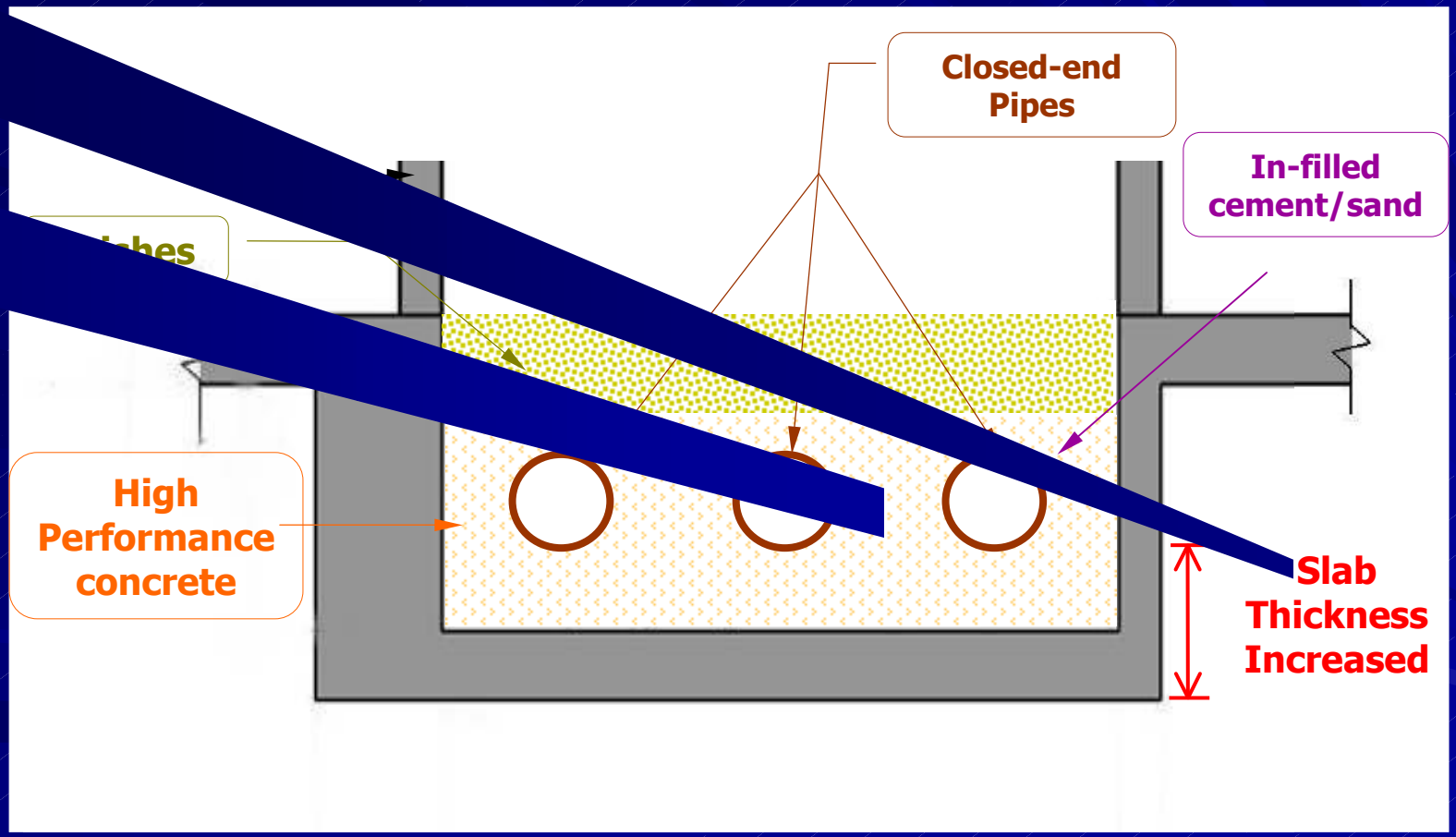


Structural and Durability Assessment Findings

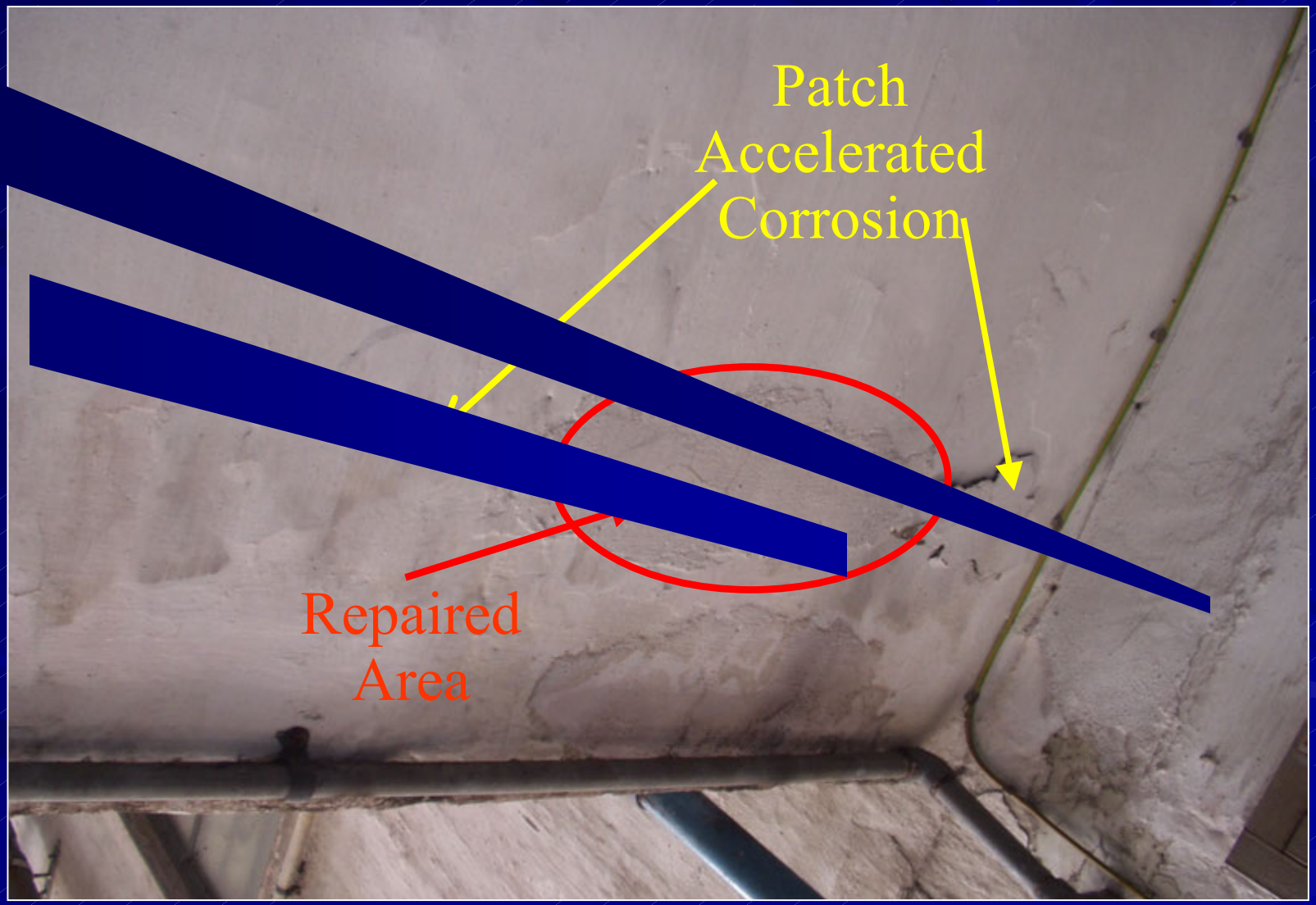
a) Structu[illegible] adequ[illegible]

b) Reinforcement[illegible] are vulnerable to deterioration

Repair Solution
Toilet Improvement



Patch Accelerated Corrosion



Installation of Sacrificial Anodes

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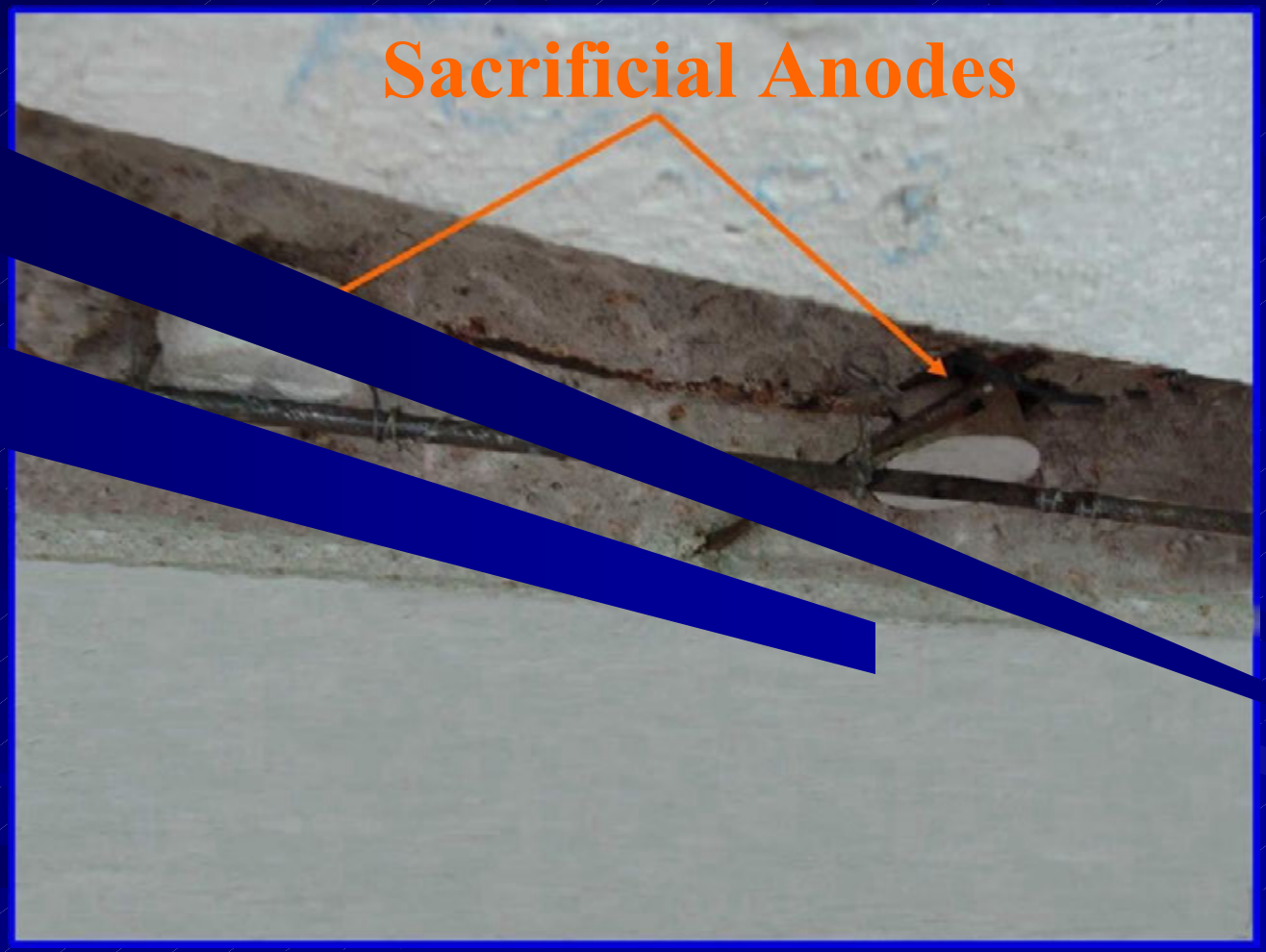

End of presentation. Thank you.