

香港混凝土大廈破損原因及維修指引

CAUSES OF DETERIORATION AND REPAIR GUIDELINES OF REINFORCED CONCRETE BUILDINGS IN HONG KONG

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- WANG Hang-kuk, Ivy

Buildings Department
Sunday, 12 August 2018

CONTENTS

- Introduction of reinforced concrete properties, cause of deteriorations, investigation and repairs
- Inspection tools and investigation equipment available in Buildings Department
- Applications of the tools and equipment, and example of works
 - Schmidt Hammer
 - Cover meter survey
 - Alkalinity pH test
 - Thermal Scanning
 - Laser Distance Meter
- Q&A



REINFORCED CONCRETE PROPERTIES, CAUSE OF DETERIORATIONS & INVESTIGATION

3

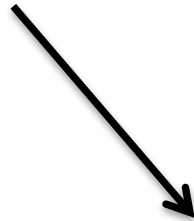
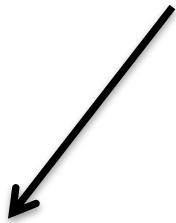
Concrete

=

Binders + Fillers + Water

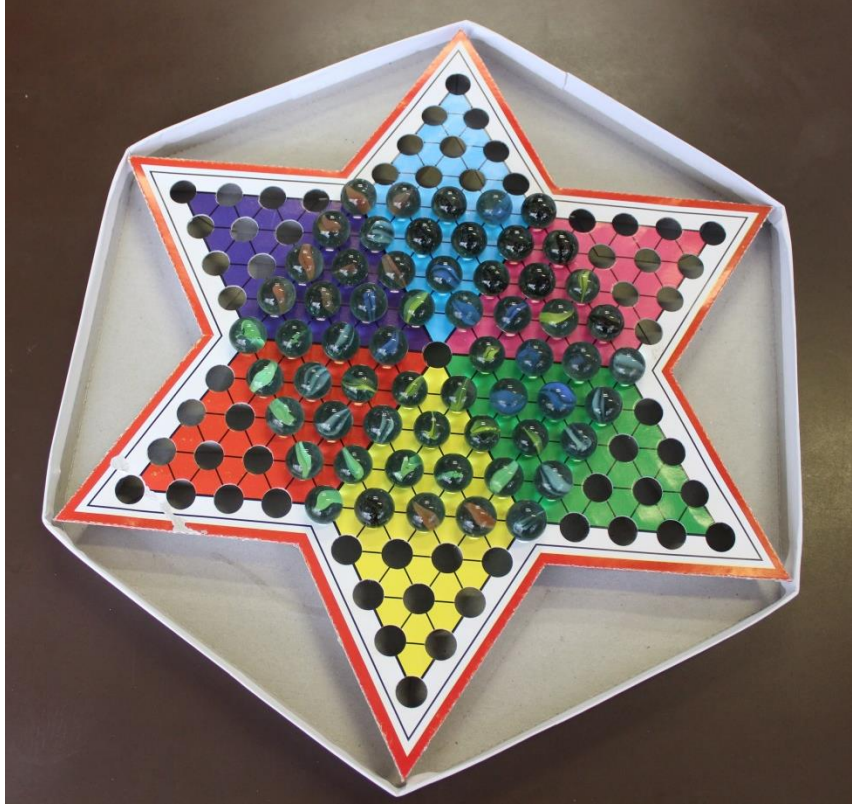
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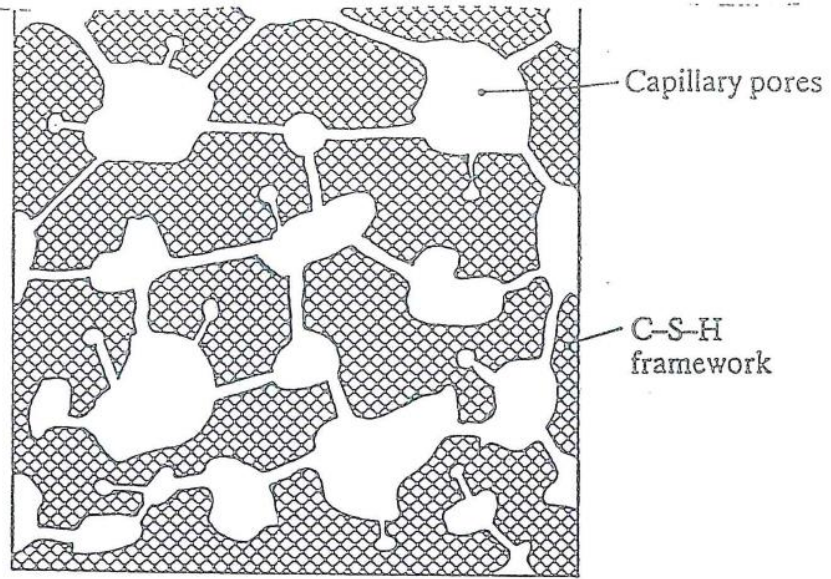
$C - S - H + Ca(OH)_2 +$ (chemicals, voids,....)



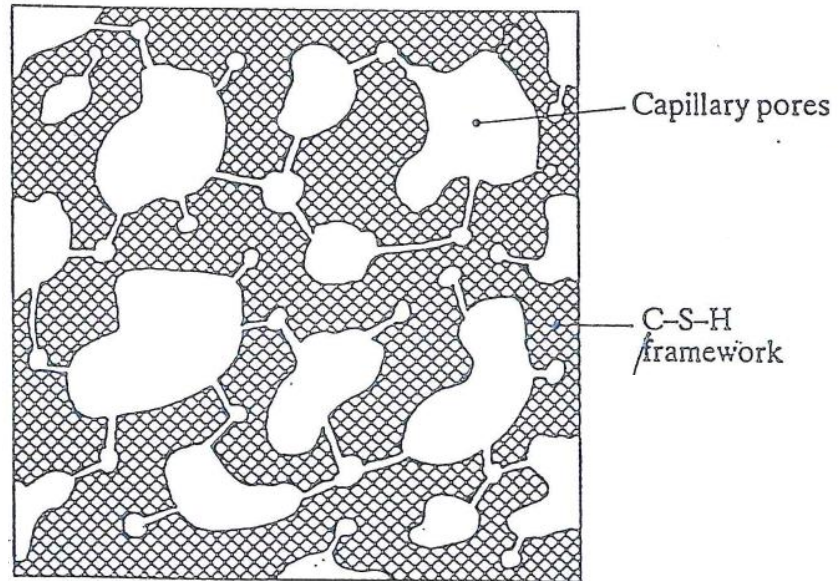
Attributed to
physical
properties, like
strength

Attributed to
chemical properties,
like corrosion and
durability





(a)



(b)



Rebar

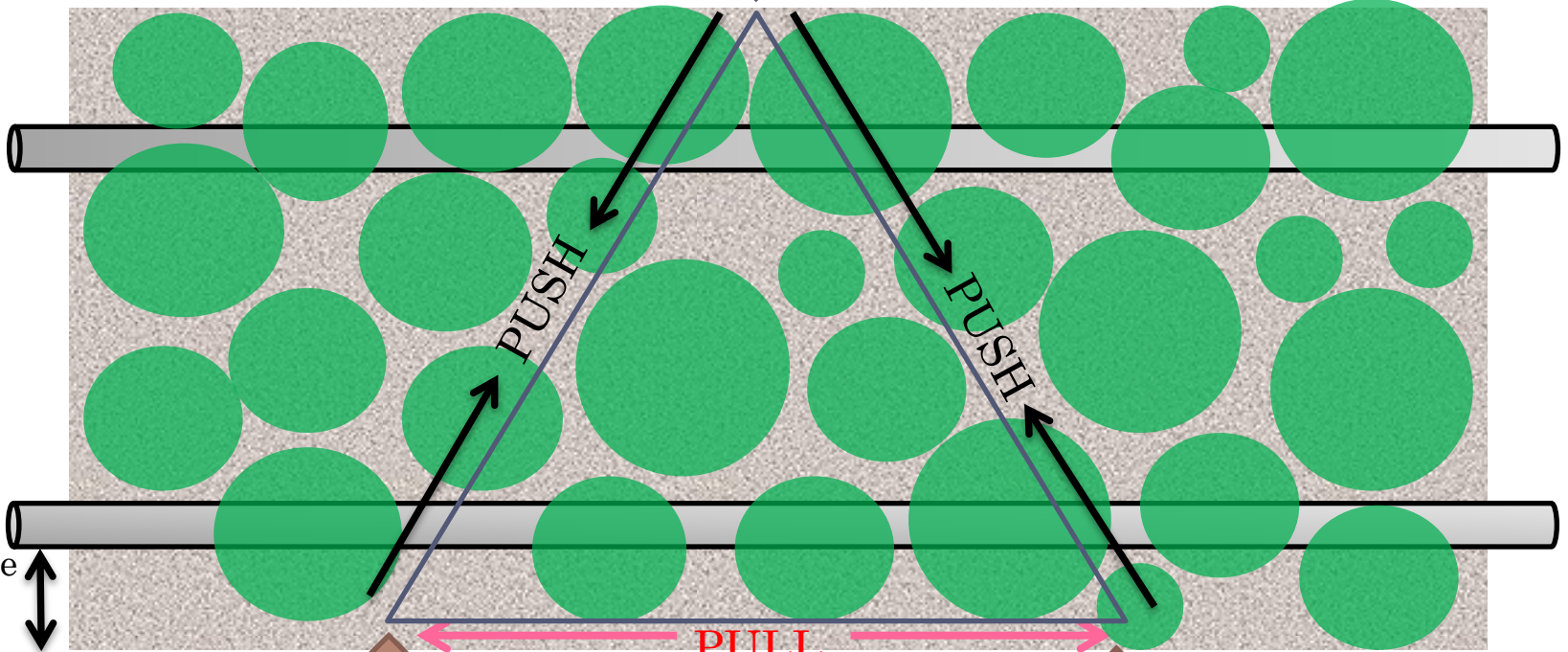


Fillers
aggregates/sand



Binders
(Cement paste/ gel)

APPLIED
FORCE



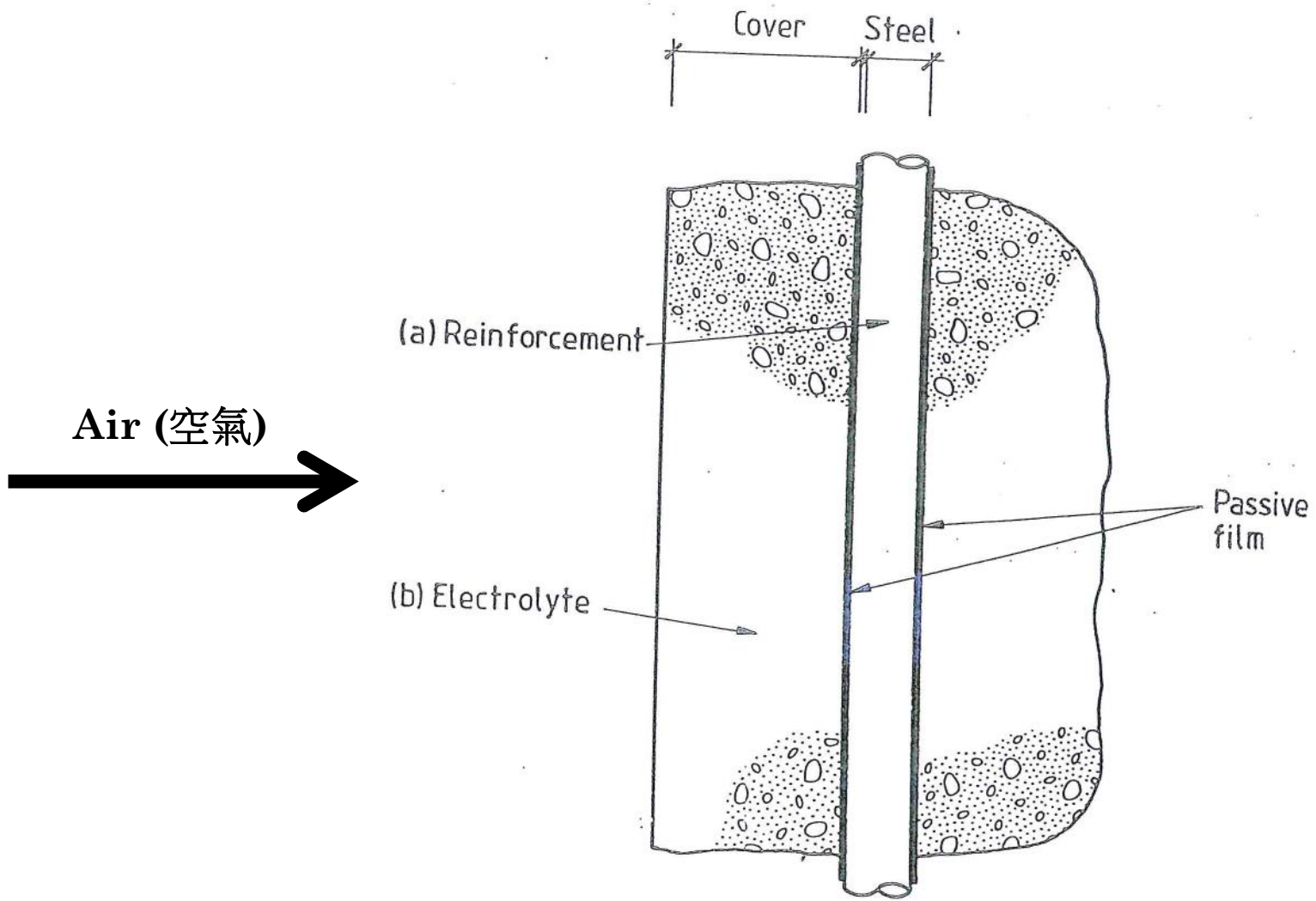
PUSH

PUSH

PULL

SUPPORT
REACTION

SUPPORT
REACTION



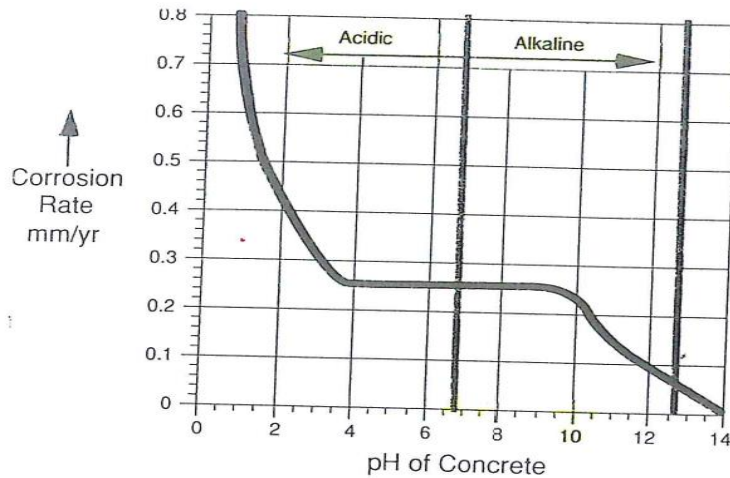
Passivation of reinforcement in good quality concrete

○ Steel Protection

Hydration

- Release alkalis (Sodium, potassium and calcium hydroxides)
 - pH Value 12.5-13.6
 - Passive condition: Corrosion process stops
-
- Loss of passivity: two factors
 - Reduction of alkalinity
 - Presence of free chloride which destroys passivity

Embedded Metal Corrosion Process



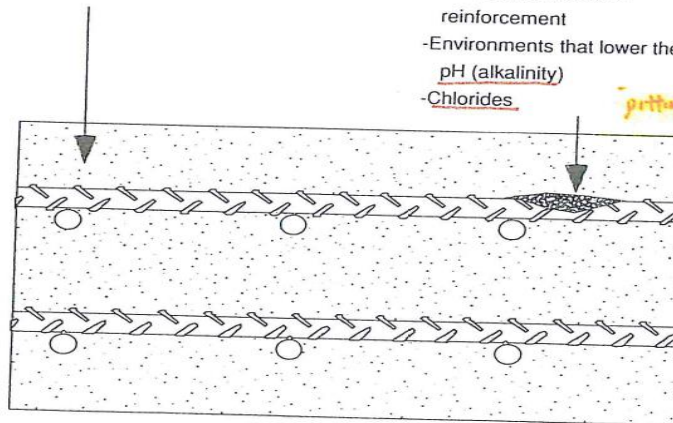
Relationship between pH and corrosion rate

Corrosion Inhibitors

High quality concrete
High pH (Alkalinity)
concrete protects steel surface from corrosion.

Corrosion Promoters

- Oxygen ✓
- Water ✓
- Stray electrical currents
- Uneven chemical environment around reinforcement
- Environments that lower the pH (alkalinity)
- Chlorides



○ *Carbonation or Chloride* + O_2 + H_2O

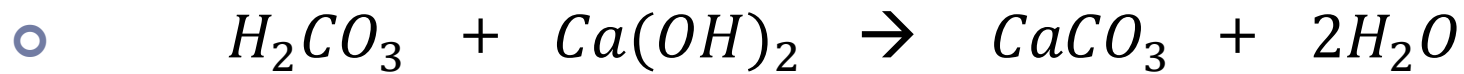
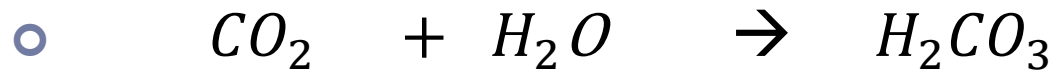
= **Corrosion activated** - Rust

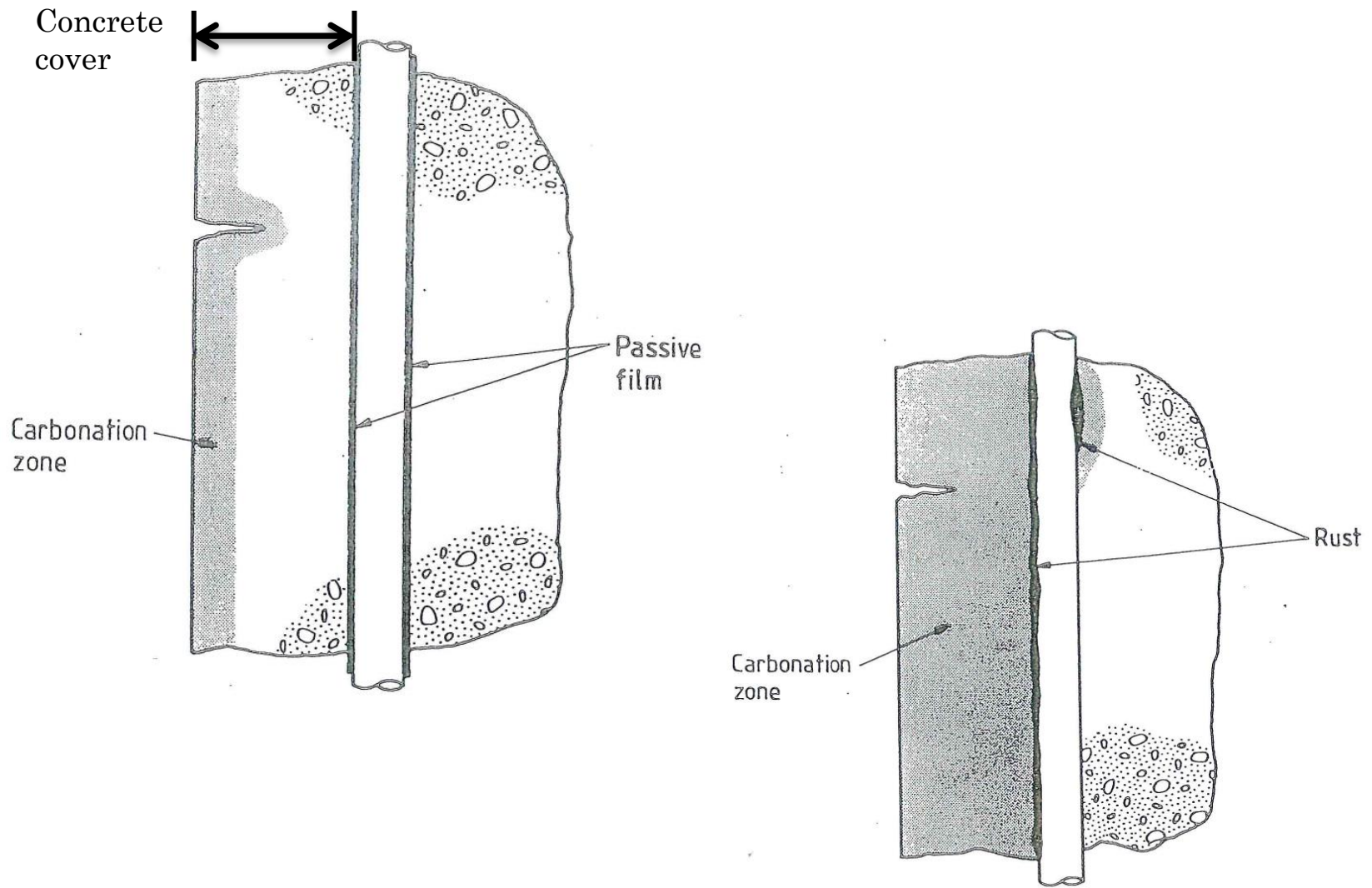
- Expansion

- Cracking

○ Electrolyte (Salt solution in hydrated cement)

CARBONATION





Progression of carbonation front through concrete

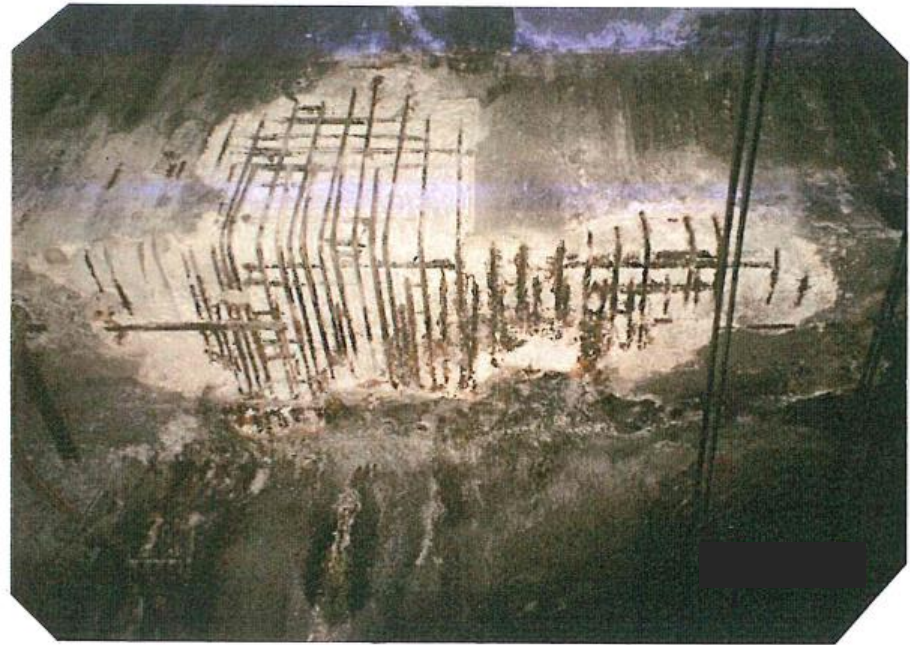
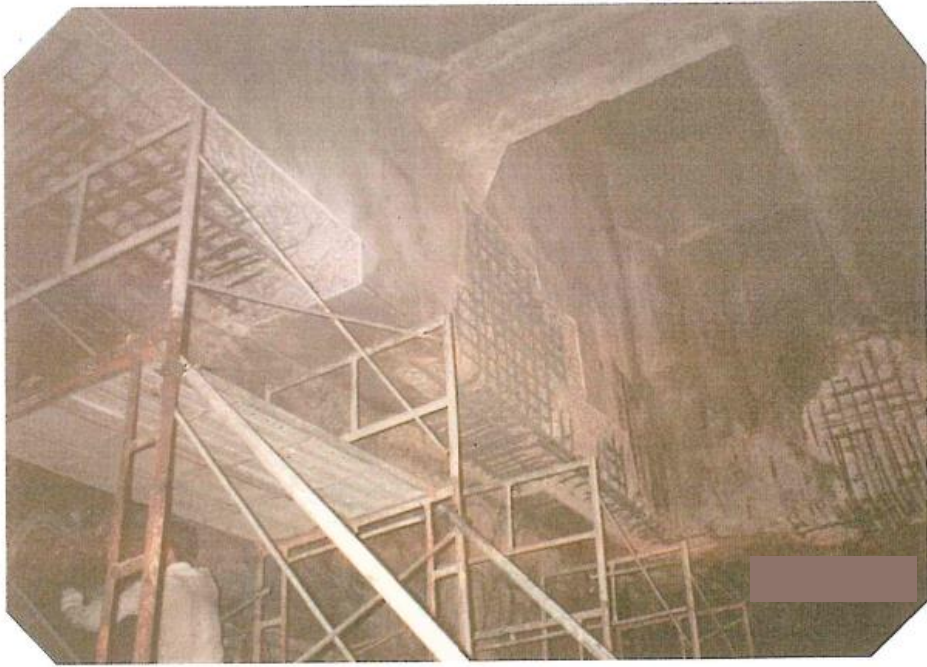
Depth of carbonation = constant \times time^{1/2}

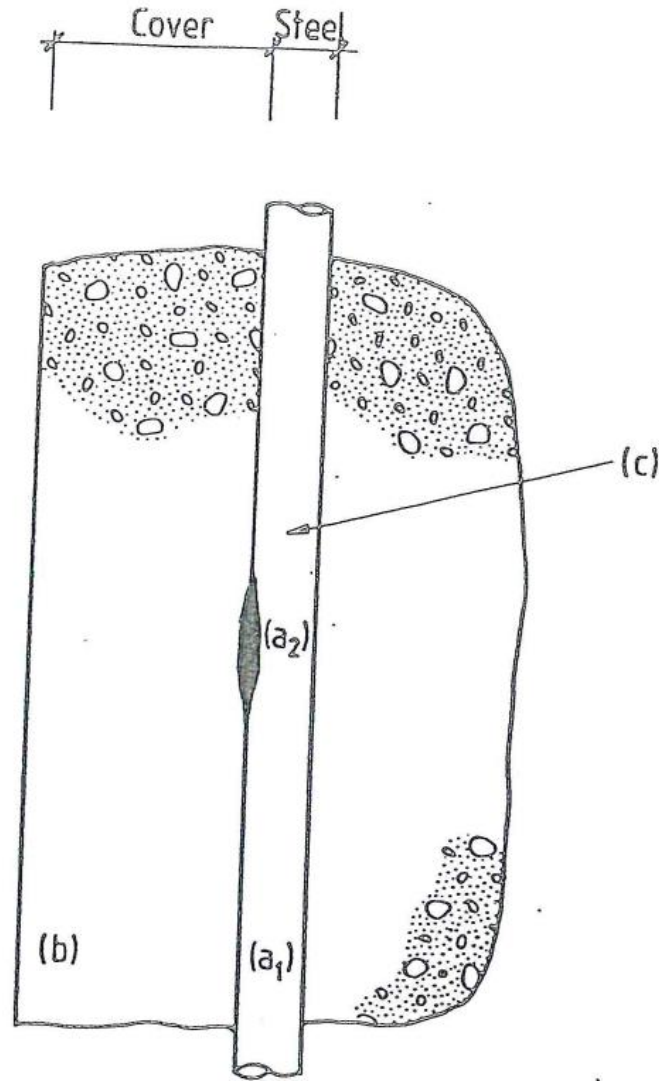
Carbonation time (years) for various depths of cover and W/C ratios.

Ordinary Portland Cement (no additives), aggregate type, sand and gravel						
W/C Ratio	Cover mm					
	5	10	15	20	25	30
0.45	19	75	100 +	100 +	100 +	100 +
0.50	6	25	56	99	100 +	100 +
0.55	3	12	27	49	76	100 +
0.60	1.8	7	16	29	45	65
0.65	1.5	6	13	23	36	52
0.70	1.2	5	11	19	30	43





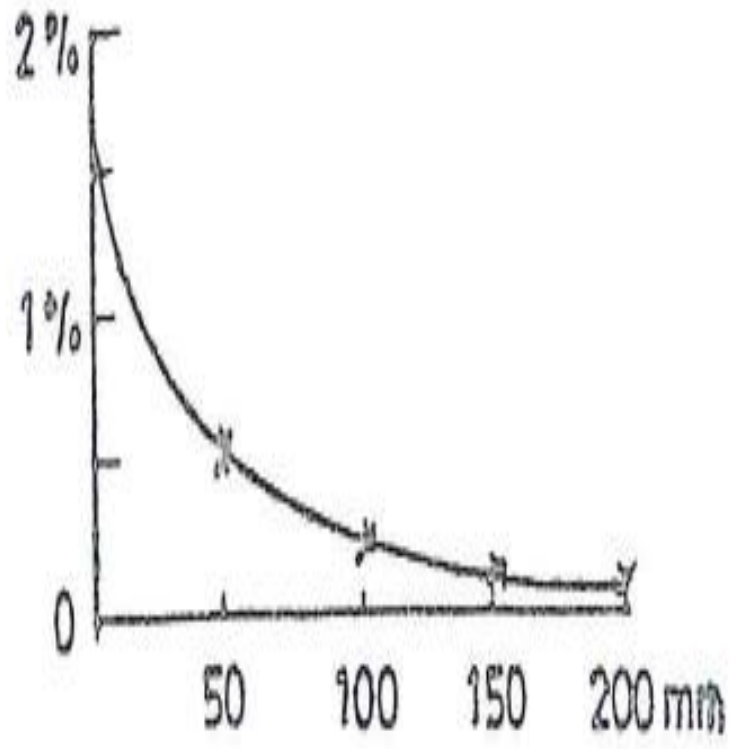
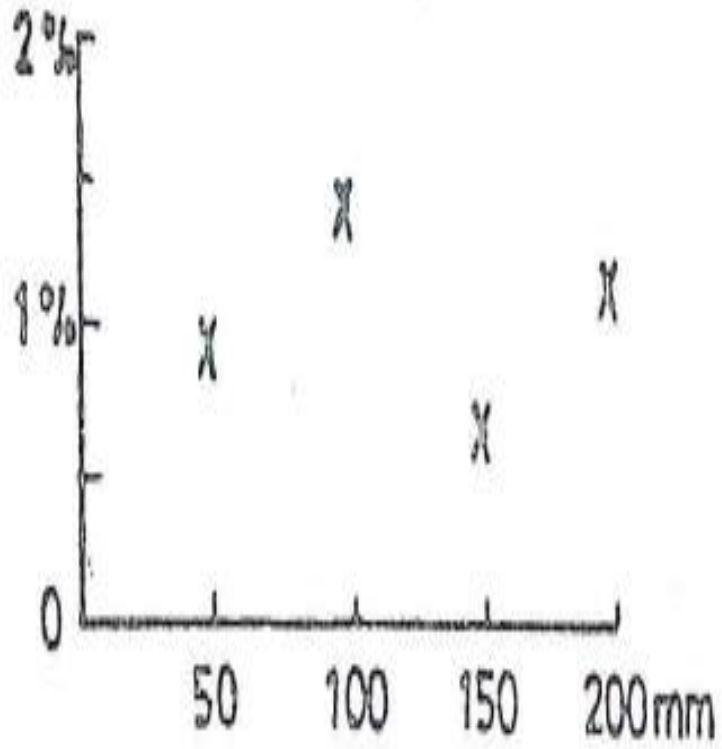




Schematic diagram of chloride induced corrosion of steel

Type or use of concrete	Maximum total chloride content expressed as a percentage of chloride ion by mass of cement ⁽¹⁾
Prestressed concrete. Steam-cured structural concrete	0.1
Concrete made with Sulphate Resisting Portland cement	0.2
Concrete with reinforcement or other embedded metal	0.35
Note: 1. Inclusive of pfa or ggbs	

Table 4.5 - Limits of Chloride content of concrete





Concrete attack by sea water





Concrete attack by sea water



REPAIR SEQUENCE

- ◆ Access (very costly)
- ◆ Protection/ precautionary measure

- Survey
- Test (NDT)
- Mark out
- Hacking off
- Bar cleaning
- Substrate preparation
- Steel priming
- Bond coat
- Patching
- Curing

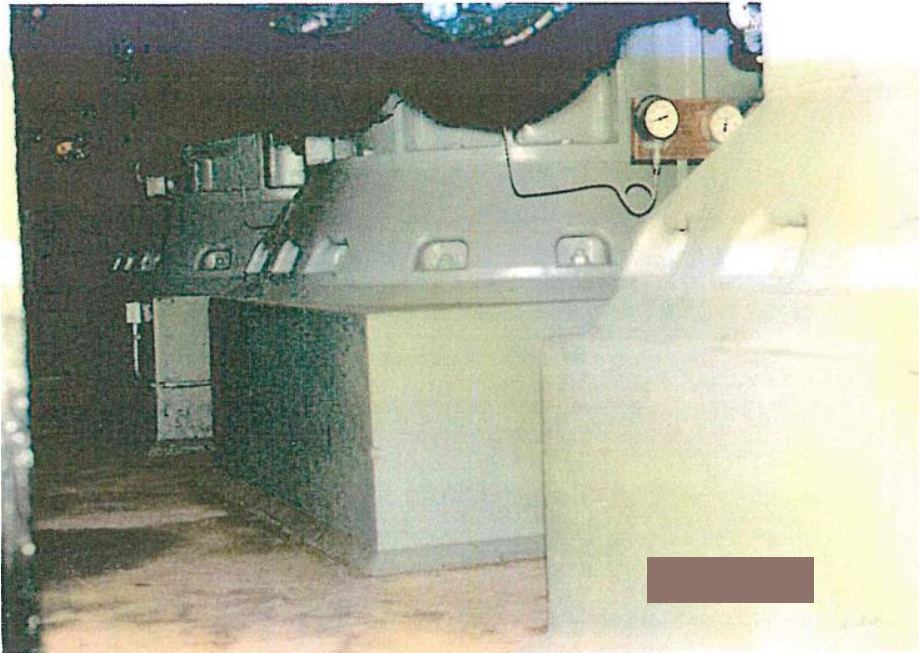




Cement & sand prebagged for site mixed mortar



Concrete plinth before repair



Concrete plinth after repair

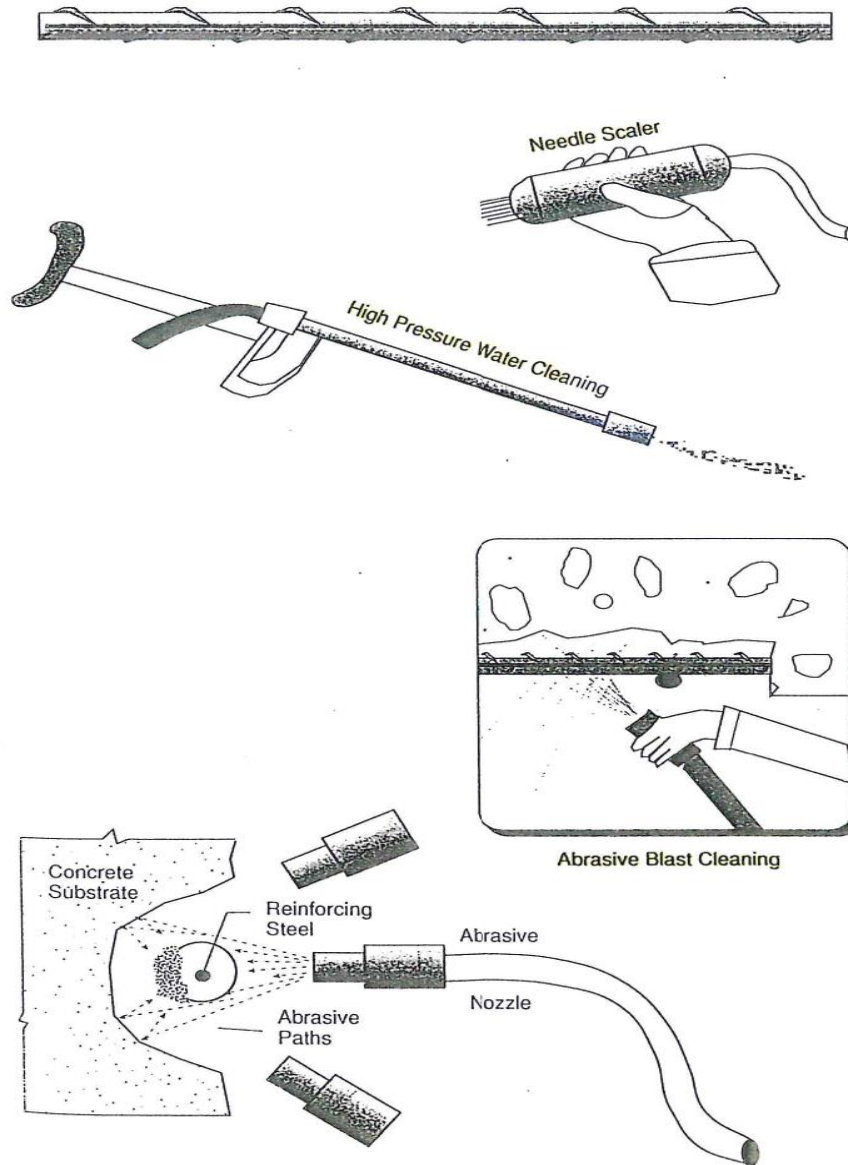


1200mm thick diaphragm wall condition after removal of the spalled concrete



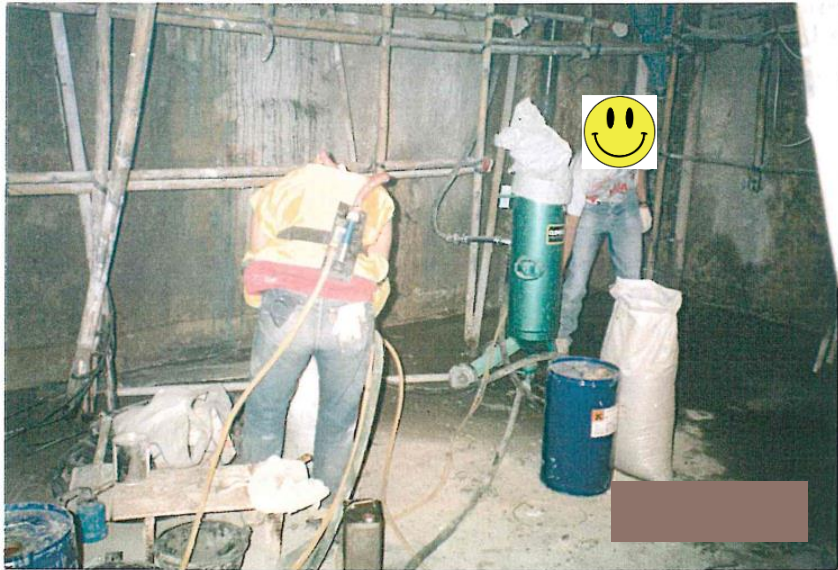
Steel bar condition after removal of the spalled concrete

Reinforcing Steel Cleaning

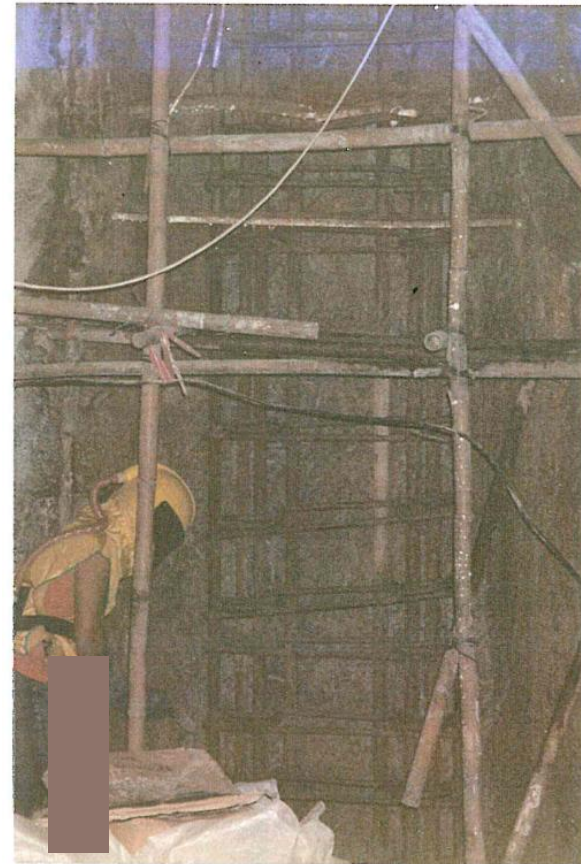


Adapted from IACRS—*Surface Preparation Guideline 3731*, October 15, 1989.

GRIT BLASTING (SAND BLASTING)



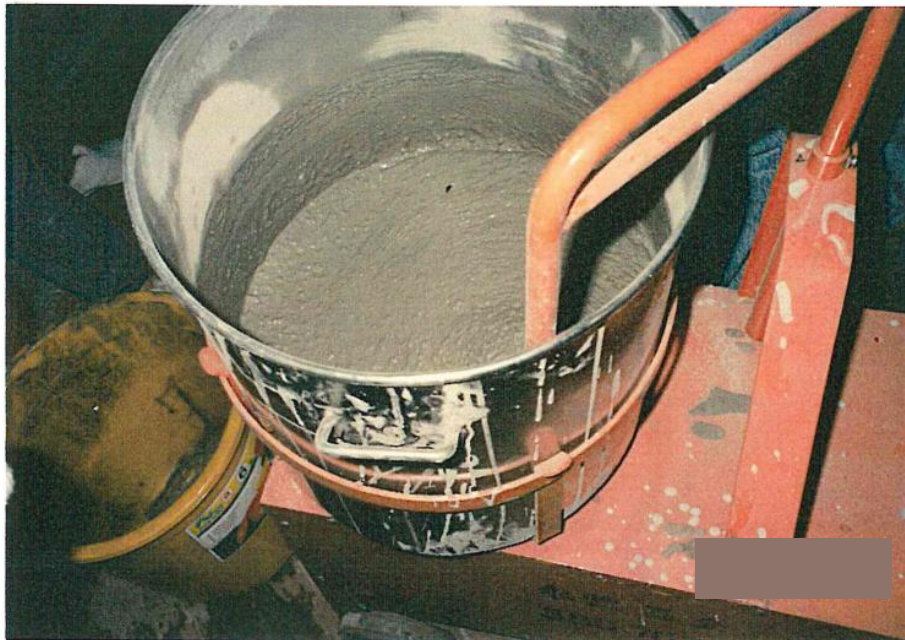
Setting-up of the grit blasting equipment



Grit blasting in progress



Steel bar primed after grit blasting



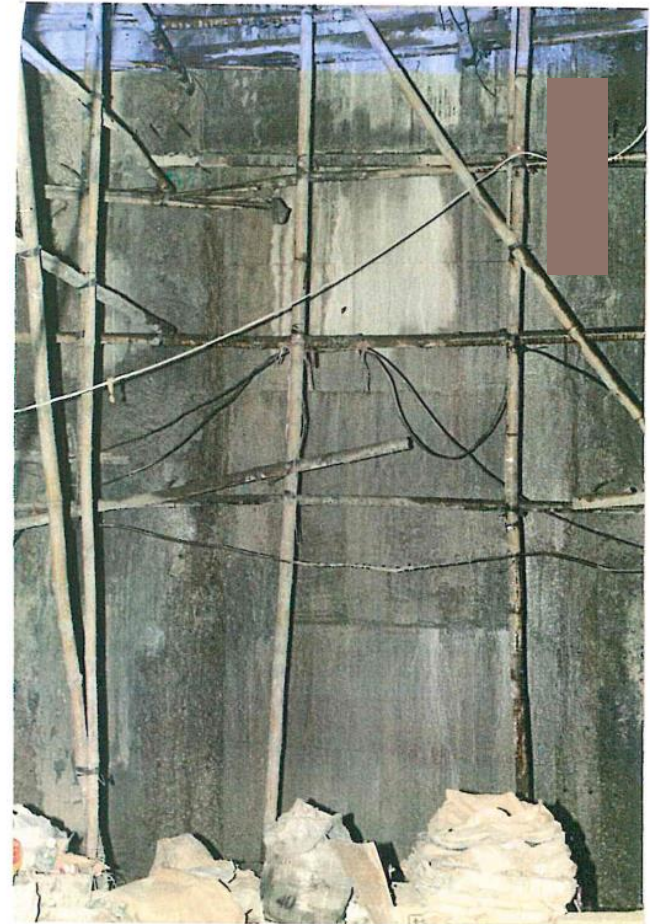
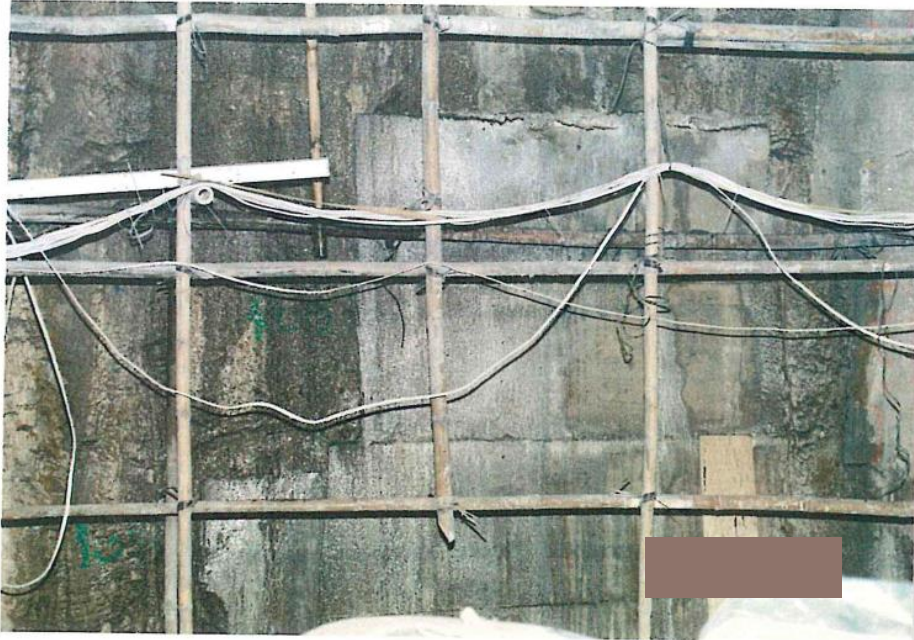
Recasting material, Renderoc LA after mixing



Deleterious/ muddy material within diaphragm wall

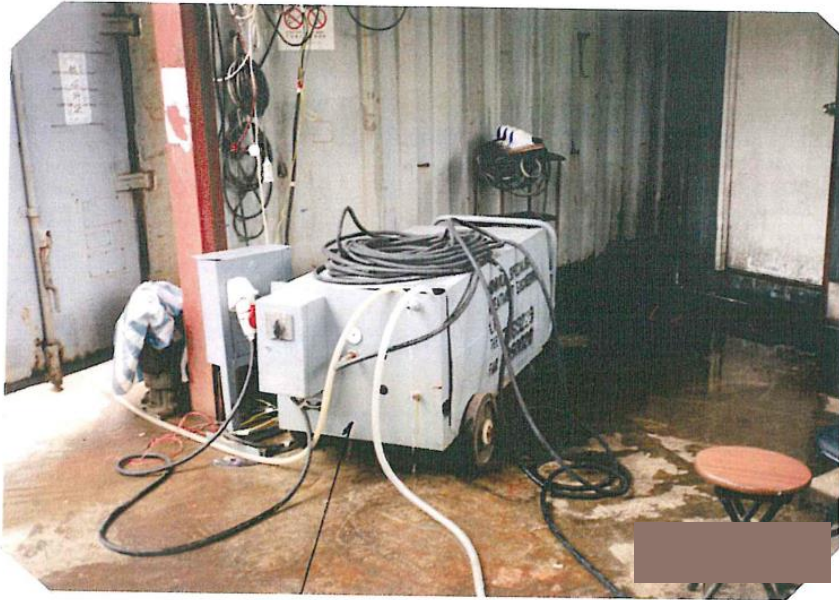


Formwork for recasting



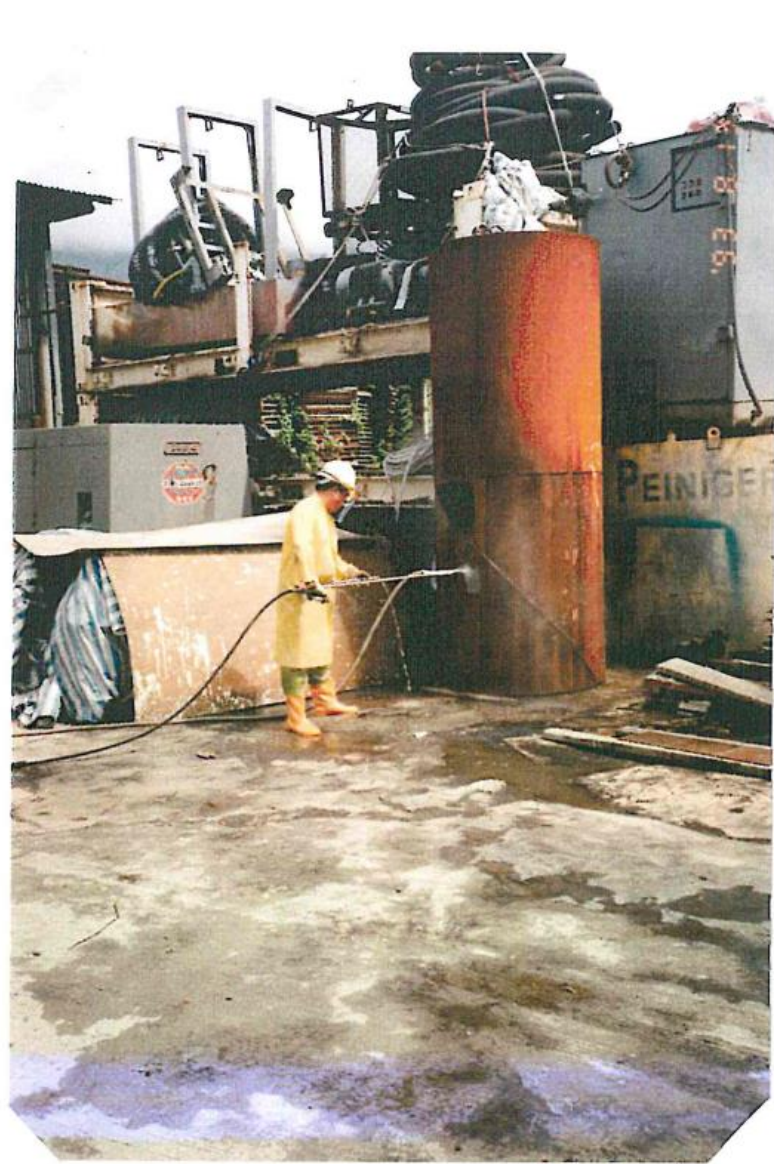
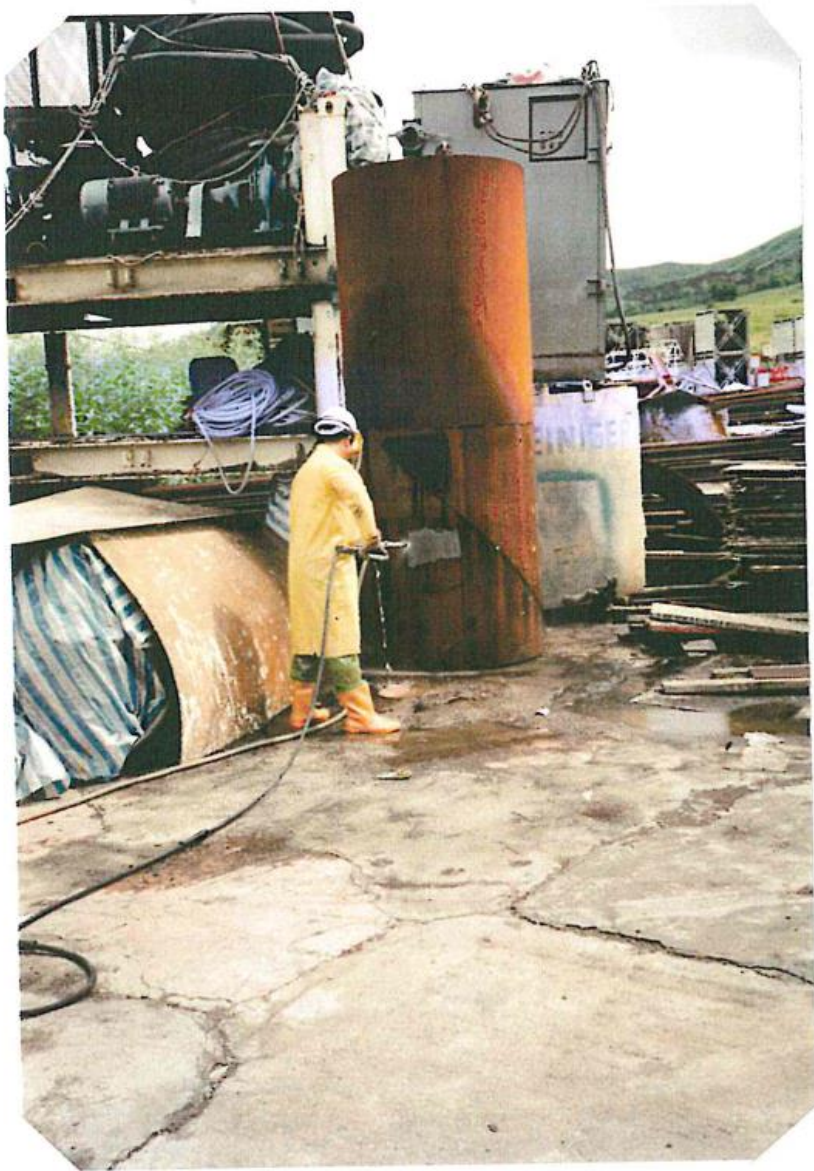
Wall after repair

GRIT BLASTING (WET BLASTING)

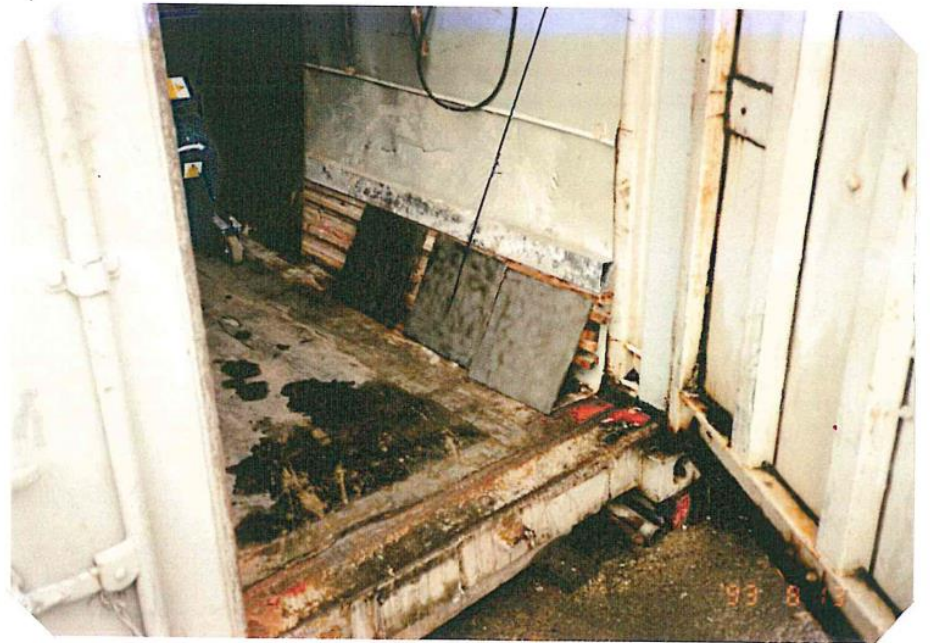


Wet Grit Blasting Trial





Wet Grit Blasting Trial



Wet Grit Blasting Trial

BLAST N'VAC

The Leader in Abrasive Vacuum Blasting



**“A DUST FREE/FULLY ENCLOSED/DRY
BLAST CLEANING REVOLUTION”**

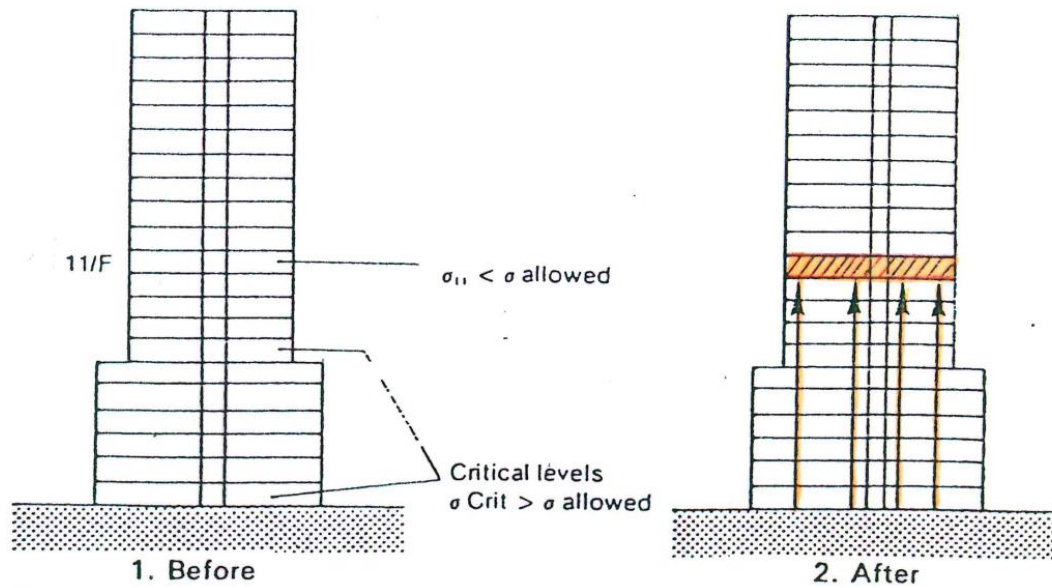


Fig 12. **Internal load jacking technique**

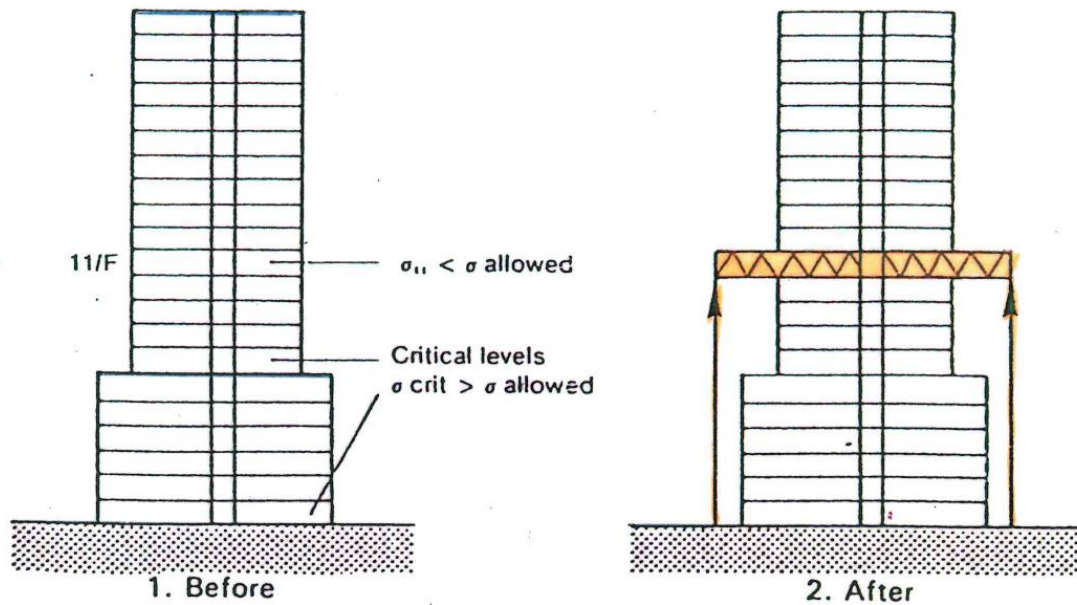


Fig 13. **External load jacking technique**







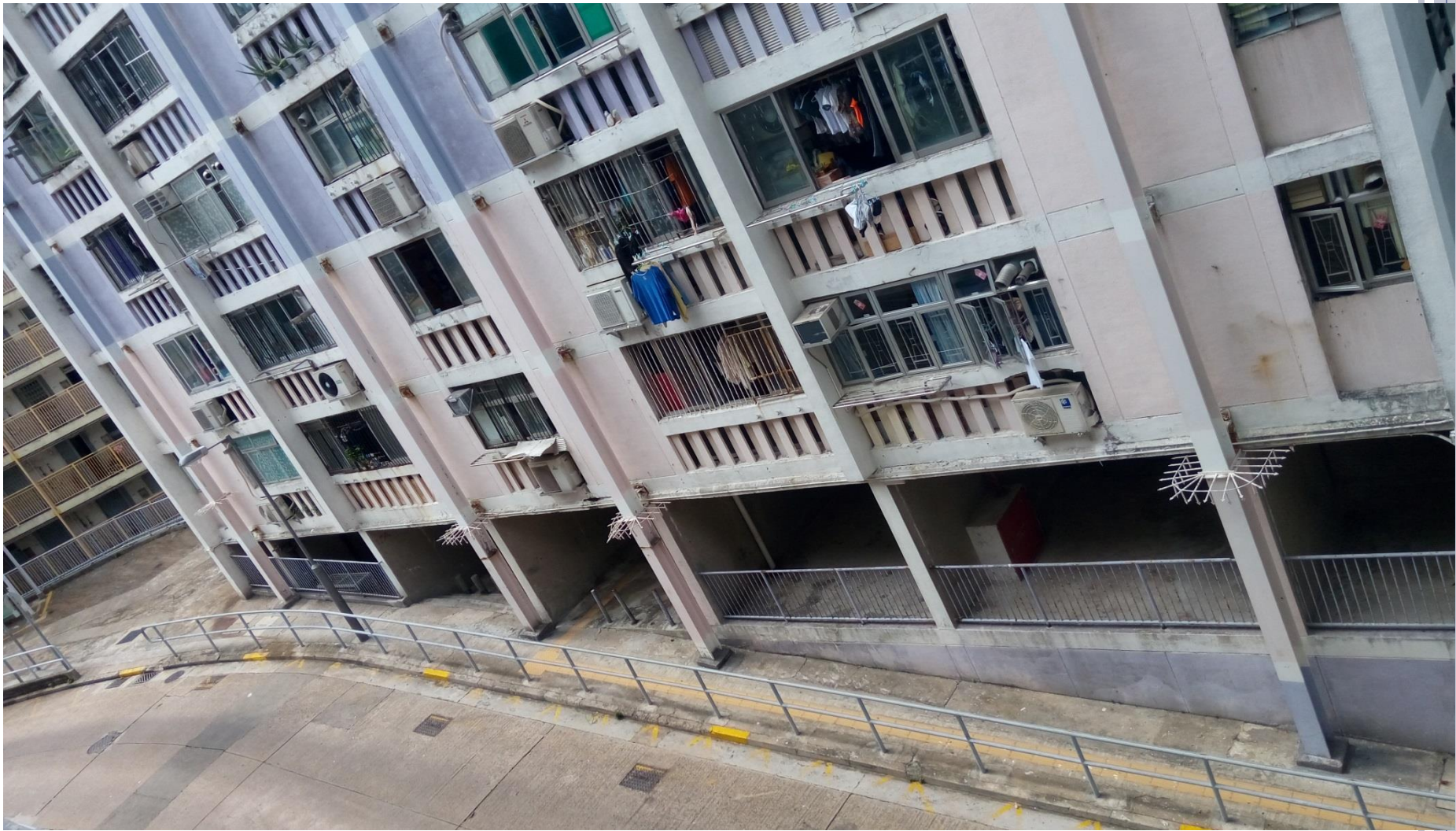
















The left side of the slide features a vertical stack of decorative elements. At the top, there are several thin, vertical stripes in shades of gray and white. Below these stripes, a series of blue circles of varying sizes are arranged in a descending, staggered pattern. The largest circle is at the top left, and the circles become progressively smaller and more widely spaced as they move down and to the right. The text is positioned to the right of these decorative elements.

INSPECTION TOOLS AND INVESTIGATION EQUIPMENT AVAILABLE IN BUILDINGS DEPARTMENT



APPLICATIONS OF THE TOOLS AND EQUIPMENT, AND EXAMPLE OF WORKS

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Schmidt Hammer

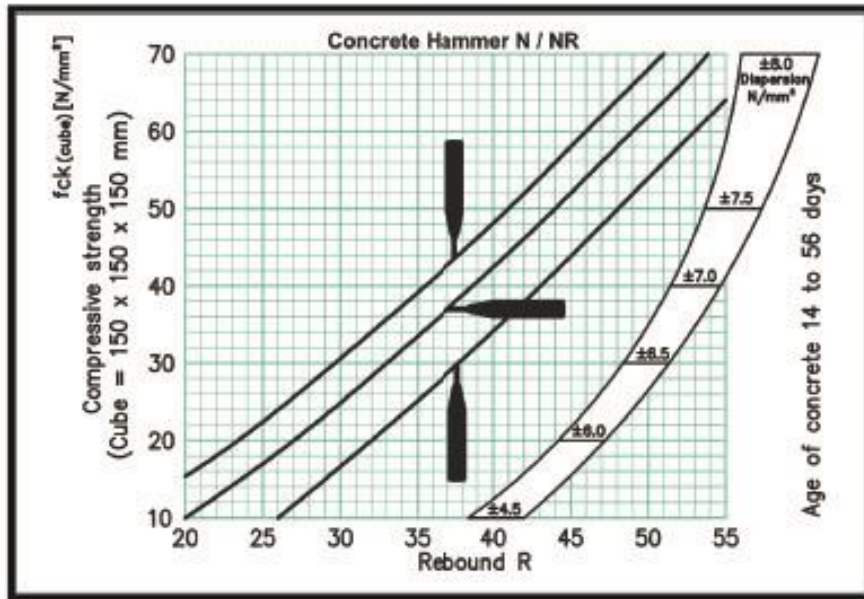
SCHMIDT HAMMER



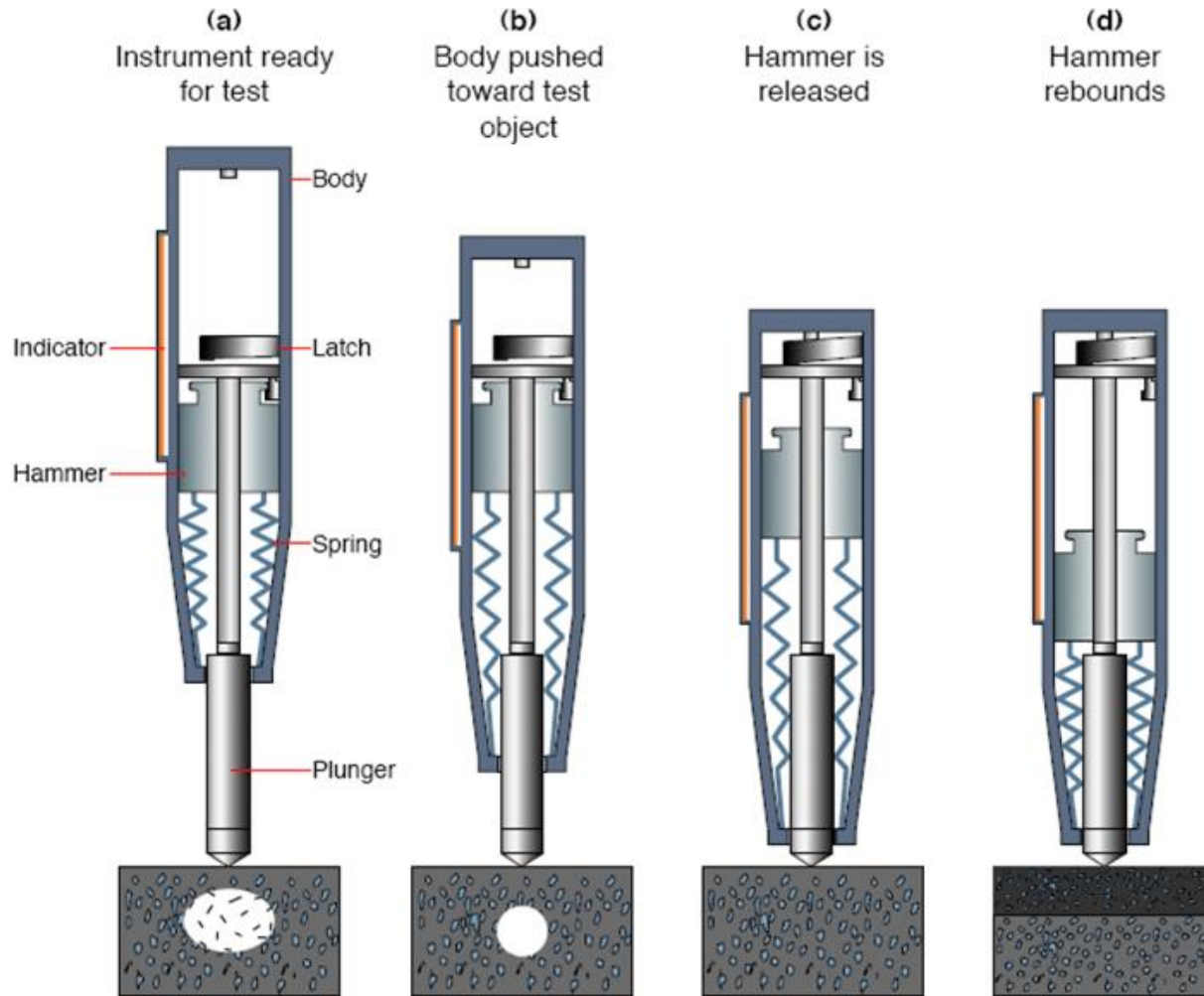
INTRODUCTION

- The rebound hammer test is one of the non-destructive tests used to check the compressive strength of concrete

REBOUND HAMMER CHART



REBOUND HAMMER TEST





APPLICATIONS OF THE TOOLS AND EQUIPMENT, AND EXAMPLE OF WORKS

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Cover meter survey

COVER METER SURVEY



Hilti PS35
Ferrodetector



Proceq Profoscope+ Rebar
Detector



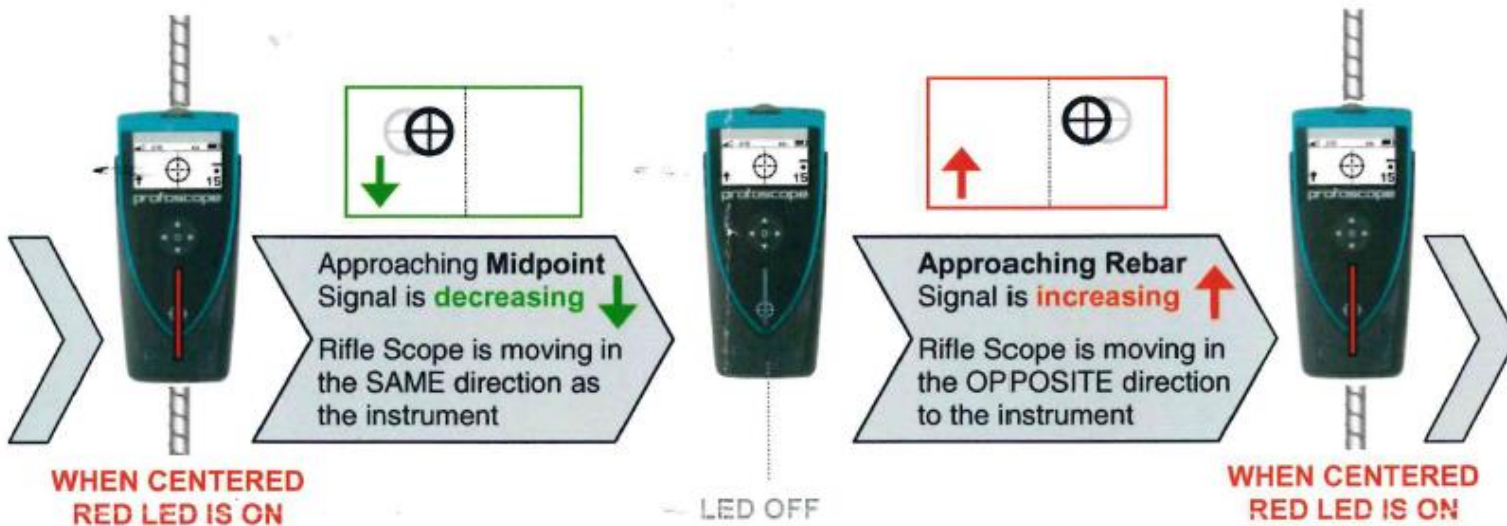
INTRODUCTION

PROCEQ PROFOSCOPE+ REBAR DETECTOR

- Fast and accurate rebar detection, cover and diameter size measurement

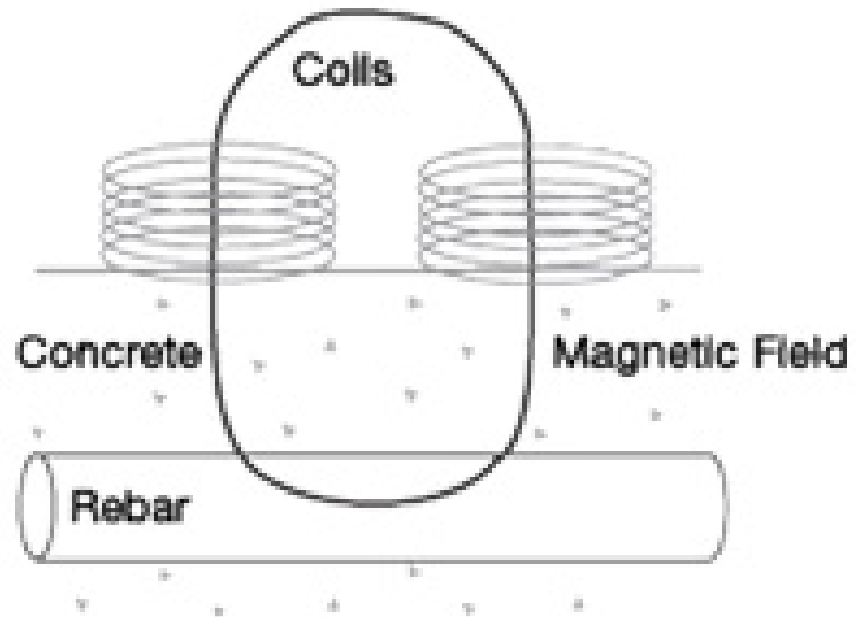


HOW TO DISTINGUISH BETWEEN A REBAR AND A “MIDPOINT”?



THE MEASUREMENT PRINCIPLE

- The Profoscope used electromagnetic pulse induction technology to detect rebars.



APPLICATION





APPLICATIONS OF THE TOOLS AND EQUIPMENT, AND EXAMPLE OF WORKS

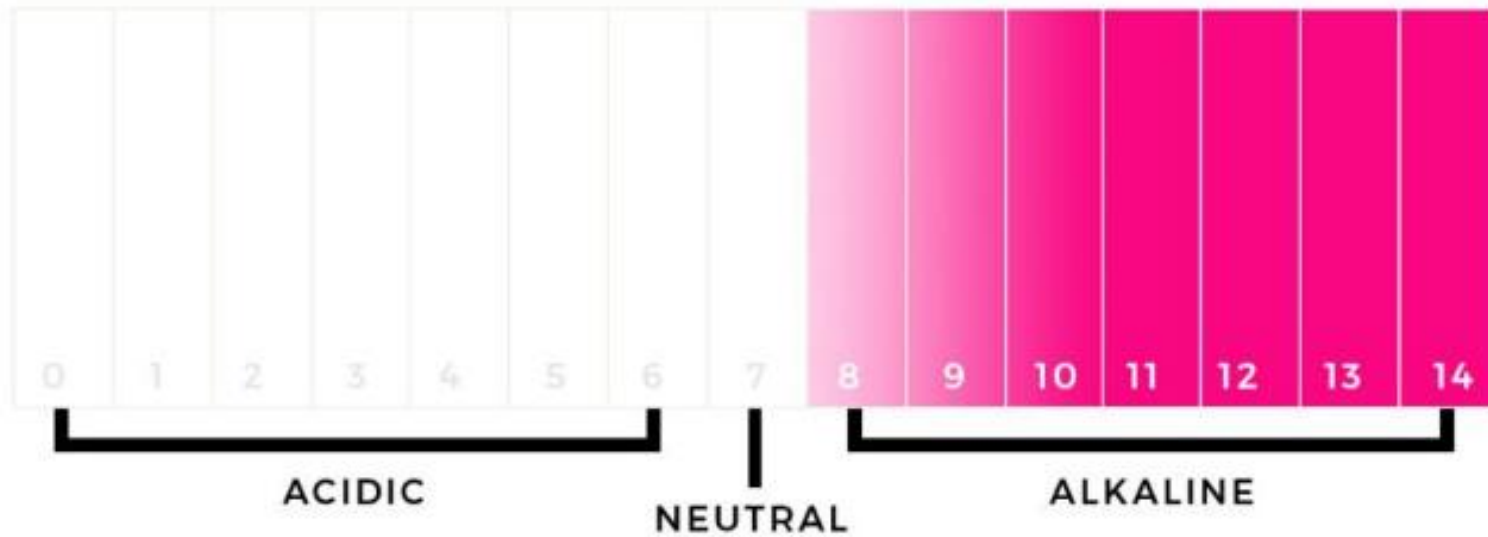
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Alkalinity PH test

INTRODUCTION

- This simple test allows the measurement of depth of carbonation through the surface of concrete. During the test, the broken or cored surface is sprayed with phenolphthalein solution to detect the loss of alkalinity associated with carbonation.
 - 1 plastic wash bottle
 - 1 liter of phenolphthalein solution

PHENOLPHTHALEIN COLOR CHANGE







↓ Carbonated Area
indicates below pH 8.2, colorless

↑
Sound Area
indicates above pH 10, fuchsia (pink)



← Non-carbonated area (pinky-red)

← Carbonated area (colorless)

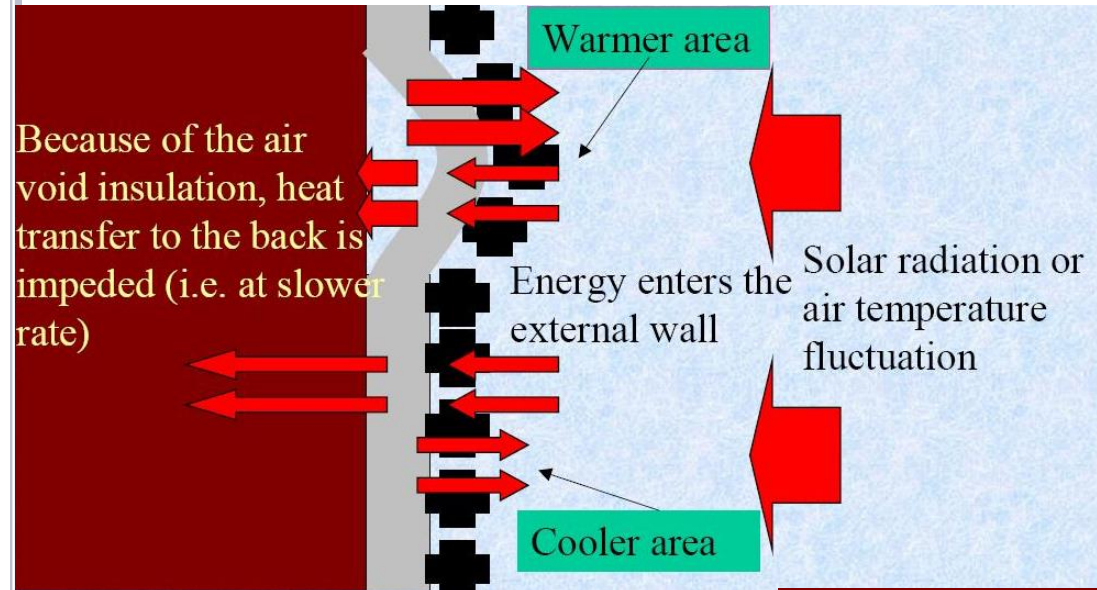


APPLICATIONS OF THE TOOLS AND EQUIPMENT, AND EXAMPLE OF WORKS

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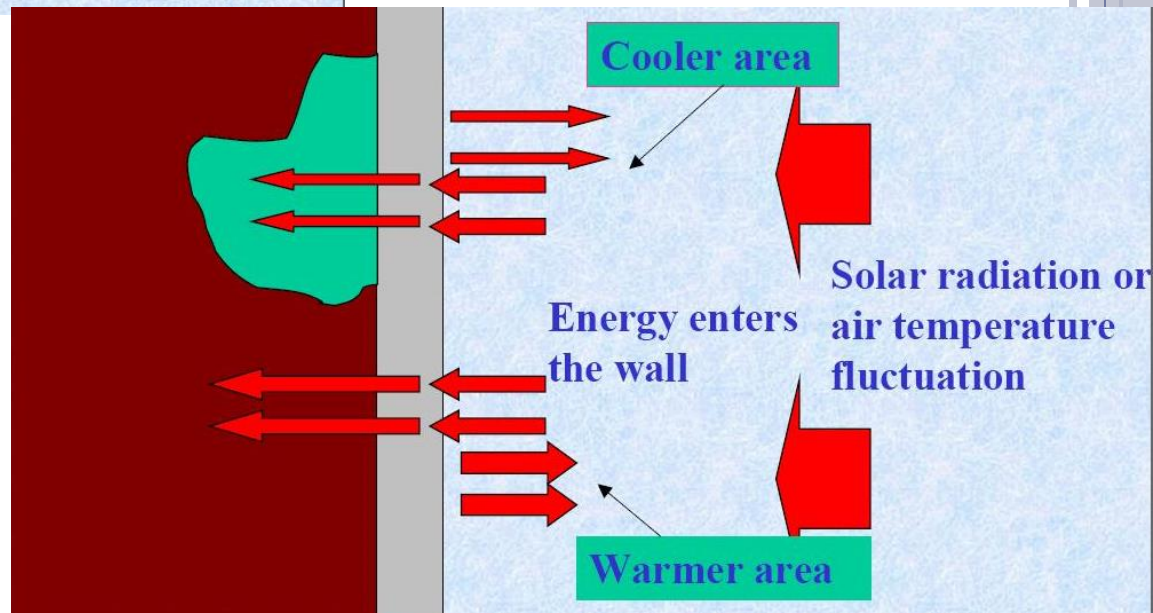
Infrared Thermal Imager

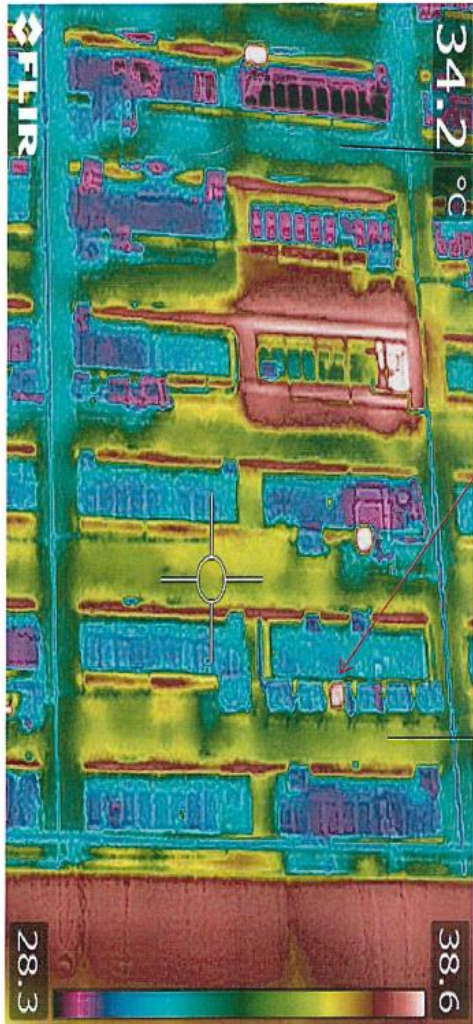
BUILDING THERMOGRAPHY



Air is a poor heat conductor, higher surface temperature results

Water is a good heat conductor, cold spots on the local surface





Low temp.

High temp.

11/F

Heat source (high temp.) suggested the air conditioning unit was switched on.

Premises concerned:

Date and time:
11 Oct 2017 8:00pm

Carried out and attended by

7/F



11/F

7/F

Inspection Date: 23.11.2017

Location: , Ceiling Soffit, Living Room

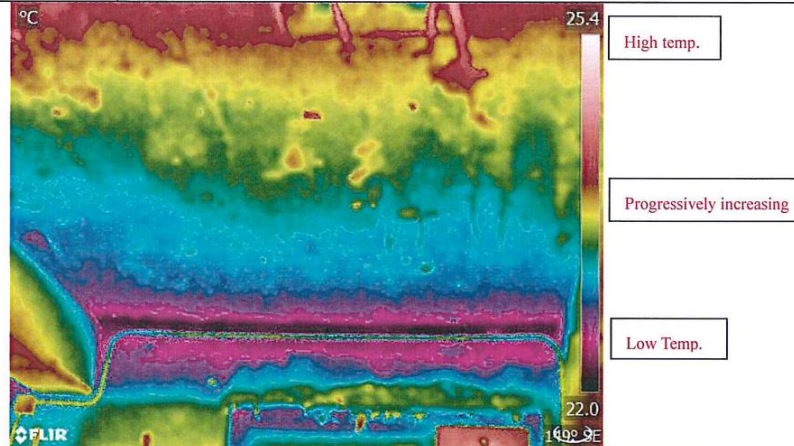


Photo no. 1



Photo no. 1a

Note:

Scanning Date : 23rd November 2017, 11:00-12:15

Attended by:

RDU observation:

- Thermal scanning record consistent with the site conditions
- Water seepage not evident



APPLICATIONS OF THE TOOLS AND EQUIPMENT, AND EXAMPLE OF WORKS

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Laser Distance Meter

PRACTICAL APPLICATION:



PRACTICAL APPLICATION: ROOF TOP STRUCTURE





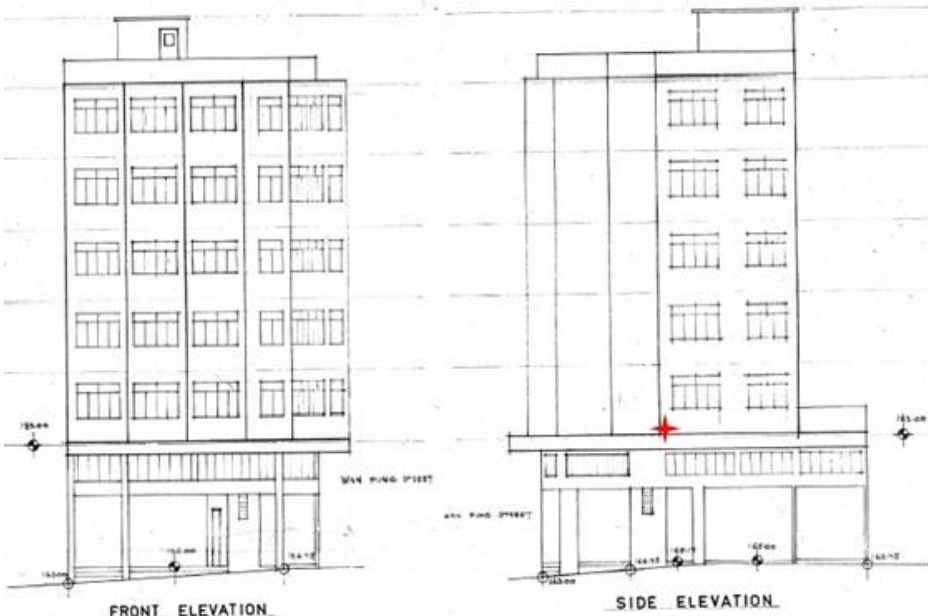


鐵器裝修工程
捲換廚批油坐洗簾換
開彈弓柜灰擦廁手盆蓬門鎖
手提: 9080 0093
環鳳街59號

承接
樓外牆翻新
樓內牆磚
油漆批灰
泥水批滿
安裝坐廁
洗手盆
9080 0093

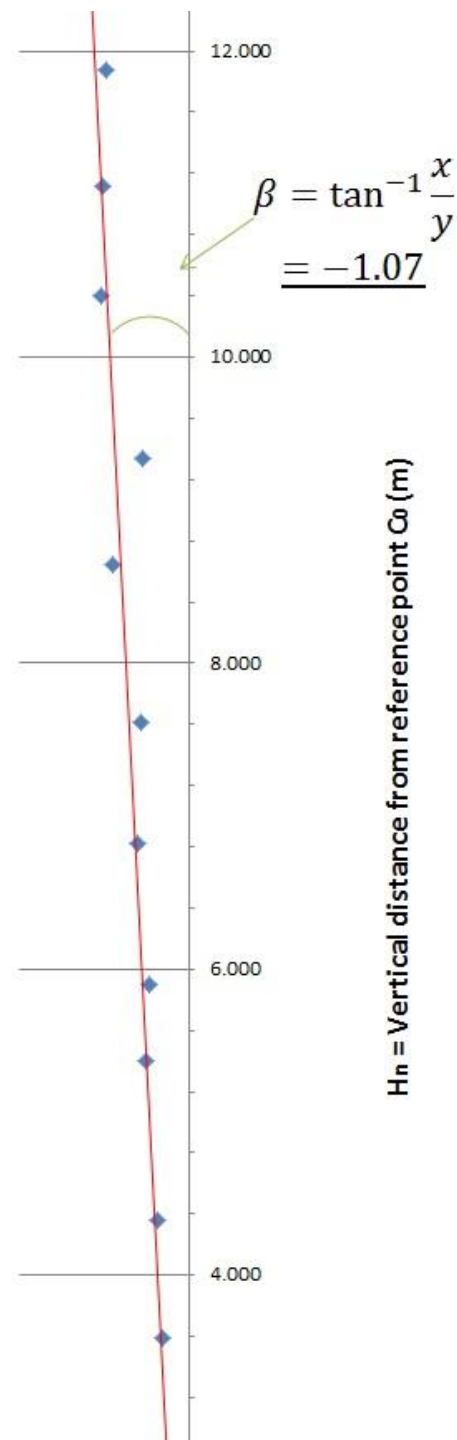


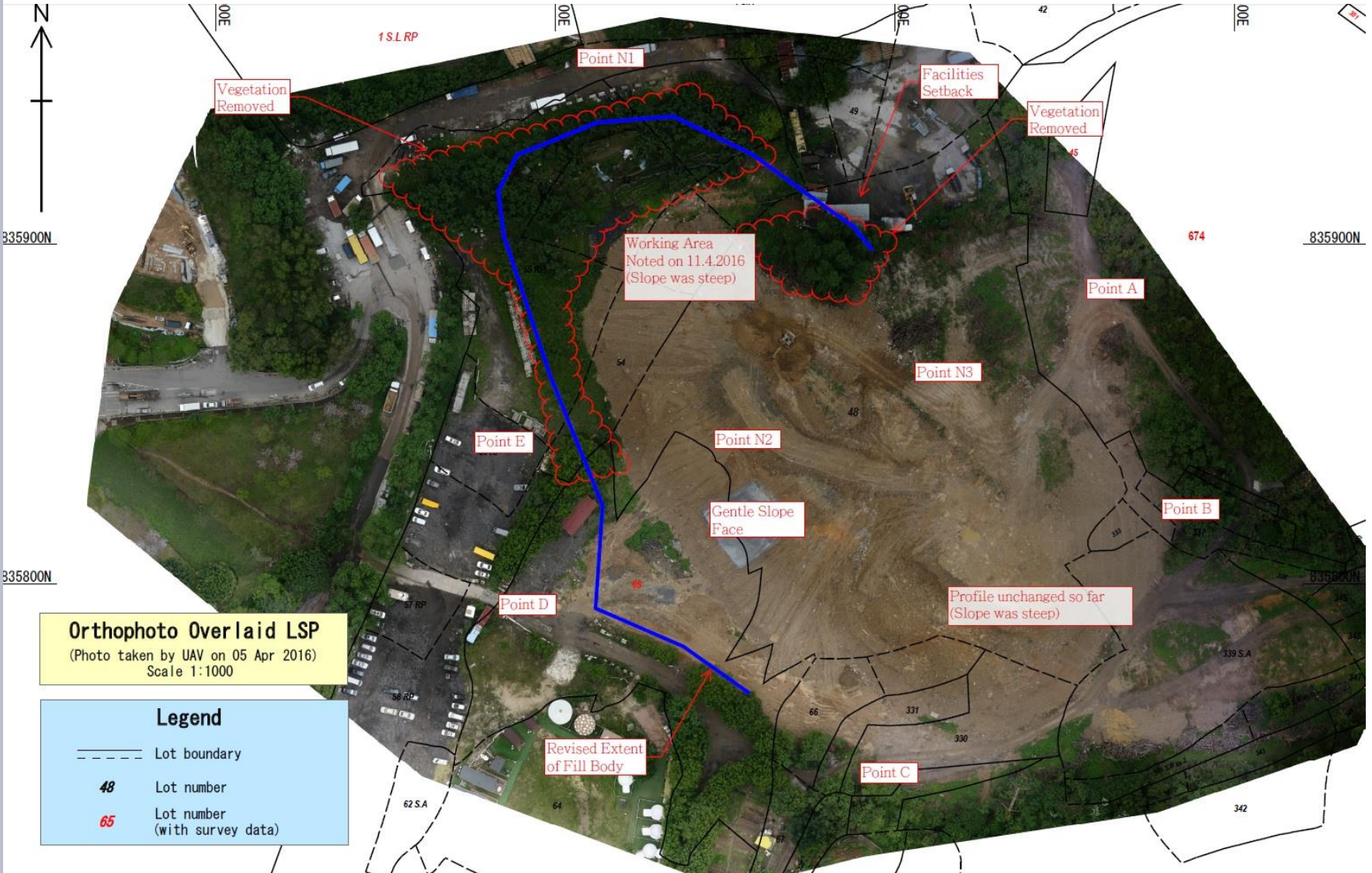
C ₁	6.204	14.447	9.335	-0.112
C ₂	7.273	14.352	10.404	-0.207
C ₃	7.984	14.353	11.115	-0.206
C ₄	8.744	14.363	11.875	-0.196
C ₅	9.341	14.325	12.472	-0.234
C ₆	10.152	14.329	13.283	-0.230
C ₇	11.297	14.236	14.428	-0.323
C ₈				



← Shooting direction of the Meter

★ Location of reference point Co





Orthophoto Overlaid LSP
 (Photo taken by UAV on 05 Apr 2016)
 Scale 1:1000

Legend

- Lot boundary
- 48** Lot number
- 65** Lot number (with survey data)

