EXCELICRETE™
優化混凝土

# Innovations in Excelicrete™


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Housing Department


**Standing Committee on Concrete Technology**
**Annual Concrete Seminar 2013**
18 April 2013, Hong Kong, China


Content
Introduction
Excelicrete™ – A Genius Invention
Technical Review of Self Compacting Concrete
Self Compacting Excelicrete™ – An Earnest Exploration
Summary and Way Forward


INTRODUCTION


## Kai Tak Site 1B

- Site Area : 5.7 Hectares
- Domestic Plot Ratio : 5.51
- Number of Flats : 8,164 (9 Blocks)
- Contract Period : November 2009 – August 2013
- Main Contractor : Yau Lee - Hsin Chong Joint Venture
- Contract Price : Approximately HK$3,000M


Carport
Kindergarten
Commercial Facilities
Kai Tak Site 1B in March 2013

# Public Rental Housing Development at Kai Tak Site 1B

## Integrated Contract Arrangement

- Design and construction of foundation and superstructure.
- Implementation of all proposals for innovation submitted by Contractor at tender stage and accepted by Employer.
- Among 28 innovation proposals, **Application of Excelicrete™ System** (formerly known as iCrete™) was used for production of concrete for all structural works of commercial facilities, carport, kindergarten and external works.

# Introduction to Excelicrete™ System

- **Less cement/cost; less adverse environmental impact.**
- **Housing Department** is the **Pioneer** that marks a breakthrough by bringing in performance based approach for concrete production technology in Hong Kong.
- Many job references in the US; the most renowned example is the 104-storey **One World Trade Center** in New York City
  - Achieved a record breaking 14,000 psi or **~100 MPa** of compressive strength.
  - Mix contains **42% less cement** than conventional concrete.

# 11 Times Square

New York, US

40-storey

Completed in 2010

70 MPa


Revel Atlantic City, New York
48-storey, opened in 2012, top strength of 100 MPa

# Beekman Tower, New York

76-storey, opened in 2011, top strength of **85 MPa**

**Beekman Tower Testimonial:**

"I've never seen a **concrete** like this – high performance, cost effective and, best of all, environmentally responsible. I would like to specify it for my projects." - Frank Gehry, Architect

# Other Masterpieces of Frank Gehry

Dancing House in Prague, Czech

Gehry Tower in Hannover, Germany

Guggenheim Museum in Bilbao, Spain

IAC-Building in New York, USA

Chrome Building in Germany


傲璇 Opus Hong Kong

# 傲璇 Opus Hong Kong

Octopus



Floor 02

# 傲璇 Opus Hong Kong

## Octopus


Floor 03

# 傲璇 Opus Hong Kong

## Octopus


Floor 05

# 傲璇 Opus Hong Kong

## Octopus


Floor 06

# 傲璇 Opus Hong Kong

## Octopus


Floor 07

# 傲璇 Opus Hong Kong

## Octopus



Floor 08

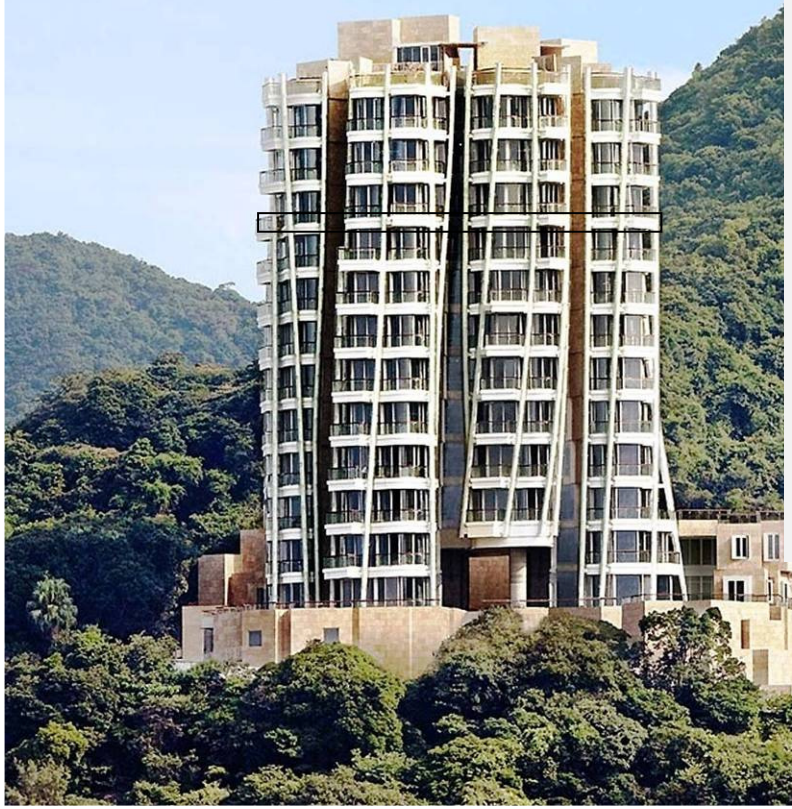
# 傲璇 Opus Hong Kong

## Octopus



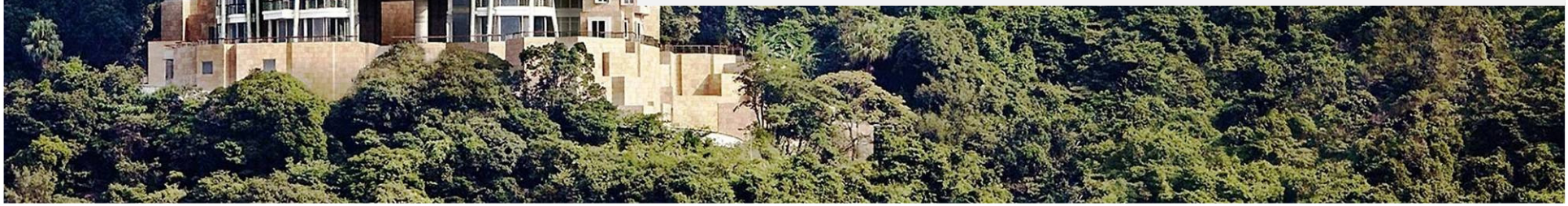
Floor 09

# 傲璇 Opus Hong Kong



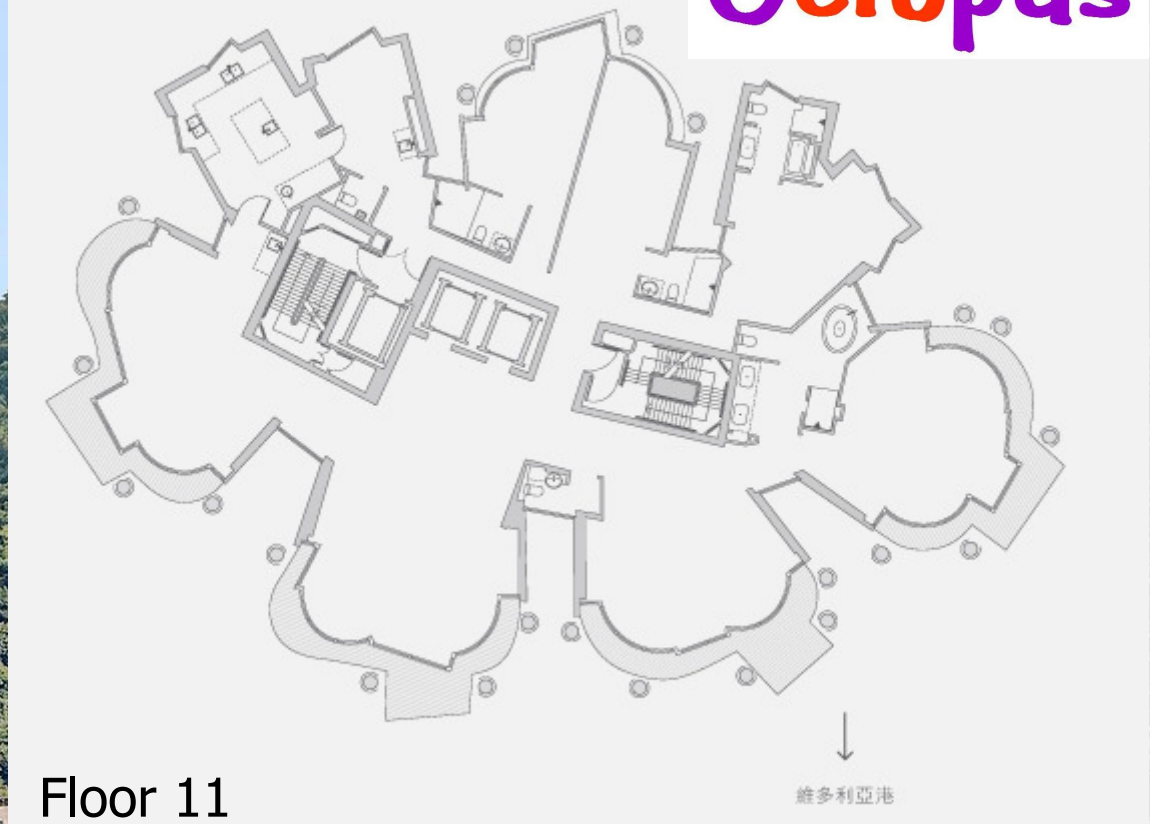
## Octopus

Floor 10



# 傲璇 Opus Hong Kong

## Octopus




Floor 11

# 傲璇 Opus Hong Kong

Octopus



Floor 12

維多利亞港

# 傲璇 Opus Hong Kong

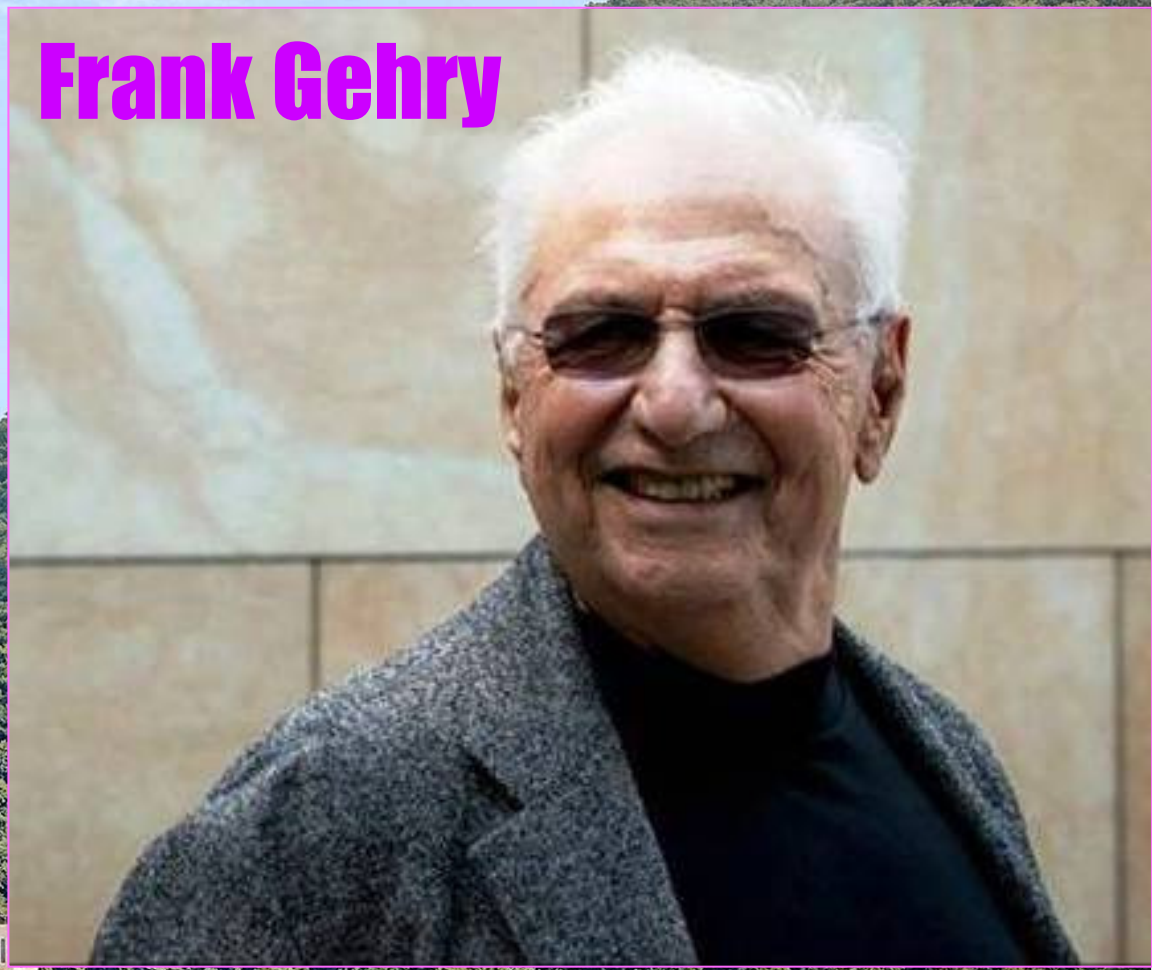
Octopus



Sky Terrace

維多利亞港

# 傲璇 Opus Hong Kong



## Beekman Tower, New York

76-storey, opened in 2011, top strength of 85 MPa

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"I've never seen a **concrete** like this – high performance, cost effective and, best of all, environmentally responsible. I would like to specify it for my projects." - Frank Gehry, Architect

***The recognition by this Genius makes Excelicrete™ all the more Genius***

# Excelicrete™ vs iCrete™

# Excelicrete™ – An Innovation

- An intelligent concrete mix design technology developed in the mid-1990s in USA.
- Through real time QC system to the entire concrete production process, it optimizes particle packing, resulting in enhanced concrete strength and workability while reduction in cement content.
- Can achieve higher strength and enhanced workability with less cement constituents.
- Reduction of cement usage up to **42%**, hence the harmful carbon dioxide emissions.
- Durability, shrinkage, creep and permeability are significantly improved.

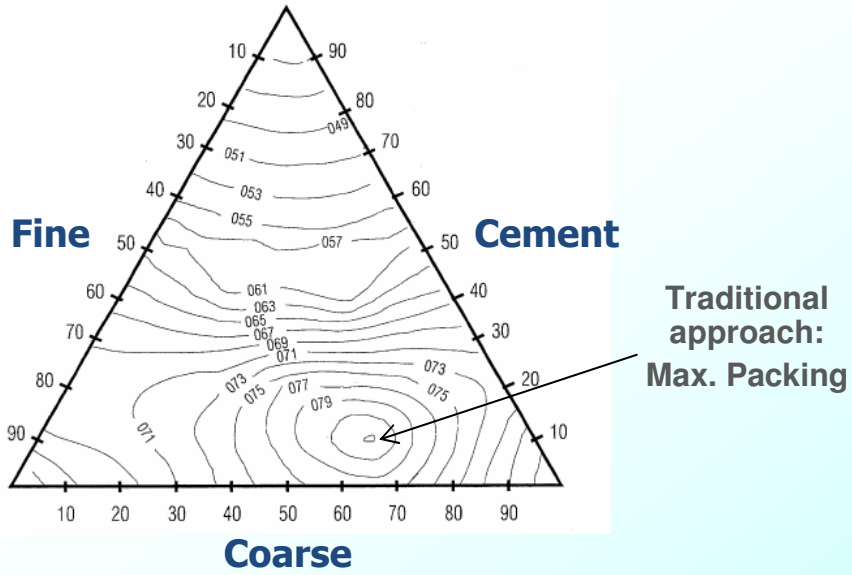
# Excelicrete™ – An Innovation

## Mix Design Technology: Unique and Novel Approach

Excelicrete Concrete designs for optimal:

- Workability
- Strength
- Cost
- Any performance specification

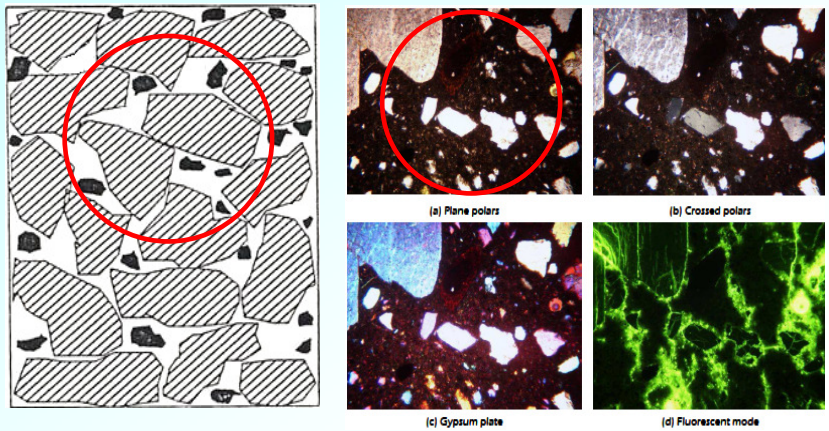
**Ternary Packing Diagram:**




Excelicrete Concrete identifies the **optimum** particle packing (not the maximum) through the application of its proprietary materials testing methods and computer algorithms

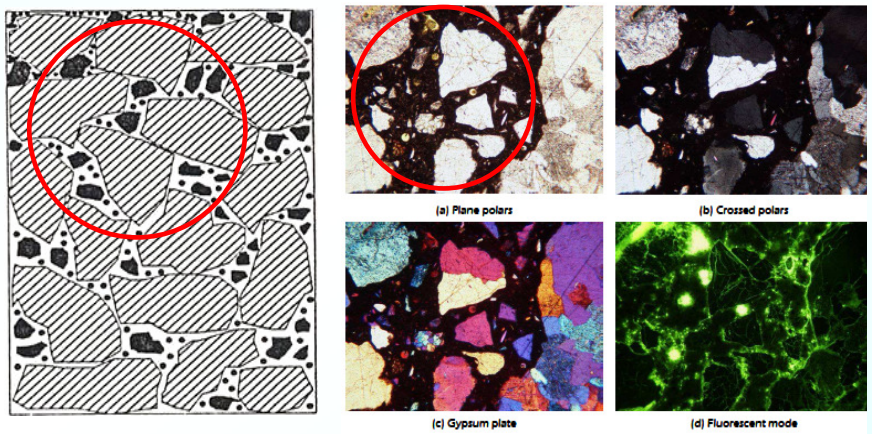
# Excelicrete™ Mix Design Overview

## Conventional Concrete Mix




- Larger void spaces require more water and cement
- Cement paste is the an expensive material in concrete
- Excess cement generates excess heat of hydration
- Excessive trial and error
- No way to predict properties

## ExceliCrete™ Concrete Mix

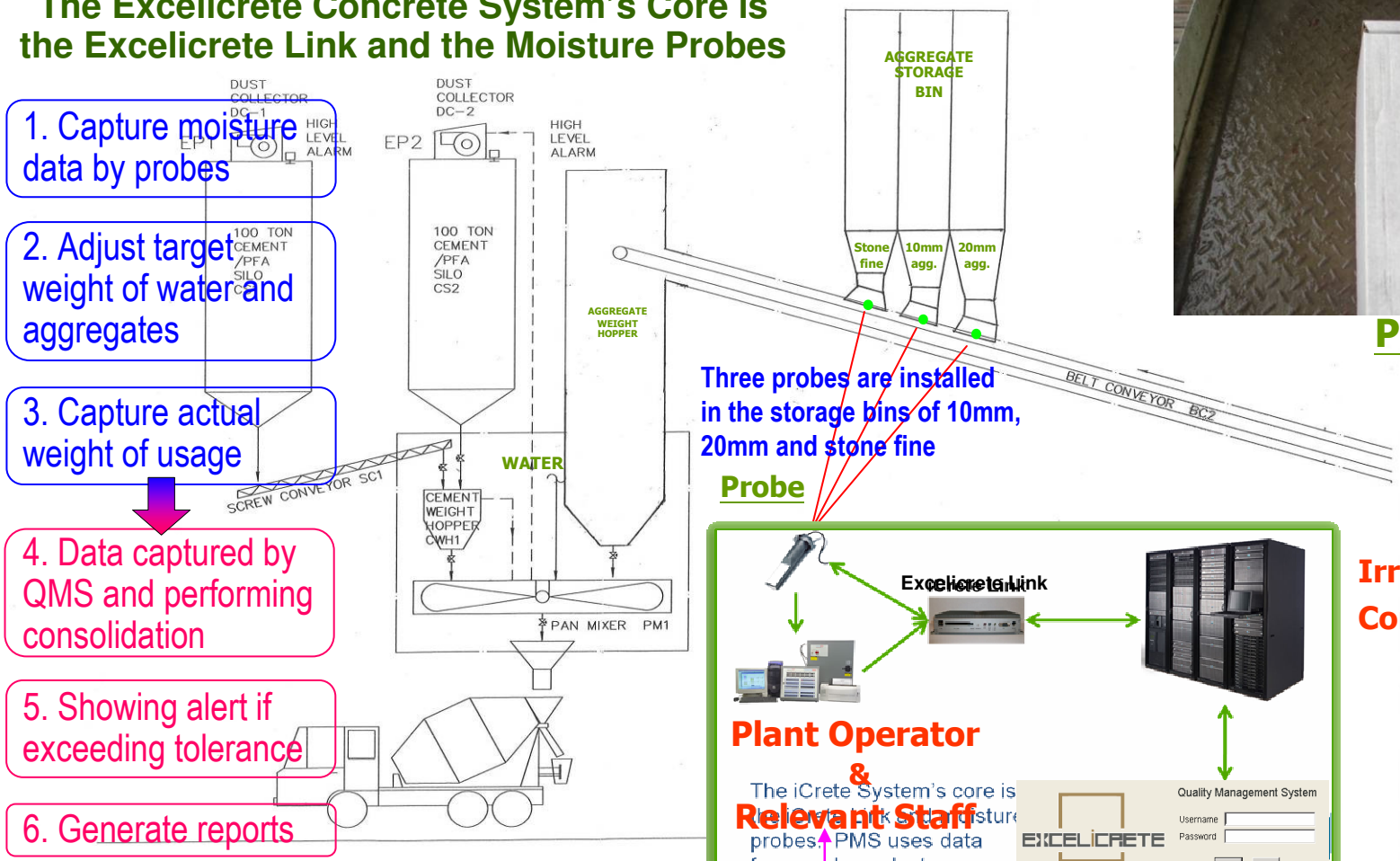



- Void spaces are reduced by optimized packing of aggregates
- Sand to aggregate ratio is optimized for reduced viscosity and increased cohesion to give improved flow and stability
- Aggregates replace excess cement paste to give less shrinkage and lower cost
- Lower hydration temperatures
- Easier handling, better flow and easier finishing

# Excelicrete™ Mix Design Overview

**The Excelicrete Concrete System's Core is the Excelicrete Link and the Moisture Probes**

1. Capture moisture data by probes
2. Adjust target weight of water and aggregates
3. Capture actual weight of usage
4. Data captured by QMS and performing consolidation
5. Showing alert if exceeding tolerance
6. Generate reports




Probe

Three probes are installed in the storage bins of 10mm, 20mm and stone fine

Probe



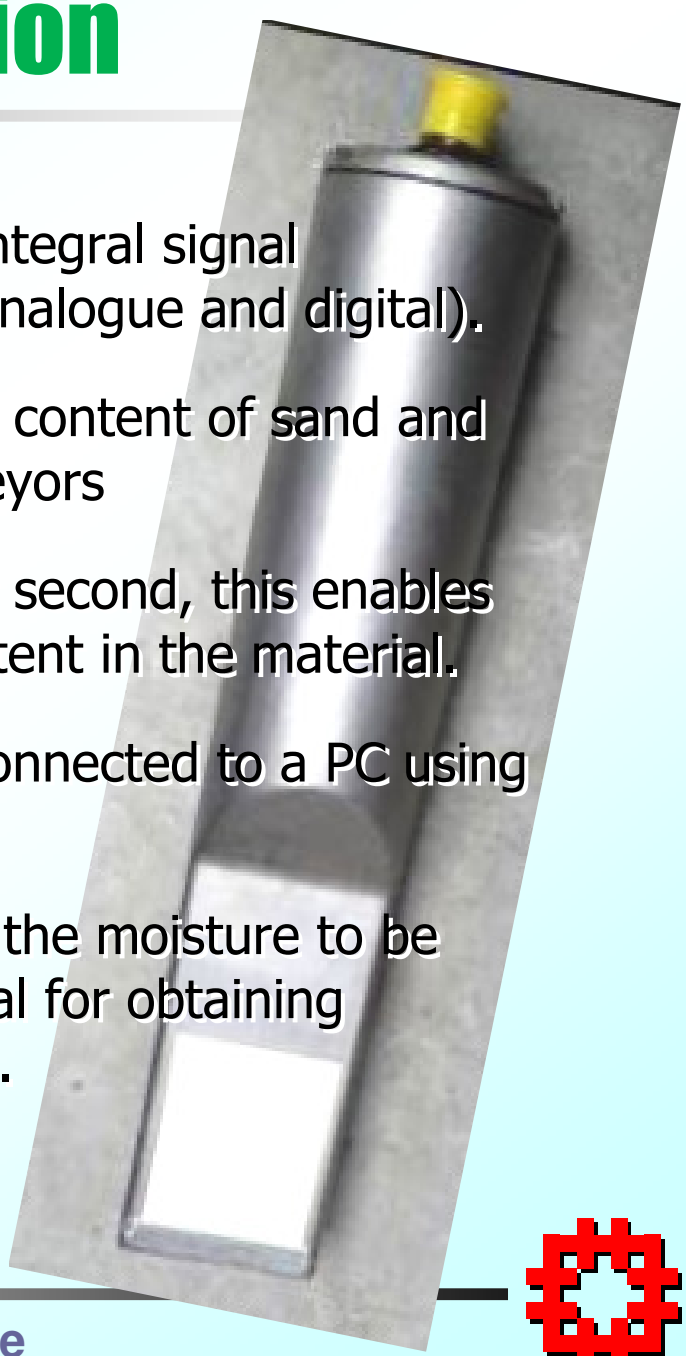

Irregularities in Concrete Production

Alarm/Alert

By SMS/E-mail

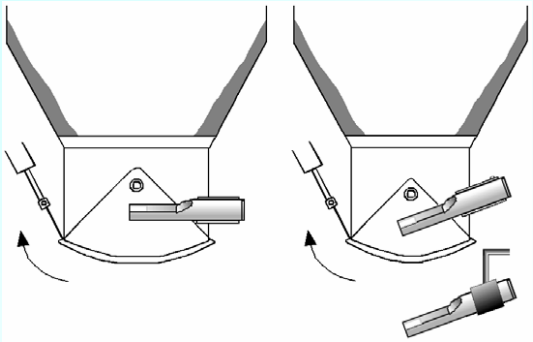
EXCELICRETE™ 優化混凝土

# Probe Installation

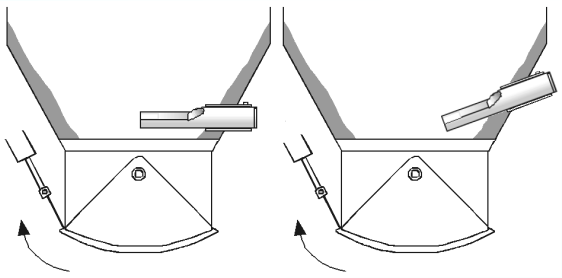


1. A digital microwave moisture sensor with integral signal processing provides a linear output (both analogue and digital).
2. Ideally suitable for measuring the moisture content of sand and aggregates in bins, hopper, silos and conveyors
3. Probe takes measurements at 25 times per second, this enables rapid detection of changes in moisture content in the material.
4. Probe may be configured remotely when connected to a PC using dedicated Hydronix software.
5. Digital input/output capability also enables the moisture to be averaged when material is flowing, essential for obtaining representative moisture for process control.

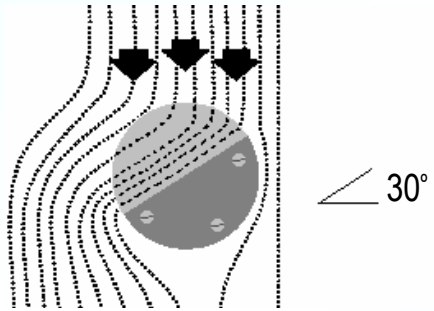
# Probe Installation



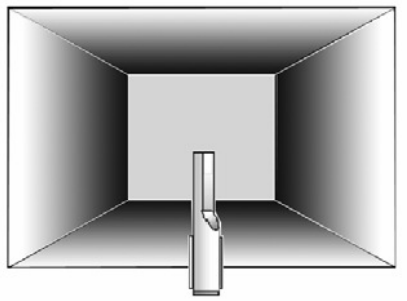
Mounting Probe in the neck of the bin



Mounting Probe in the bin wall




Mounting Angle and material flow



Probe should be positioned at the centre of the flow of material

# Probe Installation

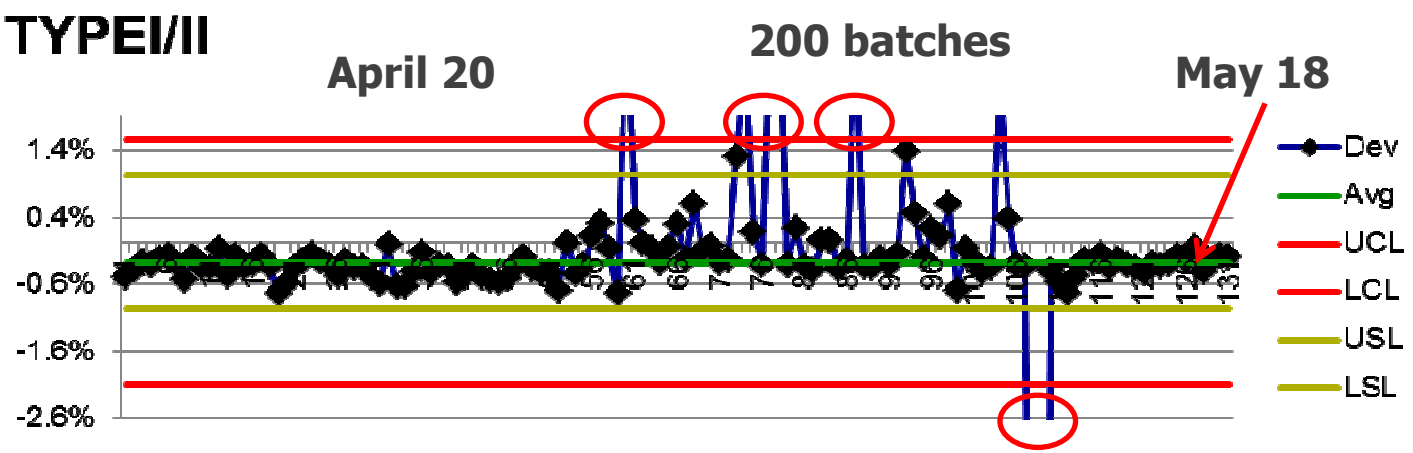
- 25 Readings per second will be taken by the probe and response the average value to the batching system.

Probe Installation for 10mm / 20mm

Probe Installation for Stone Fines

# Batching Plant on Site

# Excelicrete Link - QMS X Charts




- Material is being under weighed
- Errors of batching too much
- Workability issues
- Process limits outside of spec limits
- $C_{pk}$ = 0.39

| Material Name | TYPEI/II |
|---|---|
| Total Batches | 655 |
| Actual Material Used | 3,599,930 |
| Target Material Used | 3,617,539 |
| Batching Error | -17,609 |
| Total Batching Errors | 49 |
| Over Tolerance | 29 |
| Under Tolerance | 20 |
| Average Batching Error | -0.3% |
| Standard Deviation | 1.0% |
| Max Batching Error | 18.9% |
| Min Batching Error | -69.4% |
| Cost of Batching Error | -$882.67 |

# Excelicrete™ – An Innovation

- Apply to normal to high strength reinforced concrete up to 100 MPa with 42% saving in use of cement.
- Adopt designed mix to comply with B(C)R, Concrete CoP 2004/2013, relevant PNAPs (APP-33 on PFA & APP-74 on AAR).
- Of appropriate quality; sampling and testing to be in compliance with CS1:2010 on Testing Concrete.
- Adopt a performance specification approach; thus require a relaxation of minimum cementitious content and water cement ratio from Hong Kong Housing Authority's specification.

# Application of Excelicrete™ in Kai Tak Site 1B

Commercial Centre, Carport, Kindergarten, External Works

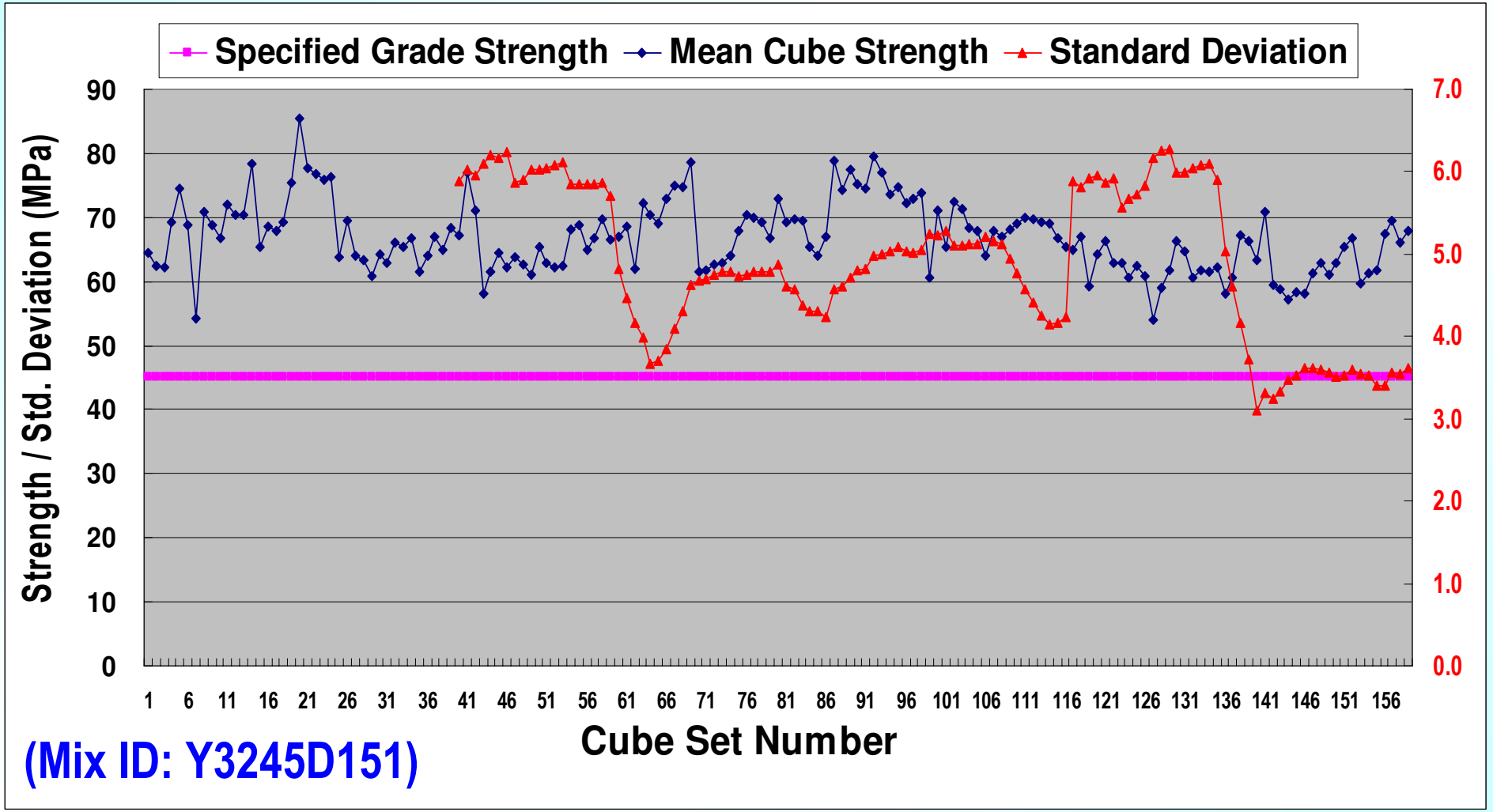
1. Footings – Grade 40 with PFA
2. Columns – Grade 45
3. Bms/Sbs – Grade 35
4. Other trials – Grade 60 Excelicrete™ & Grade 45 Self Compacting Excelicrete

# Comparison between Normal Concrete and Excelicrete™

* Minimum cementitious content for Grade 45/20D concrete stipulated in HKHA Specification is **375 kg/m³**.

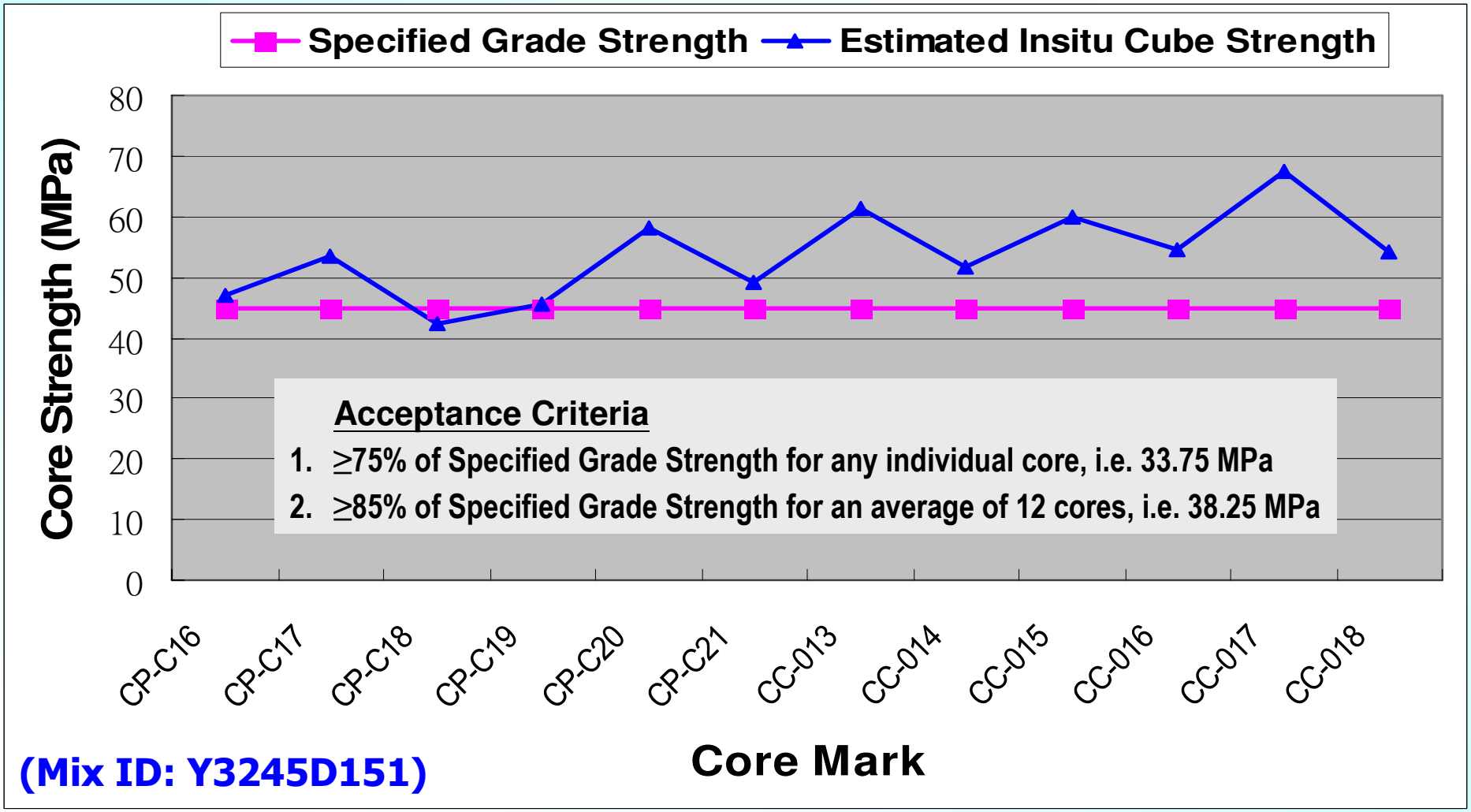
| Ingredient | Unit | Normal Concrete Grade 45/20D Mix ID: Y3245D281 Slump: 100 mm | Excelicrete™ Grade 45/20D Mix ID: Y3245D151 Slump: 100 mm |
|---|---|---|---|
| Cement (OPC) | kg/m³ | **480*** | **372*** (78%) |
| Aggregate (20mm) | kg/m³ | 640 | 519 (81%) |
| Aggregate (10mm) | kg/m³ | 280 | 481 (172%) |
| Aggregate (fine) | kg/m³ | 740 | 816 (110%) |
| Admixture (Glenium C330) | l/m³ | 3.0-5.0 | 3.5-5.5 (113%) |
| Water | l/m³ | 195 | 160 (82%) |
| Aggregate/cement ratio | --- | 3.46 | 4.88 (141%) |
| Water/cement ratio | --- | 0.41 | 0.43 (105%) |
| Alkaline Aggregate Reaction | kg/m³ | 2.49 | 1.66 (67%) |
| **Total :** | | **2,340 kg/m³** | **2,354 kg/m³** (101%) |

# Cube Strength Analysis of Excelicrete™




(Mix ID: Y3245D151)

# Core Test Results of Excelicrete™




(Mix ID: Y3245D151)

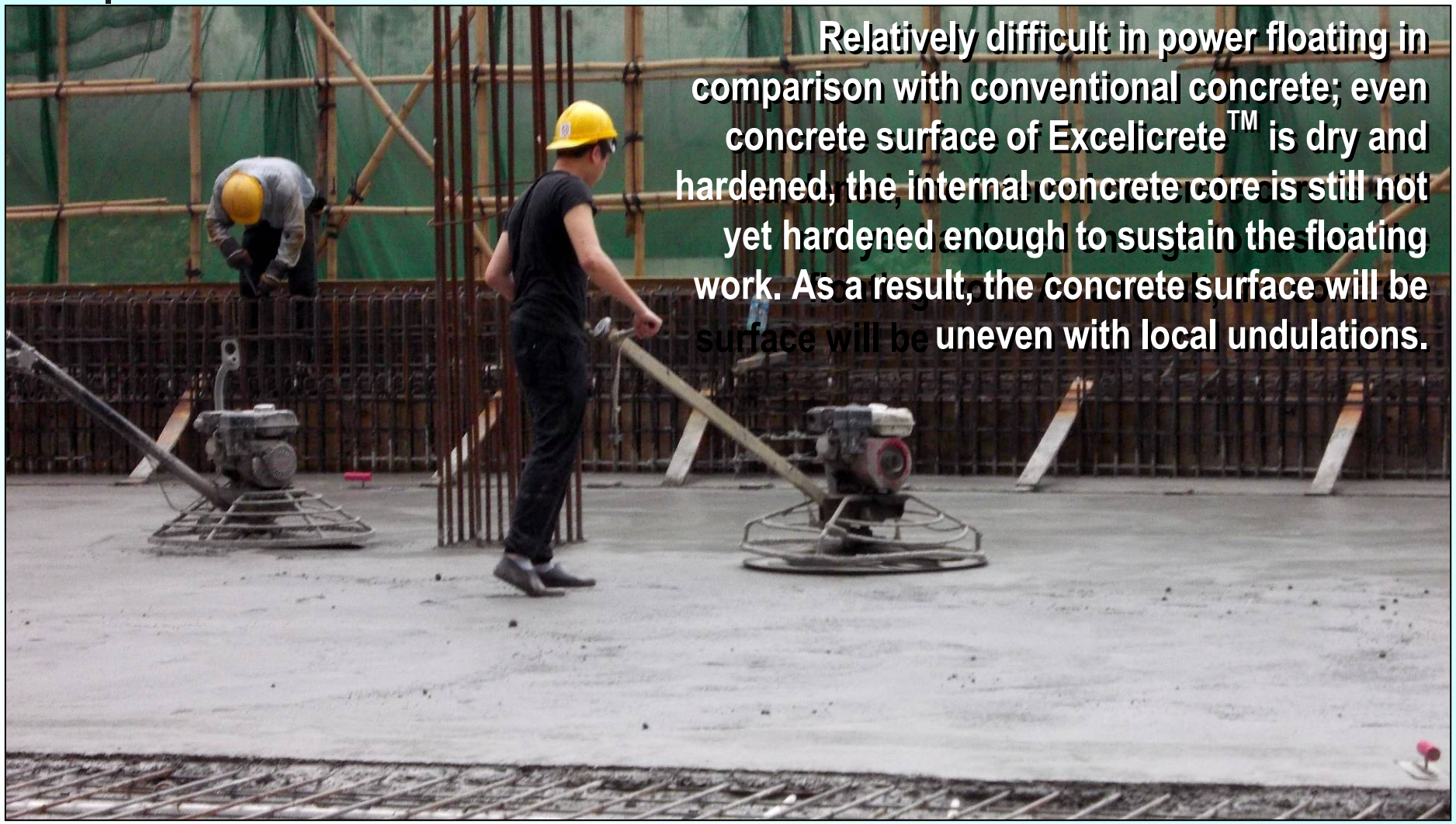
# Comparison between Normal Concrete and Excelicrete™

## Observations of Excelicrete™


- Better finished concrete surface
  - ➢ Relatively smooth and even.
- Less concrete defect appeared
  - ➢ No significant shrinkage crack & irregularity found on concrete surface.
- Longer mixing time in concrete mixer
  - ➢ 30 sec for conventional concrete vs 2 minimum for Excelicrete™.
- Longer batching time in batching time
  - ➢ 10 min for conventional concrete vs 20 minimum for Excelicrete™.
- Longer setting time after placing
  - ➢ 3-4 hrs for conventional concrete vs 5-6 hrs for Excelicrete™.

***(The setting time was roughly estimated as the duration when people step on concrete surface without leaving any footprint.)***

# Comparison between Normal Concrete and Excelicrete™



Relatively difficult in power floating in comparison with conventional concrete; even concrete surface of Excelicrete™ is dry and hardened, the internal concrete core is still not yet hardened enough to sustain the floating work. As a result, the concrete surface will be uneven with local undulations.


Self-Compacting Excelicrete™
An Earnest Exploration

# Self Compacting Concrete (SCC)

# Technical Review of SCC


- Engineering properties
- Constituent materials & mix composition
- Specification for ready-mixed & site mixed concrete
- Production for SCC
- Site requirements and preparation
- Placing and finishing on site
- Precast concrete products
- Appearance and surface finish
- Test methods for SCC

# Self Compacting Concrete

## Advantages :

- Suitable for congested RC structure.
- Improved bonding around reinforcement.
- No mechanical compaction – shorter construction time.
- Quicker concrete truck cycle time.
- Reduction in construction noise nuisance.
- Improved evenness of concrete surface to receive architectural finish.
- Ease of filling concrete features with odd shape or restricted portions.
- Improved pumpability and less wear/tear of plant.

# Self Compacting Concrete

## Required Properties of SCC :

- High **flowability** to allow the fresh SCC to flow into all spaces within the formwork under its own weight.
- High **passing ability** to allow the fresh SCC to pass through tight openings such as spaces between steel reinforcing bars under its own weight.
- High **segregation resistance** to allow the SCC to remain homogeneous in composition throughout the process of transportation and placing.

# Self Compacting Concrete vs Self Compacting Excelicrete™

***For Self Compacting Excelicrete™ .....***

## *all these advantages and requirements apply*

## *SCE = SCC + Excelicrete™ Technology*

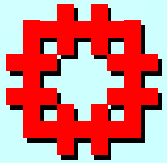
# Comparison between Normal Concrete and Self Compacting Excelicrete™ (SCE)

* Minimum cementitious content for Grade 45/20D concrete stipulated in HKHA Specification is **425 kg/m³**.

| Ingredient | Unit | Normal Concrete Grade 45/20D<br>Mix ID: H0645D021<br>Slump: 200 mm | SCE Grade 45/20D<br>Mix ID: Y3245D271<br>Slump Flow: 650-750 mm |
|---|---|---|---|
| Cement (OPC) | kg/m³ | **540** | **440*** (81%) |
| Aggregate (20mm) | kg/m³ | 660 | 0 (0%) |
| Aggregate (10mm) | kg/m³ | 310 | 786 (254%) |
| Aggregate (fine) | kg/m³ | 590 | 965 (164%) |
| Admixture | l/m³ | 12.97<br>(9.72L D17D + 3.25L D100) | 12.25 (94%)<br>(10.5L SP8S + 1.75L Rhe 150) |
| Water | l/m³ | 181 | 168 (93%) |
| Aggregate/cement ratio | --- | 2.89 | 3.98 (138%) |
| Water/cement ratio | --- | 0.34 | 0.38 (112%) |

**Total : 2,294 kg/m³ 2,372 kg/m³ (103%)**



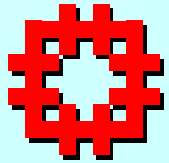


# Proposed Test Methods for SCE

## Pursuant to BS EN 12350

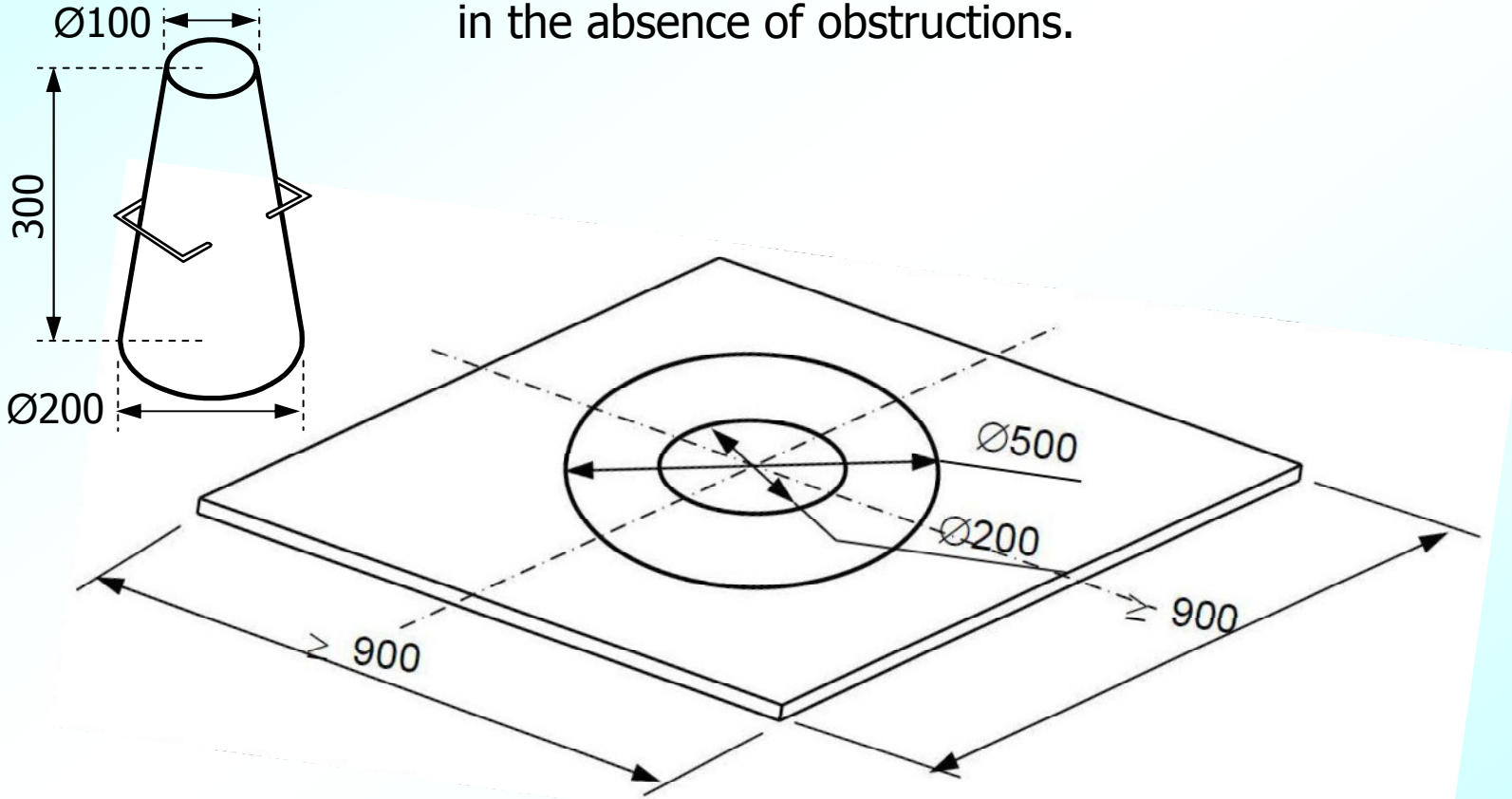
| Characteristic | Test Method |
|---|---|
| 1. Flowability | Slump-flow Test |
| 2. Passing Ability | L-box Test |
| 3. Segregation Resistance | Segregation Resistance Test |





# (1) Slump-flow Test

The slump-flow test is a test to assess the flowability of Self Compacting Excelicrete™ in the absence of obstructions.

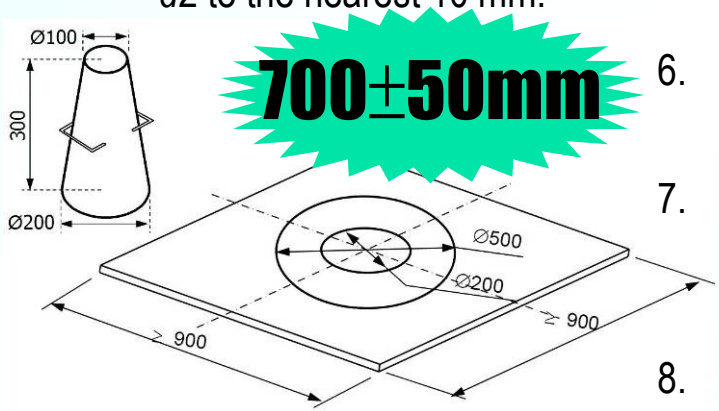



BS EN 12350-8:2010

# (1) Slump-flow Test

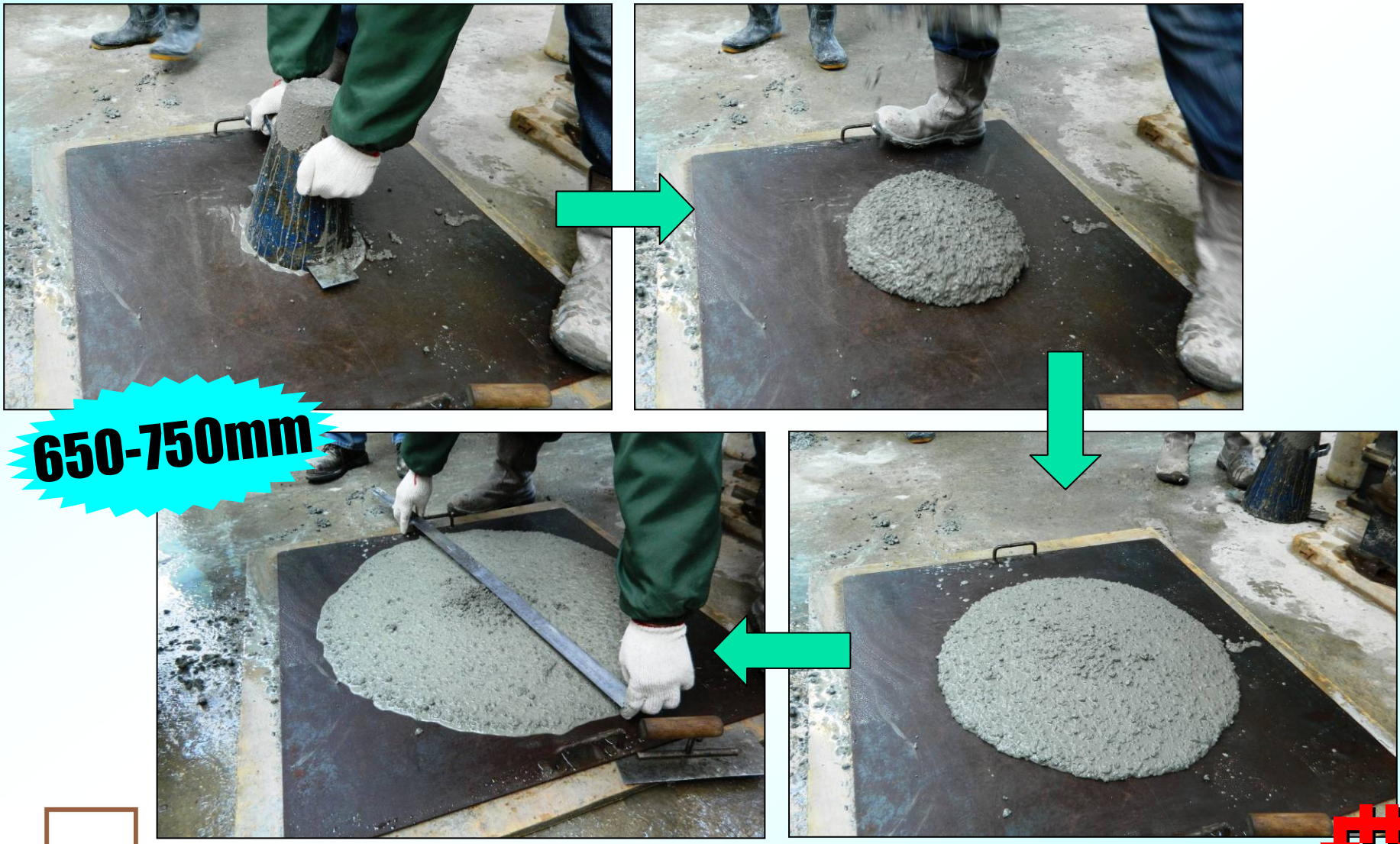
**BS EN 12350-8:2010**

1. Place baseplate on a flat and horizontal surface free from external vibration or shock.
2. Place cone centrally on the 200 mm circle on the baseplate and hold in position by standing on the foot pieces (or use the collar).
3. Fill cone with SCE in one operation without any agitation or mechanical compaction, and strike off surplus from the top of the cone. Allow the filled cone to stand for not more than 30 sec.
4. Lift cone vertically and allow SCE to flow freely.
5. After the flow of concrete has stabilized, measure the largest diameter of the flow spread and record as *d*1 to the nearest 10 mm. Then measure the diameter of the flow spread at right angles to *d*1 and record as *d*2 to the nearest 10 mm.



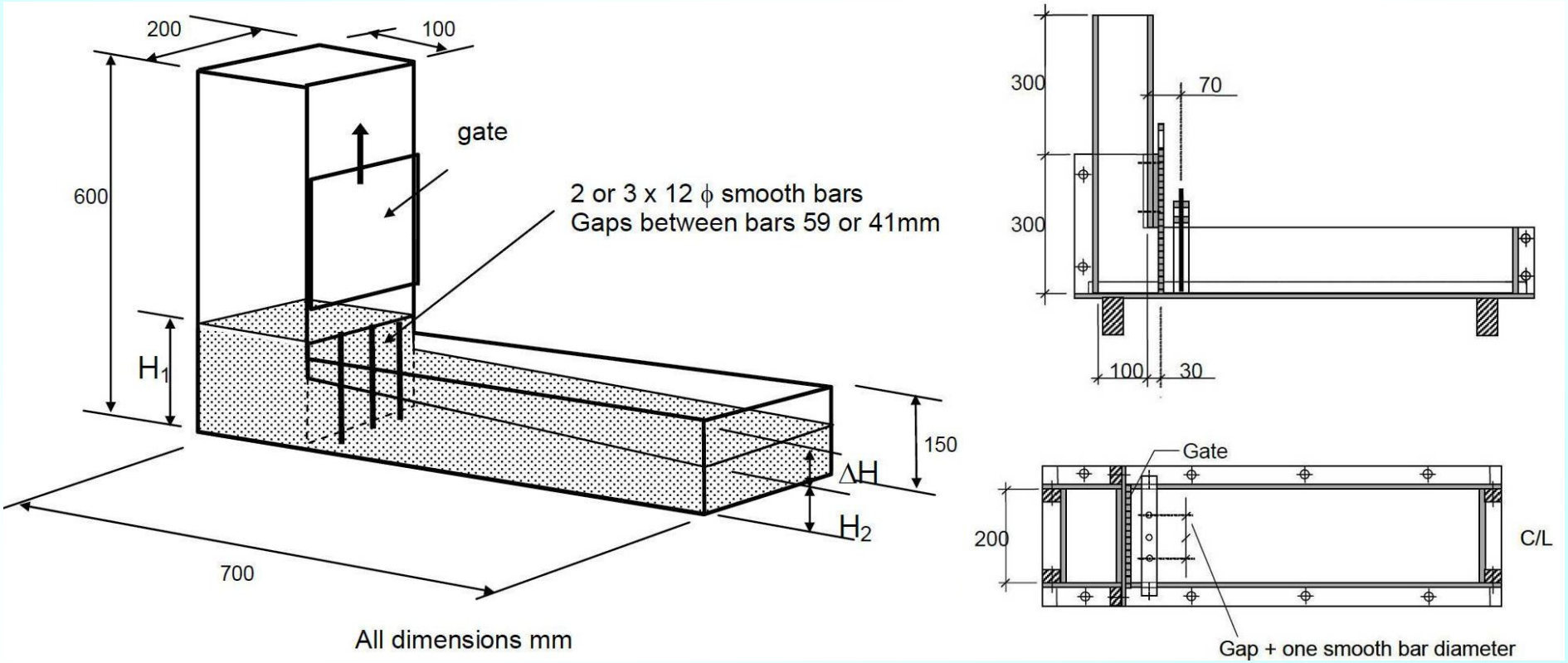

6. If the difference between *d*1 and *d*2 is greater than 50 mm another sample shall be taken and the procedure repeated.
7. If two consecutive tests show the difference between *d*1 and *d*2 to be greater than 50 mm, the concrete lacks the necessary flowability for the slump-flow test to be suitable.
8. The slump-flow is the mean of d1 and d2 expressed to the nearest 10 mm.

# (1) Slump-flow Test



# (2) L-box Test

The L-box test is used to assess the passing ability of Self Compacting Excelicrete™ to flow through tight openings including spaces between reinforcing bars and other obstructions without segregation or blocking. There are two variations; the two bar test and the three bar test; the three bar test simulates more congested reinforcement.

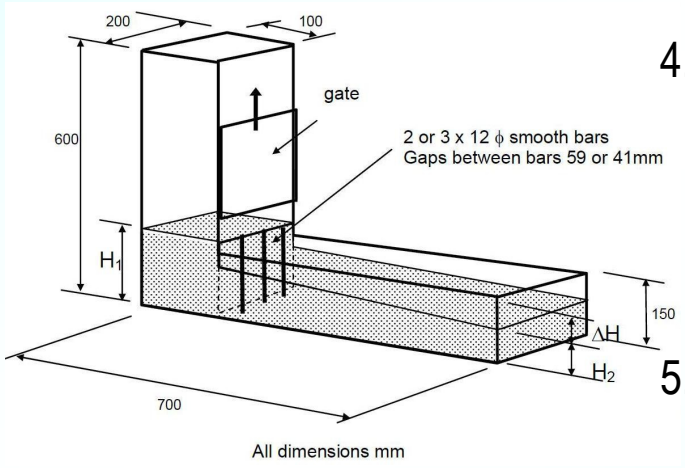



**BS EN 12350-10:2010**

# (2) L-box Test

**BS EN 12350-10:2010**

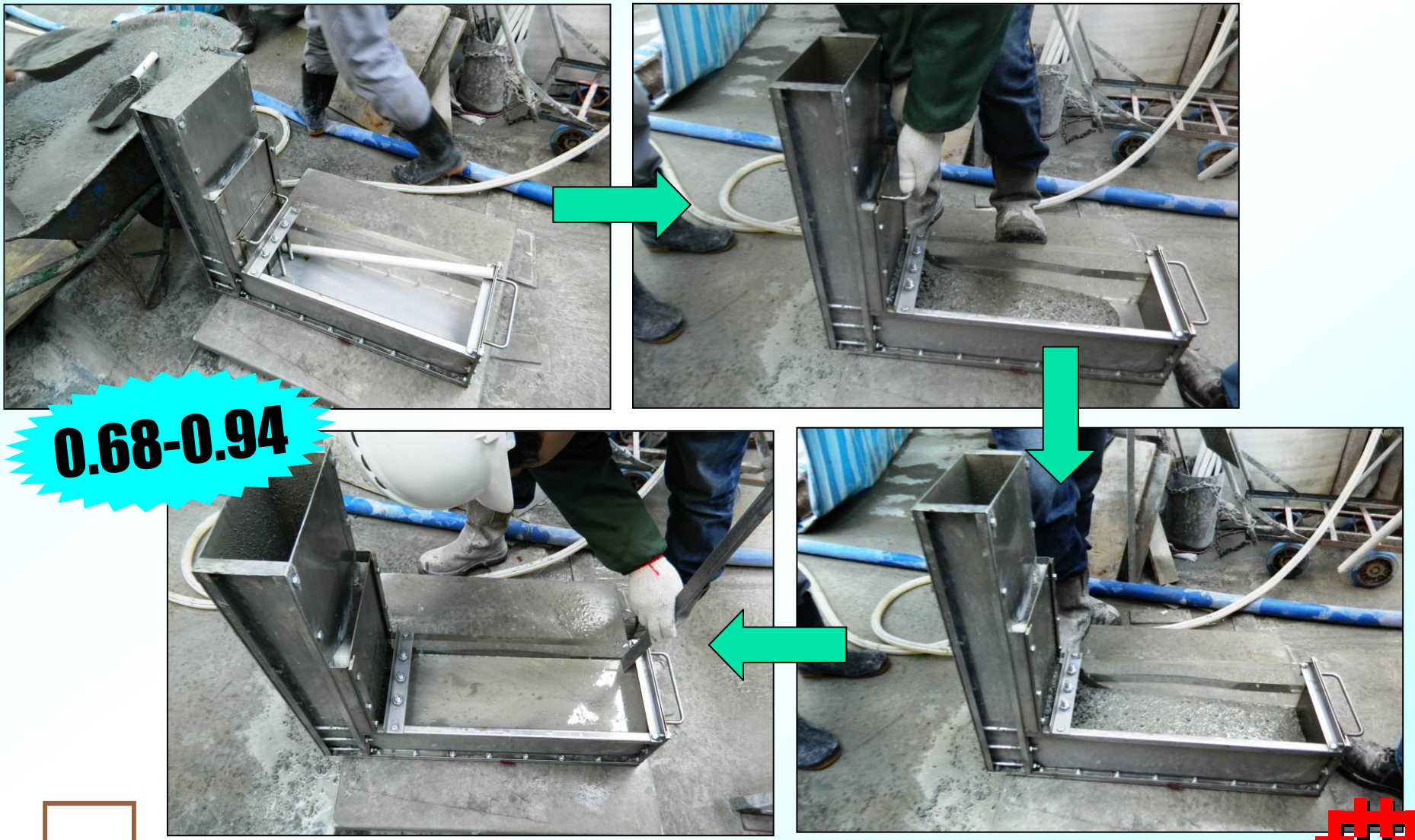
1. Close gate and pour SCE into filling hopper of L box, level top face and allow to stand for 60±10 sec.
2. Fully open sliding gate to allow SCE to flow into the horizontal section.
3. When movement has ceased, measure drop in height of the level of concrete △H1 to the nearest 1 mm in vertical section on gate side of L-box at three positions equally spaced across the width of it. The mean depth of the concrete H1 is the difference between the height of vertical section and the average of the three readings of △H1.




4. The same procedure is used to calculate the mean depth of the concrete at end of horizontal section of the L box H2 from the difference with the height of the horizontal section and the average of the three readings of △H2. Record H2 to the nearest 1 mm.
5. The passing ability ratio PL is calculated to the nearest 0.01:
   **PL = H2 / H1**

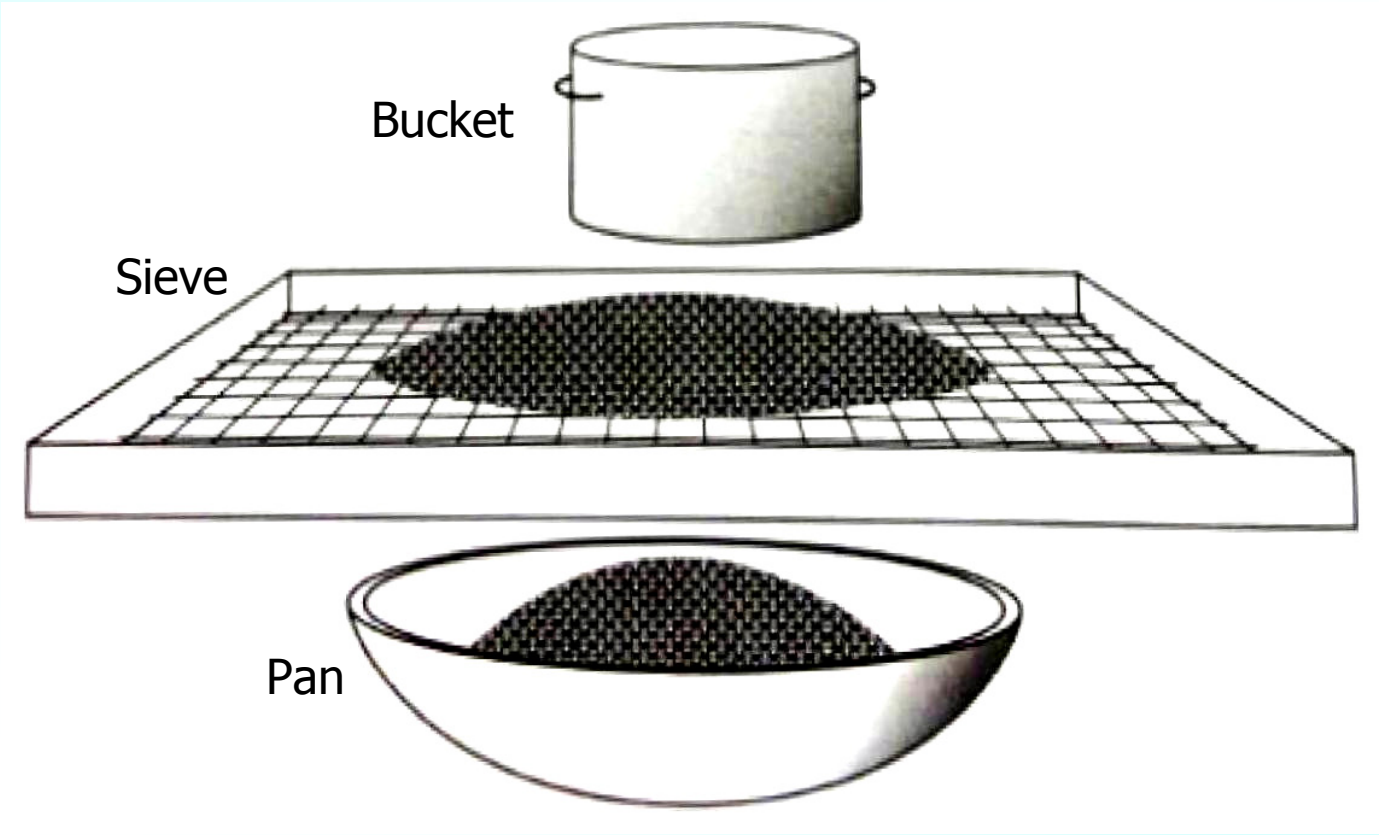
**≥0.7**

# (2) L-box Test



# (3) Segregation Resistance Test

The sieve segregation resistance test is used for assessing the resistance of Self Compacting Concrete to segregation. The testing equipment includes a bucket, a test sieve with perforated plate with 5 mm openings, and a pan.

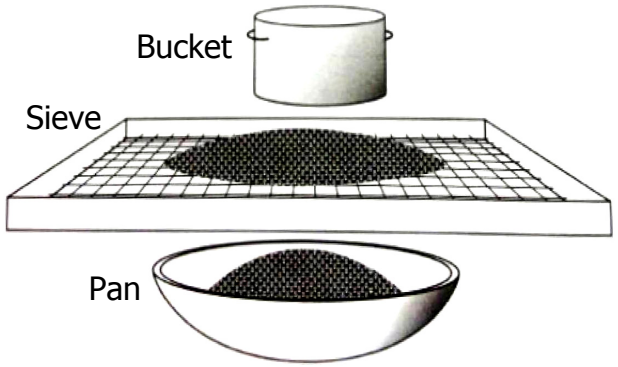



**BS EN 12350-11:2010**

# (3) Segregation Resistance Test

**BS EN 12350-11:2010**

1. Place 10 litres of SCE in a bucket and allow to stand for 15 min.
2. Place a pan on a balance and record its mass, mp.
3. Then place the sieve on the pan and record the total mass again or zero the balance.
4. At the end of the standing period, pour 4.8 kg of the SCE (including any bleed water) onto the sieve at a height of 500 mm above it. Obtain the actual mass of SCE poured, mc.
5. Allow the SCE to stand on the sieve for 2 min.
6. Then remove the sieve and record the total mass of the pan and the retained material, mps.



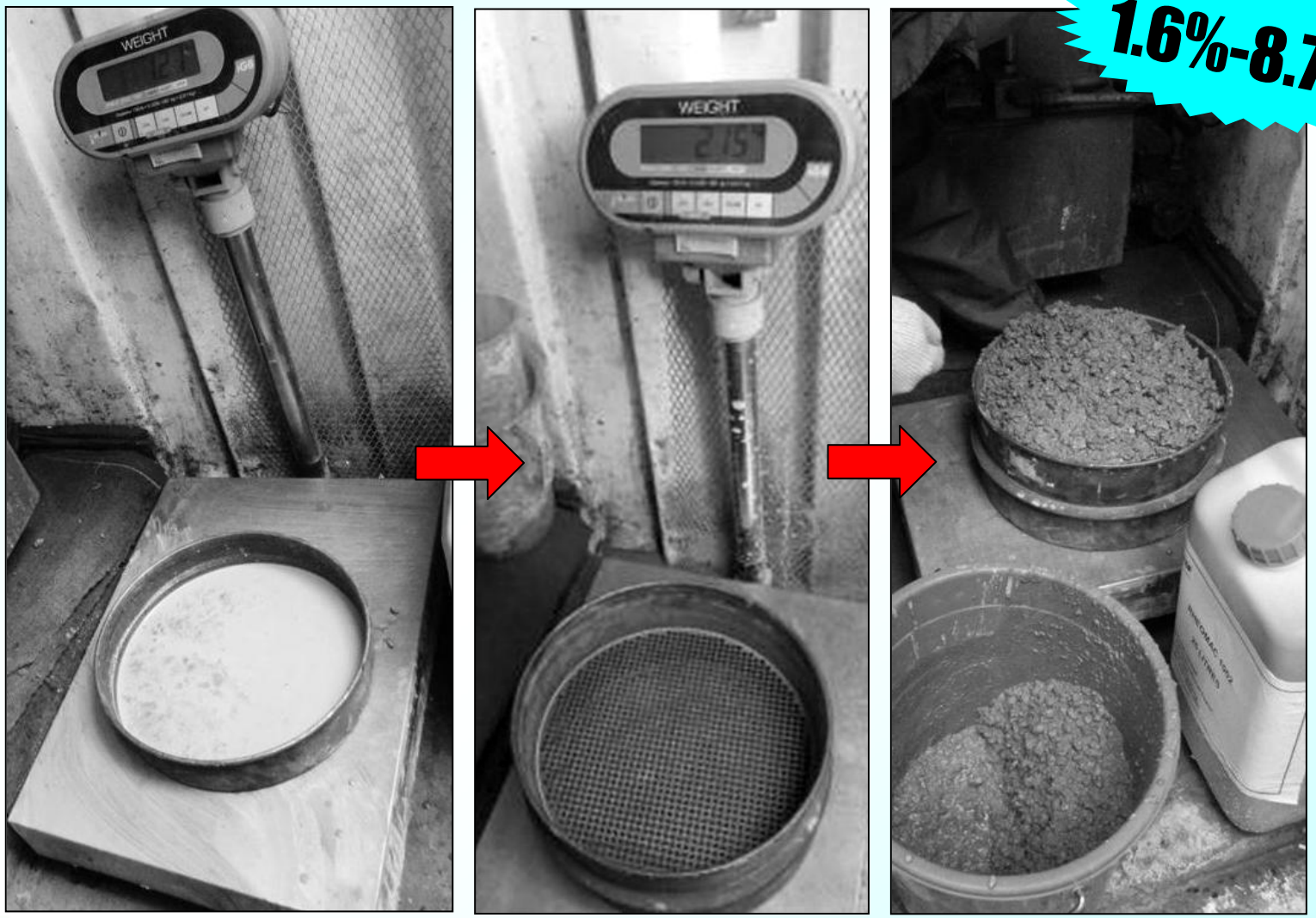

7. The segregated resistance SR is calculated from the following equation to the nearest 1% :-

**SR = [ (mps – mp) x 100 ] / mc**

≤15%

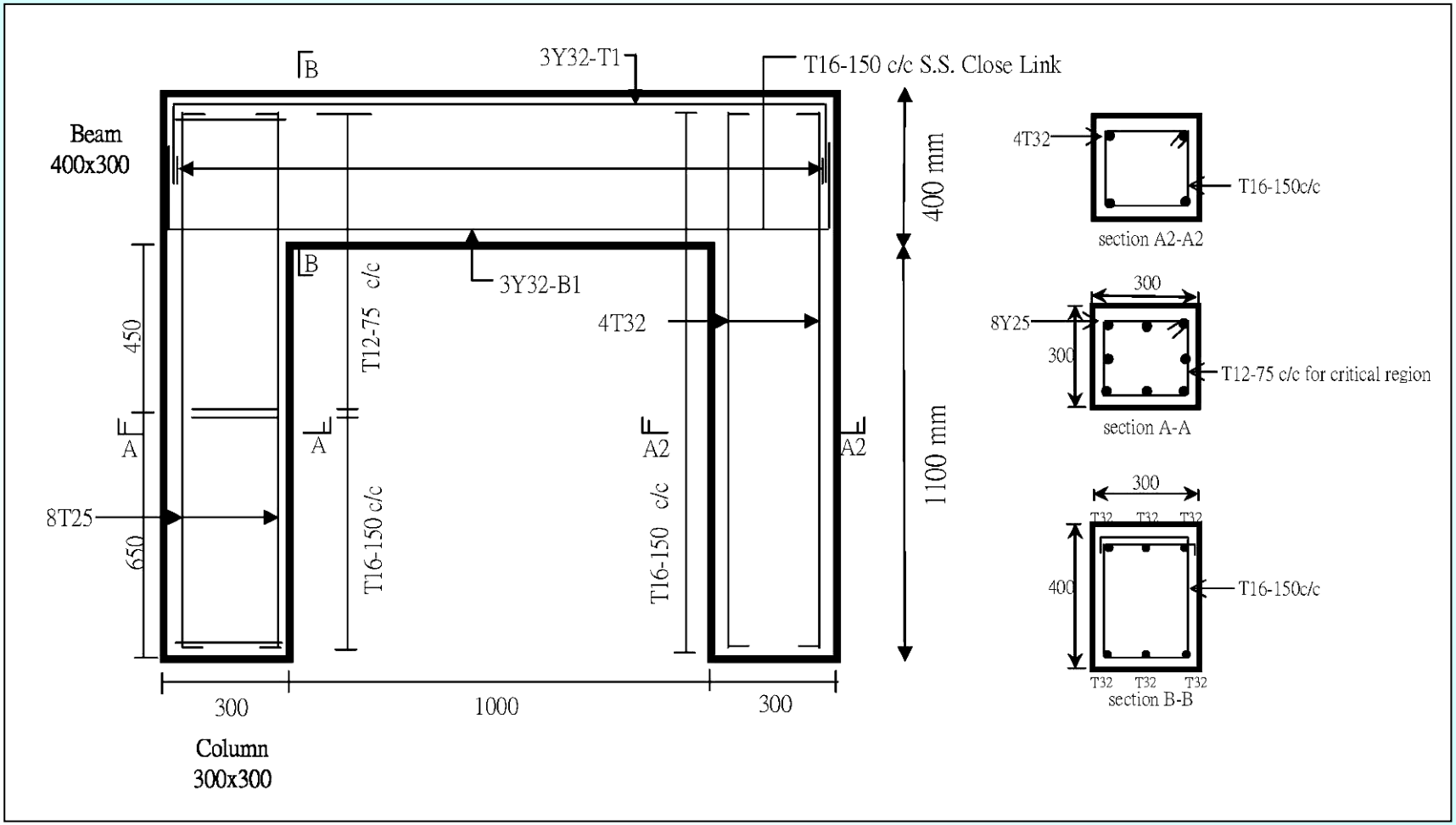
where
- mps is the mass of pan plus retained material;
- mp is the mass of the pan;
- mc is the initial mass of concrete placed onto the sieve.

# (3) Segregation Resistance Test



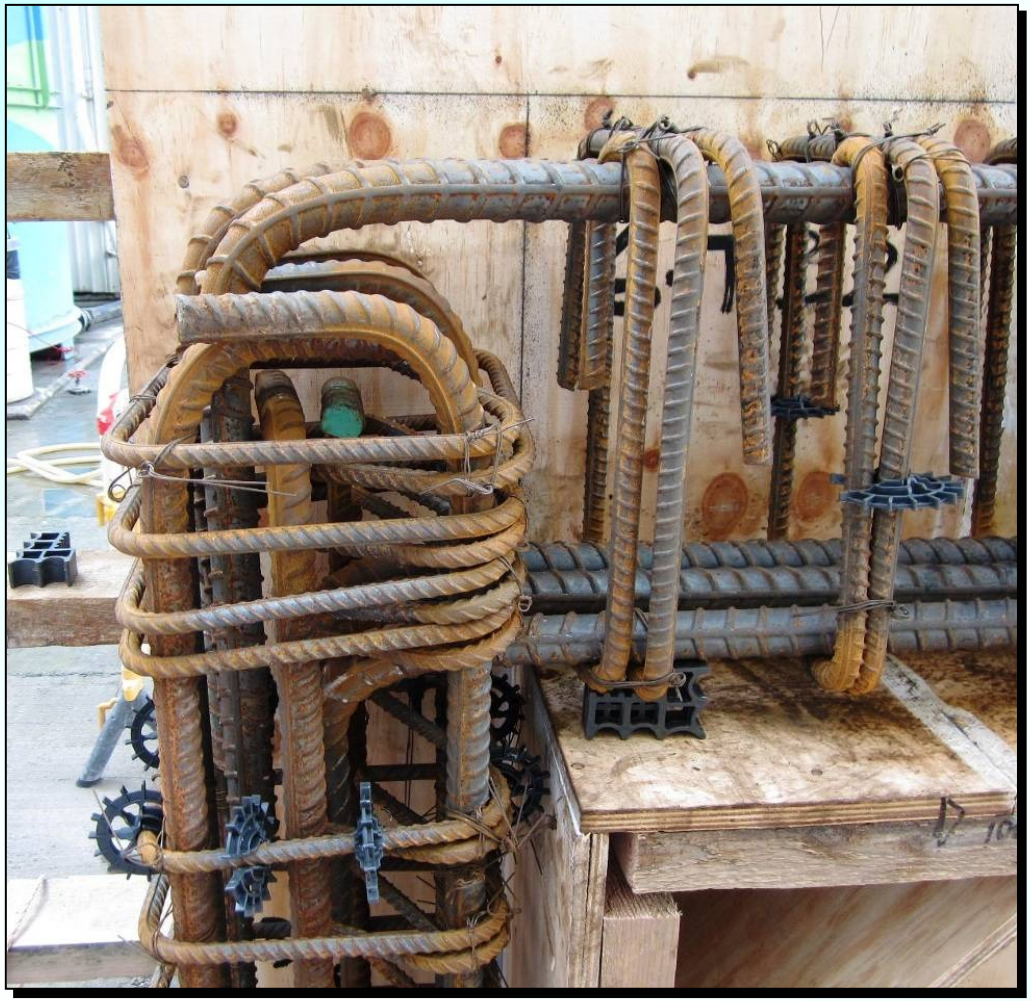
# Site Trail of SCE on Simple Portal Frame

## RC details of Trail Section



# Site Trail of SCE on Simple Portal Frame

# Site Trail of SCE on Simple Portal Frame



## Simulation of Congested Situation

# Site Trail of SCE on Simple Portal Frame

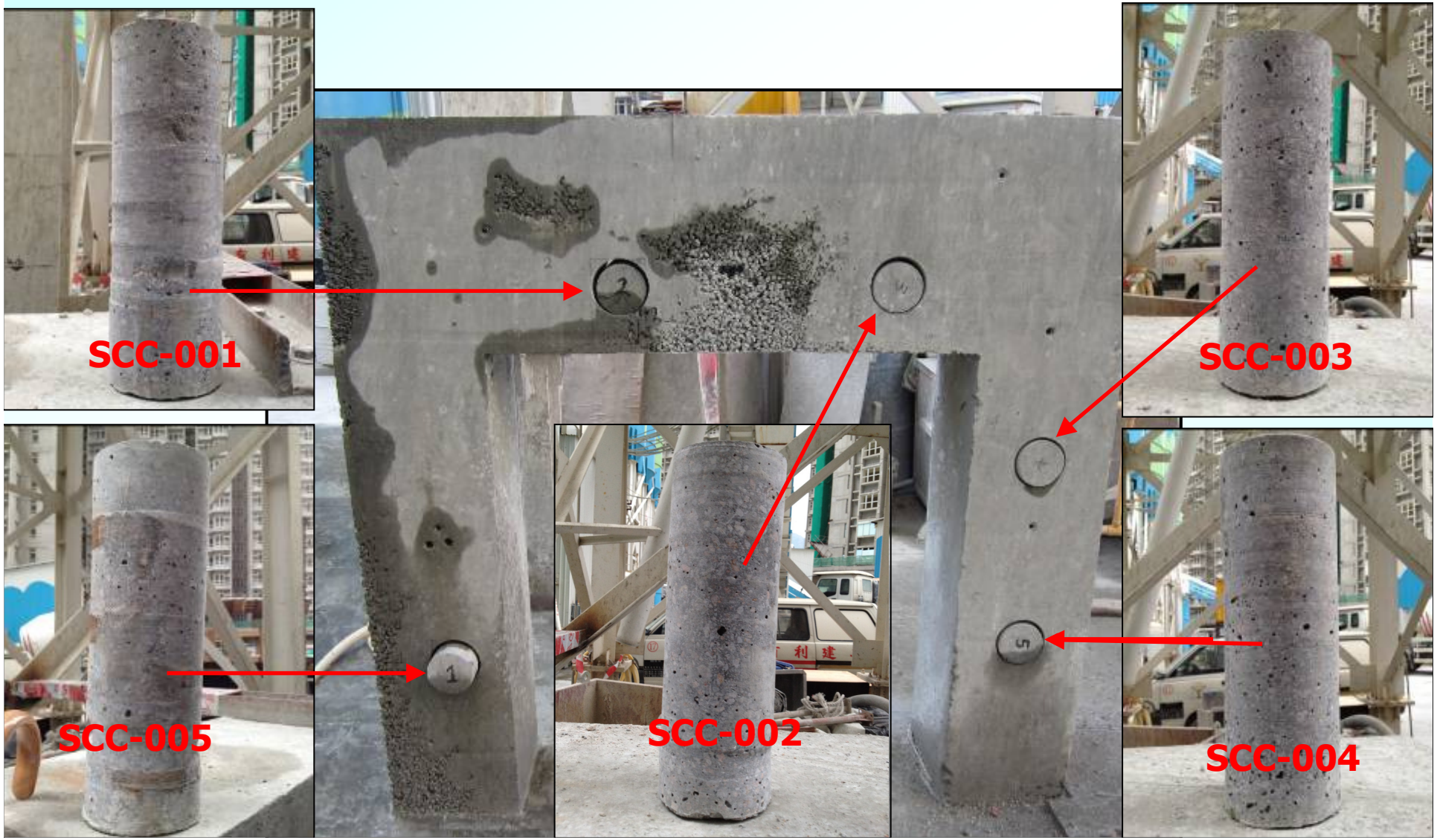
## Unsatisfactory Workmanship

# Site Trail of SCE on Simple Portal Frame

## Unsatisfactory Workmanship

# Site Trail of SCE on Simple Portal Frame

## Core Test to Verify Workmanship



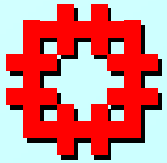
# Site Trail of SCE on Simple Portal Frame

## Compressive Strength of Concrete Cores

| Core Mark No. | Core Compression Strength (MPa) * | Age at Date of Test |
|---|---|---|
| SCC-001 | 74.0 | 45 Days |
| SCC-002 | 77.0 | 45 Days |
| SCC-003 | 74.0 | 45 Days |
| SCC-004 | 73.0 | 45 Days |

* Designed Characteristic Strength of SCE at 28 Days is 45 MPa.





# Site Trail of SCE on Simple Portal Frame

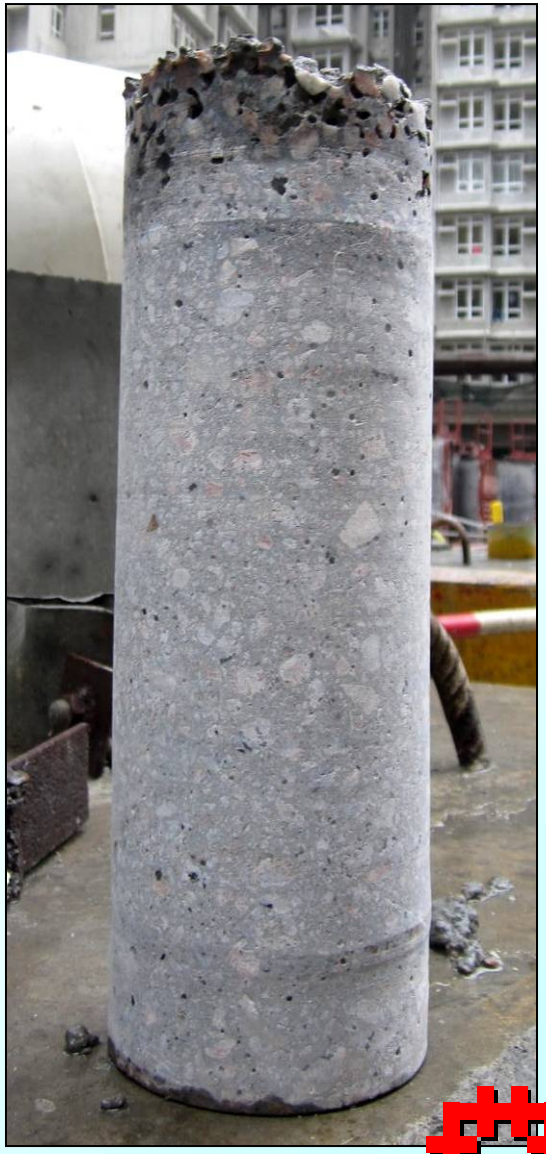
## Core: SCC-005

# Site Trail of SCE on Simple Portal Frame

## Additional concrete core taken from 1st Site Trial located at defective concrete area

# Site Trail of SCE on Simple Portal Frame

SCC-006 : Surface Defect



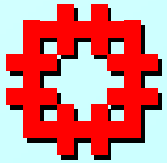
# Site Trail of SCE on Simple Portal Frame

## Compressive Strength of Concrete Cores

| Core Mark No. | Core Compression Strength (MPa) * | Age at Date of Test |
|---|---|---|
| SCC-001 | 74.0 | 45 Days |
| SCC-002 | 77.0 | 45 Days |
| SCC-003 | 74.0 | 45 Days |
| SCC-004 | 73.0 | 45 Days |
| **SCC-006** | **66.0** | **66 Days** |

* Designed Characteristic Strength of SCE at 28 Days is 45 MPa.





# Site Trail of SCE on Simple Portal Frame

## Observations

1. Defects occur at surface area
2. Self-Compaction is able to become Self-Rectification

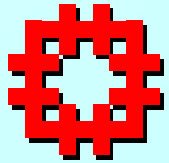
# Site Trail of SCE - Improvement

1. At 1st site trial, the SCE was directly discharged from the concrete truck without using concrete skip bucket. The SCE was discharged only at one discharge point to fill up the formwork. At 2nd site trial, ***concrete skip bucket*** was used to casting SCE, the discharge point/distance can be adjusted and controlled.

2. At 1st site trial, normal plywood formwork was used. At 2nd site trial, ***fair-face formwork*** (菲林板) was used.

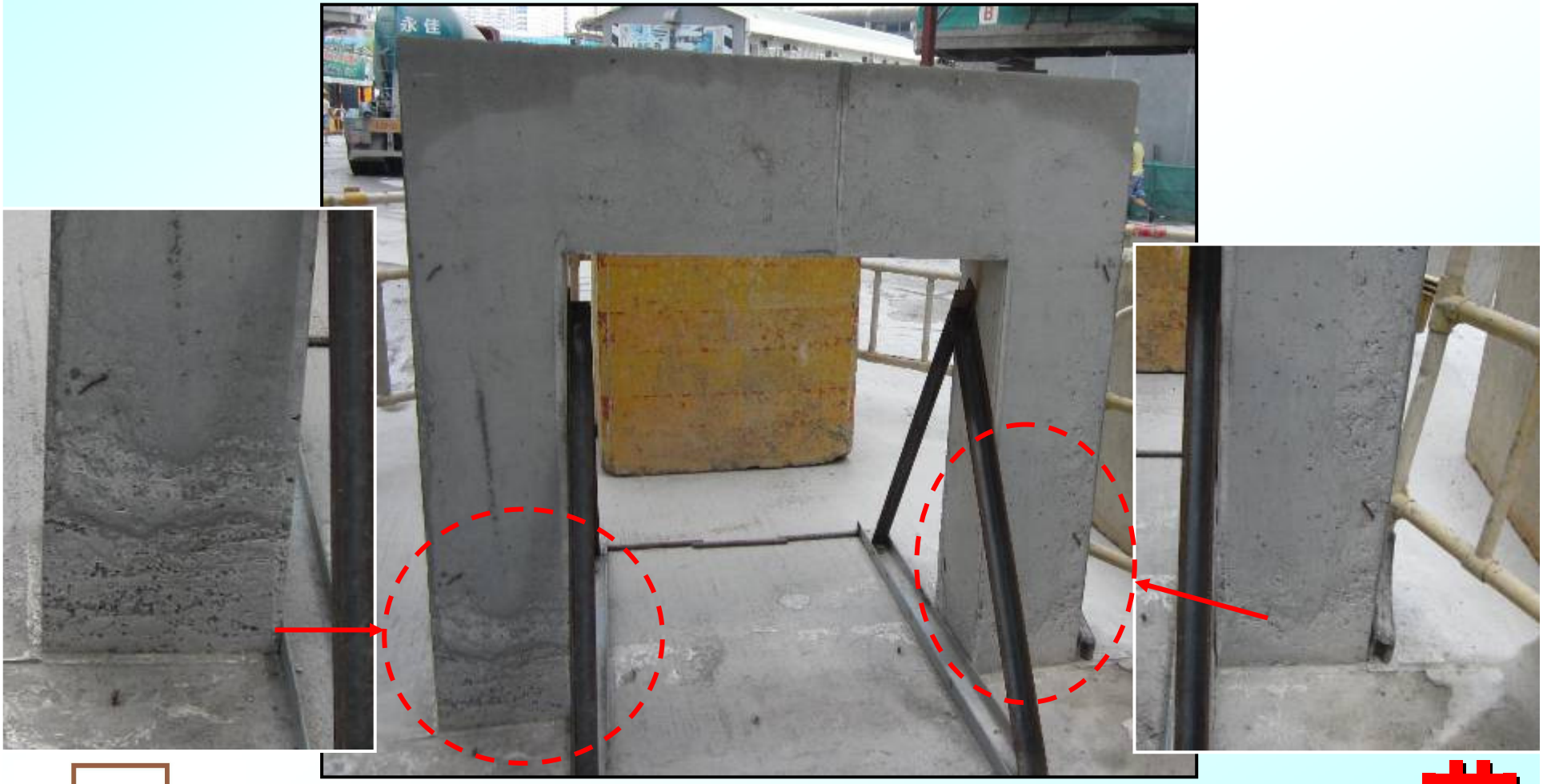
3. At 1st site trial, no joint sealant was applied to the formwork. At 2nd site trail, the ***joint sealant*** was used to seal up the large gap/joint at the formwork





# 2nd Trail of SCE on Simple Portal Frame

## Minor grout loss at bottom parts of columns



# 2nd Trail of SCE on Simple Portal Frame

## Core test to verify workmanship

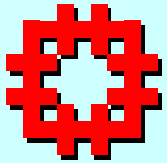
# Site Trail of SCE on Simple Portal Frame

## Compressive Strength of Concrete Cores

| Core Mark No. | Core Compression Strength (MPa) * | Age at Date of Test |
|---|---|---|
| SCC-007 | 63.0 | 42 Days |
| SCC-008 | 65.0 | 42 Days |
| SCC-009 | 66.5 | 42 Days |
| SCC-010 | 65.0 | 42 Days |

* Designed Characteristic Strength of SCE at 28 Days is 45 MPa.



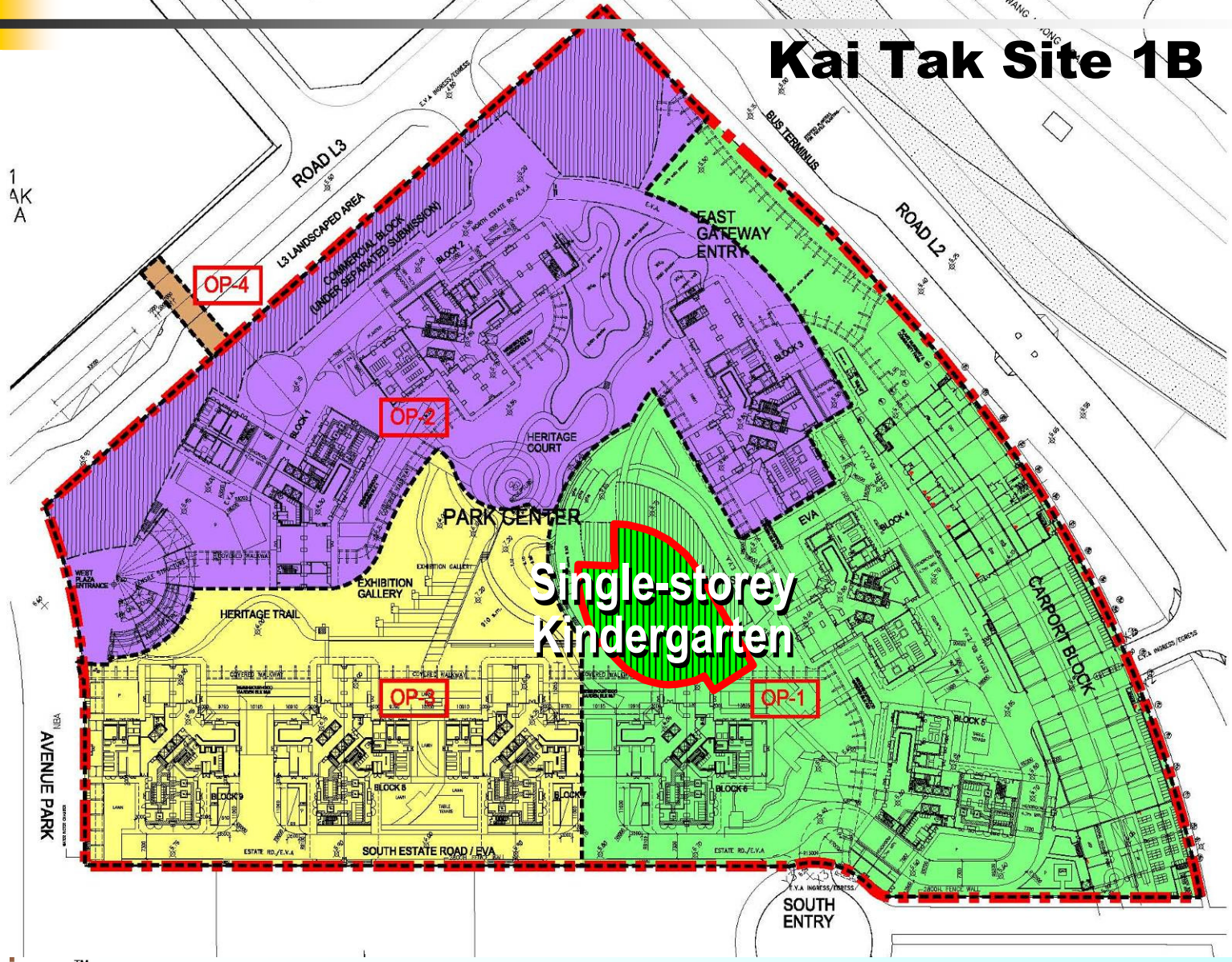


# 2nd Trail of SCE on Simple Portal Frame


Good passing ability of SCE is important.

Good bonding of SCE with rebars.

# Application of SCE on Kindergarten

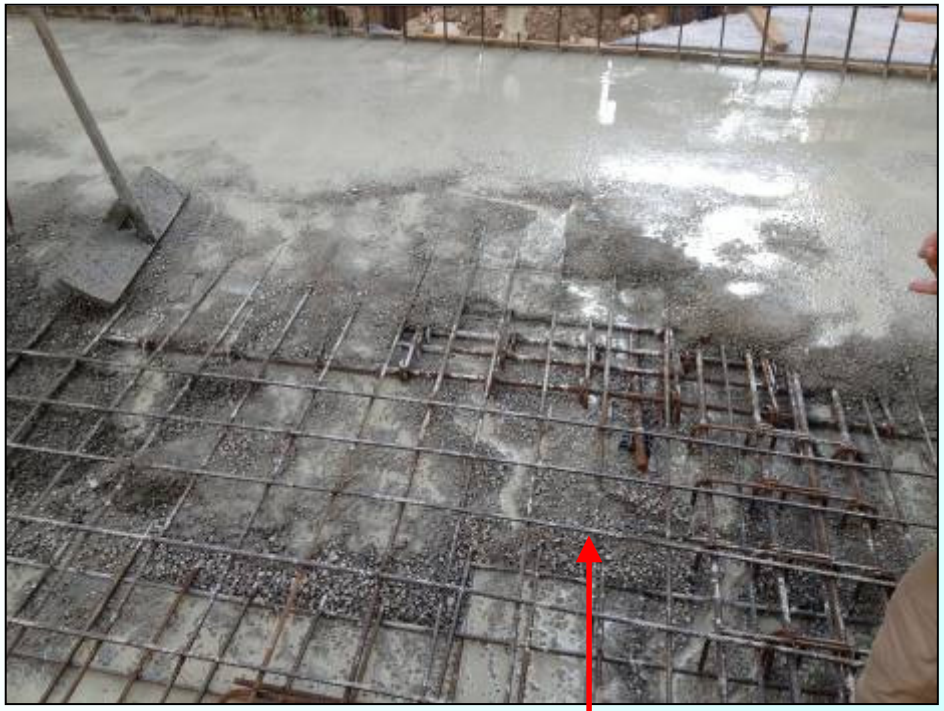


# Application of SCE on Kindergarten (Slabs)

# Application of SCE on Kindergarten (Slabs)

## Difficulties Encountered

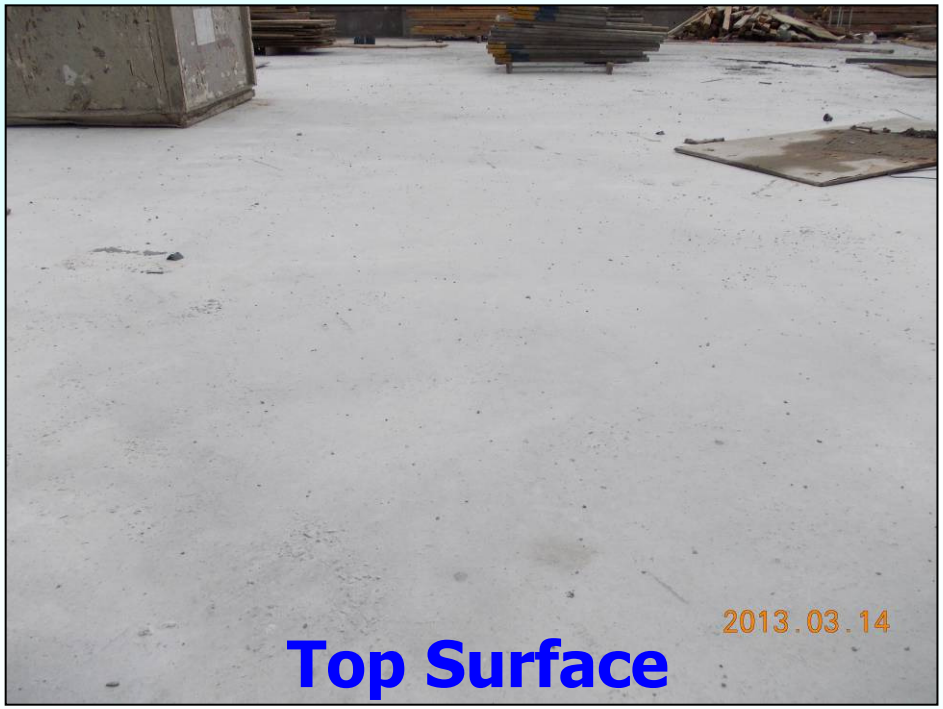
Excessive Bleeding



Segregation

# Application of SCE on Kindergarten (Slabs)

## Satisfactory Concrete Surfaces



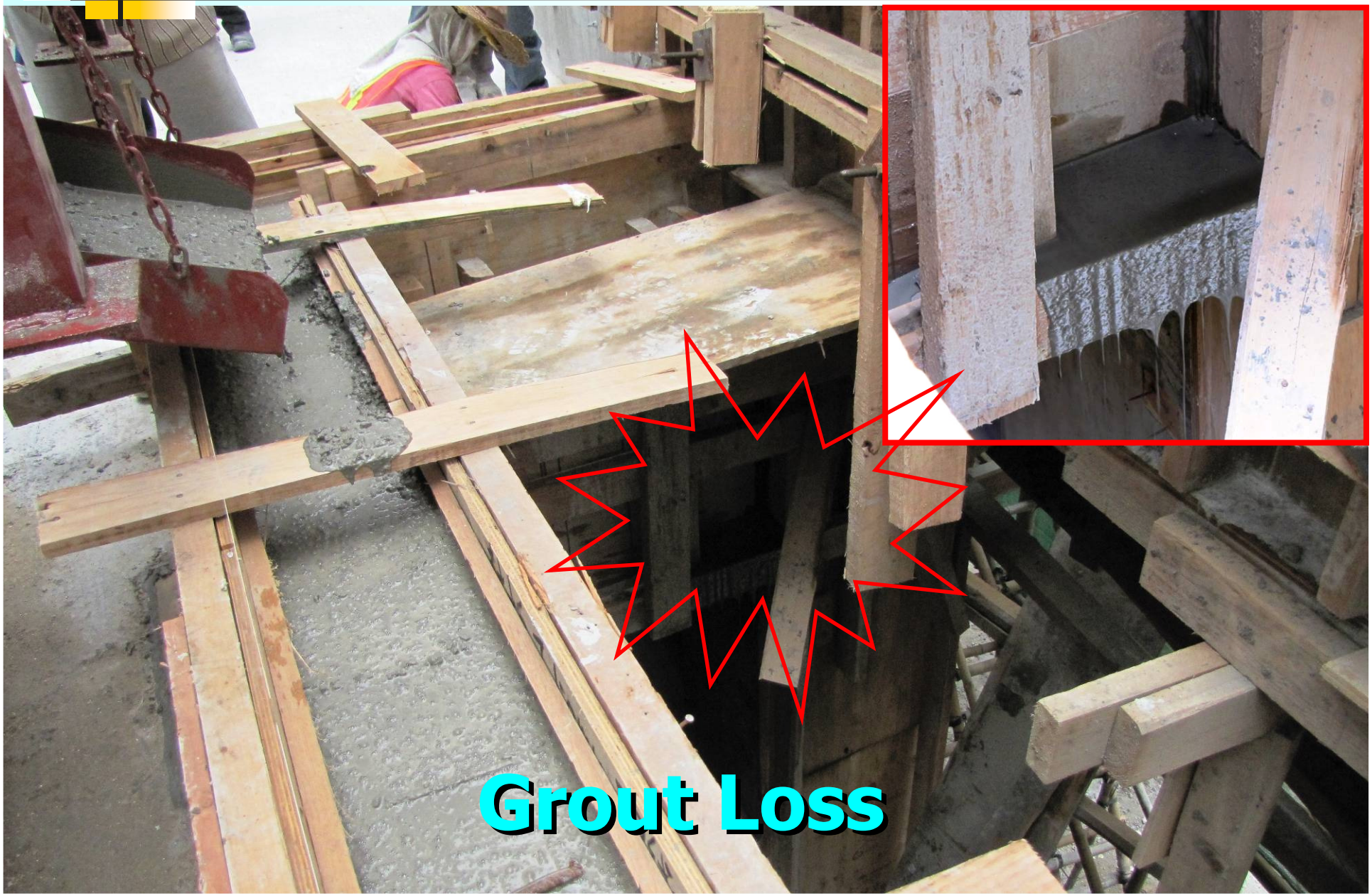

Top Surface

Bottom Surface

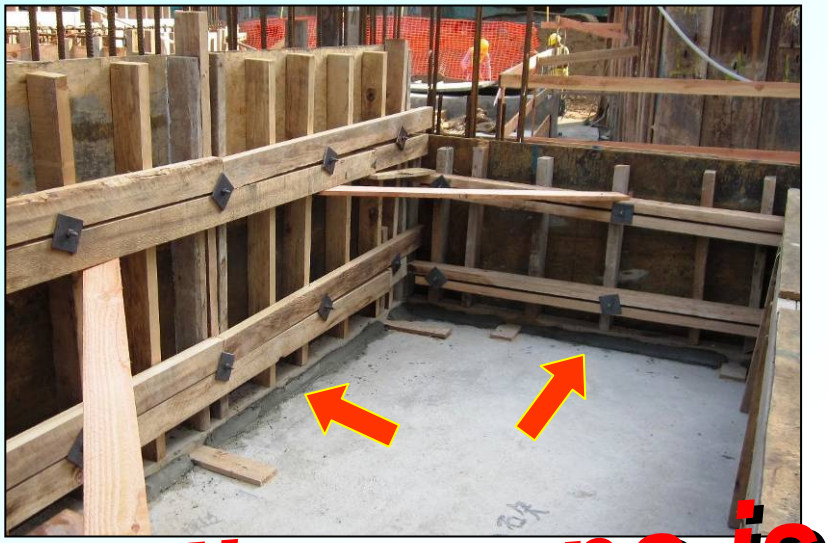
# Application of SCE on Kindergarten (Walls)

## Pouring SCE with skip, funnel and trimie pipe

# Application of SCE on Kindergarten (Walls)



# Application of SCE on Kindergarten (Walls)

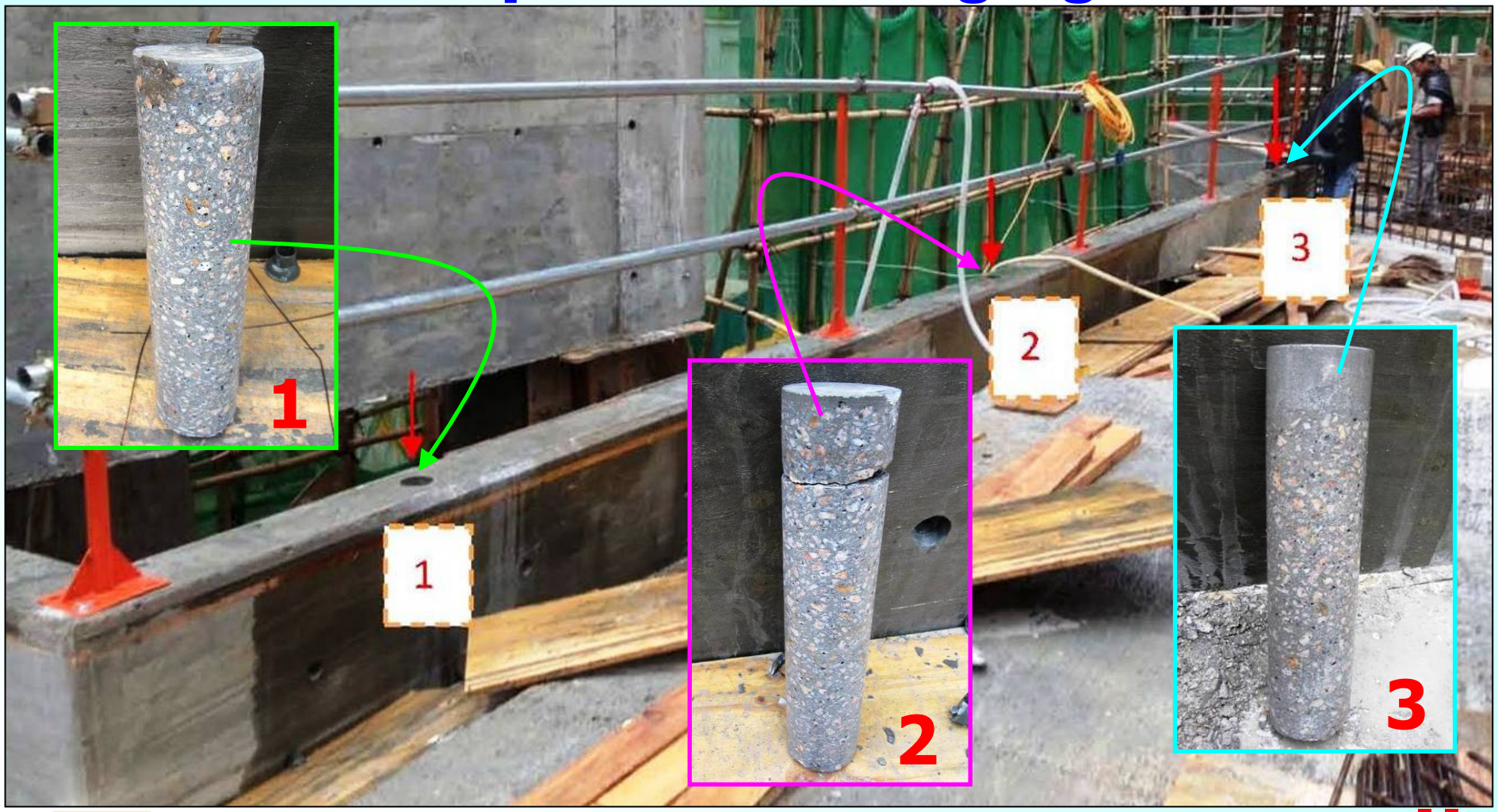


**Sealing gaps is most important !**

# Application of SCE on Kindergarten (Walls)

# Application of SCE on Kindergarten (Walls)

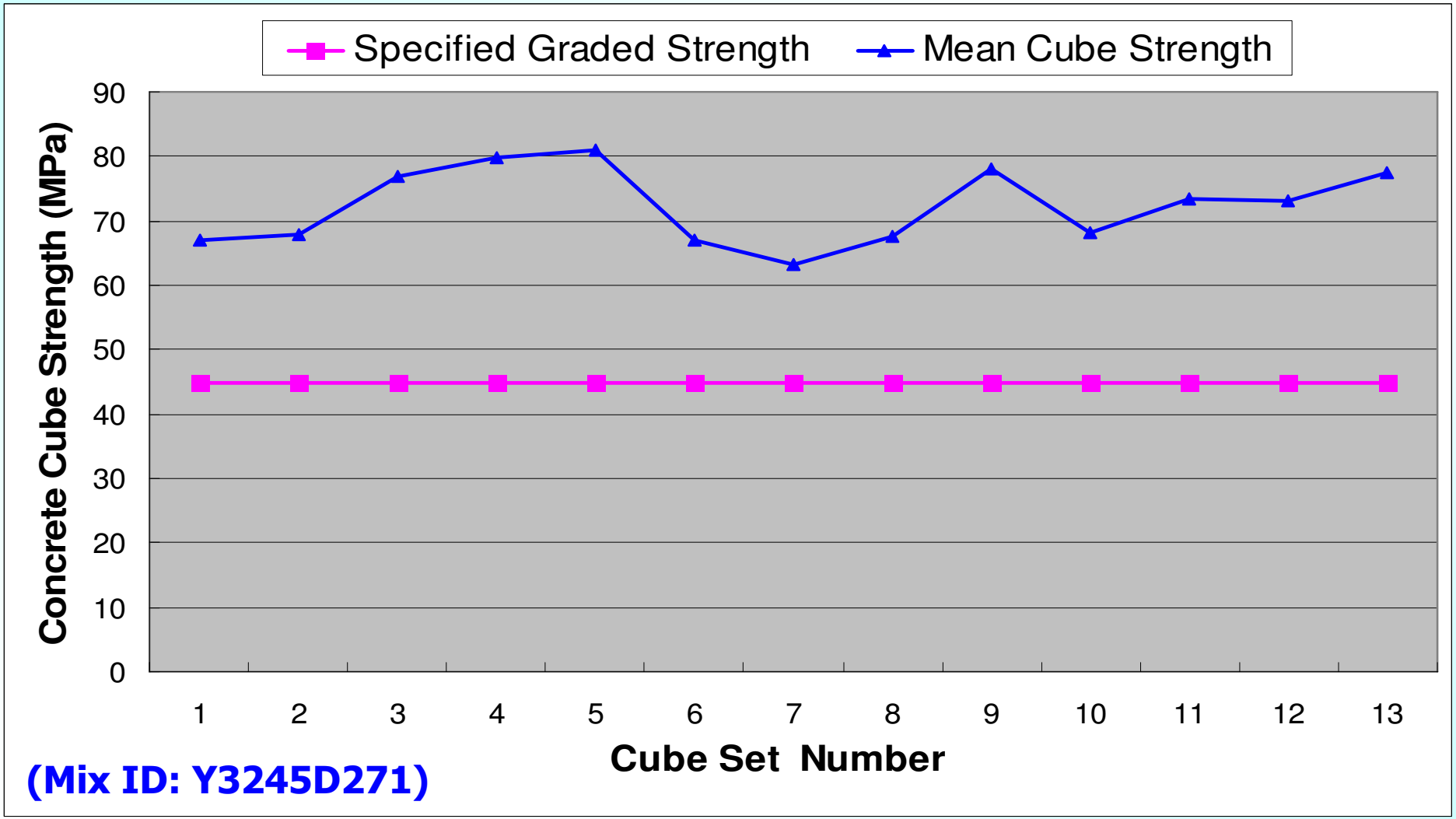
## Core Inspection for Segregation



# Application of SCE on Kindergarten (Walls)

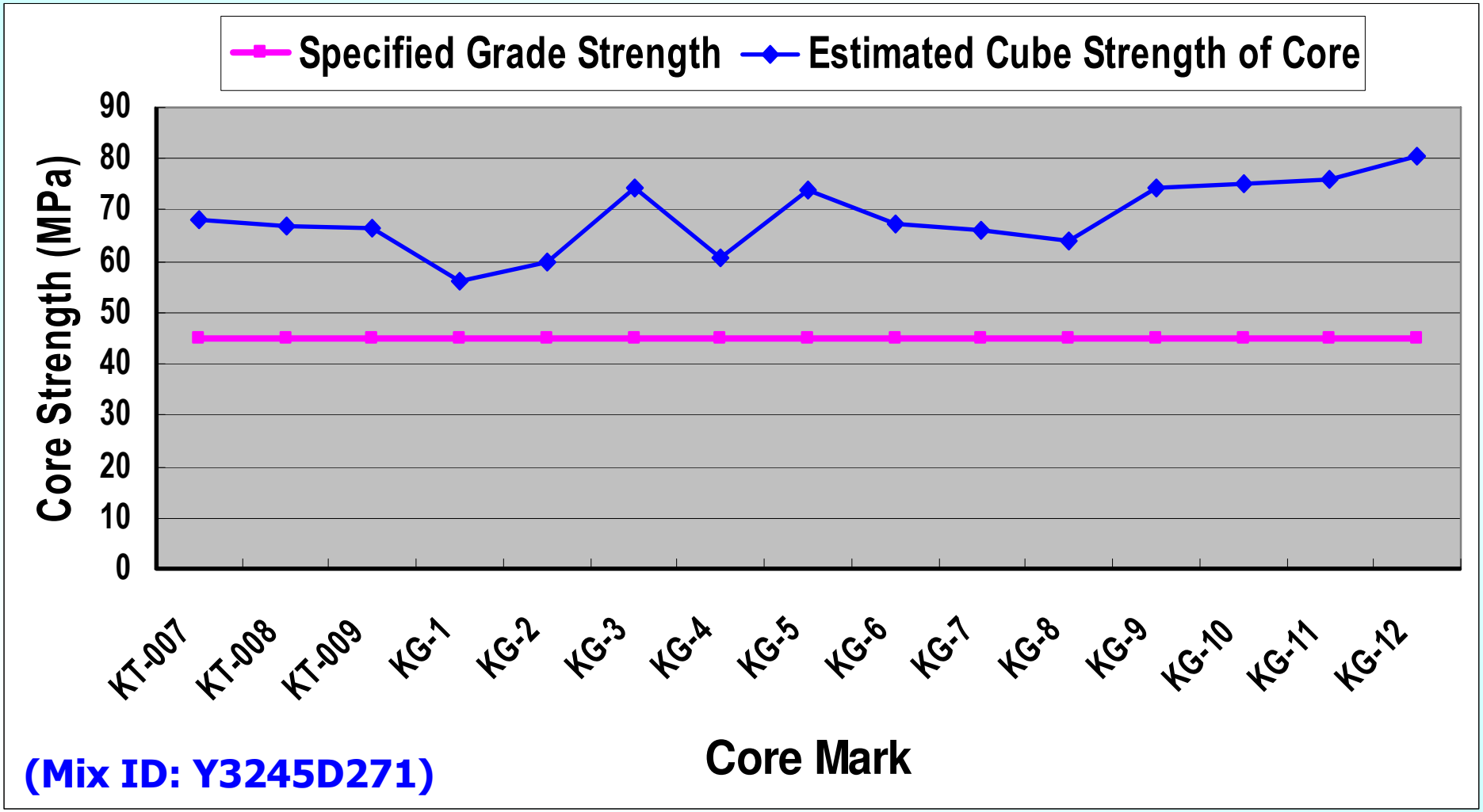
## Satisfactory Concrete Surfaces

# Cube Test Results of SCE




(Mix ID: Y3245D271)

# Core Test Results of SCE

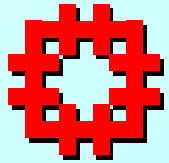



(Mix ID: Y3245D271)

# Other Observations in Using SCE

- The curing method (moist concrete surface with water sprinkler and cover concrete surface with tarpaulin sheets) is the same as that for conventional concrete.
- Less concreting labour is required.
- No compaction – concreting time is shorter and less noise nuisance.
- Concrete surface is relatively smooth and self levelled – good for flat surfaces but not suitable for ramps, stepped surfaces, and surfaces with structural fall.
- Prone to concrete defects, such as, bleeding, segregation, grout loss.





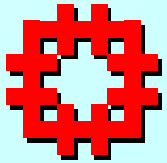
# Summary

1. Excelicrete™ is a state-of-the-art concrete technology which dramatically improve the performance of concrete.

2. Excelicrete™ optimizes void spaces between aggregates, reducing the amount of cement paste required to bond the aggregates.

3. Excelicrete™ reduces the carbon footprint of the construction effort; the higher the concrete strength, the greater the saving of cement use achieved – saving of **22%** cement in Grade **45** Excelicrete™ up to **42%** in Grade **100** Excelicrete™ in comparison with conventional concrete.





# Summary

4. Excelicrete™ concrete is a mature product that has demonstrated to have improved the performance of concrete in many aspects.

5. The developer has a lot of successful experience of using Excelicrete™ concrete in USA and the 1st successful trial in Hong Kong (Kai Tak Site 1B).

6. For Self Compacting Excelicrete™, it requires some refinement in the mix design and production to achieve high consistence in placing with satisfactory performance.

*The Chief Executive in the 2013 Policy Address stated that he had asked the DEVB and the THB to examine all projects in the pipeline to increase the plot ratio as appropriate. Apparently, buildings in Hong Kong are going to jack up high into the sky. It could be envisaged that the intelligent Excelicrete™, which is of high strength, sustainable and relatively inexpensive, will soon be widely adopted in the industry.*

# WAY FORWARD


Appreciation & Compliments
Yau Lee Construction Co., Ltd,
Dr Per Just Andersen &
Mr Simon Hodson
of DOCrete, LLC.
Hong Kong Housing Authority
Housing Department


**Standing Committee on Concrete Technology**
**Annual Concrete Seminar 2013**
18 April 2013, Hong Kong, China