QA-QC of Concrete In MAHA-METRO Rail Projects - A 360 Degree Perspective

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Vision

To create an energy efficient metro rail system of international standard which will enhance the quality of life of the citizens of Maharashtra and be instrumental in the overall development of the city by making it more vibrant & attractive and utilize the full potential of 'green energy' in the form of solar, wind, etc.

Mission

To provide a safe, reliable, efficient, affordable, commuter friendly and environmentally sustainable rapid public transport system for the Metro Region.

Nagpur Metro on Completed Viaduct

Completed Double Decker Bridge

A Project of Excellence

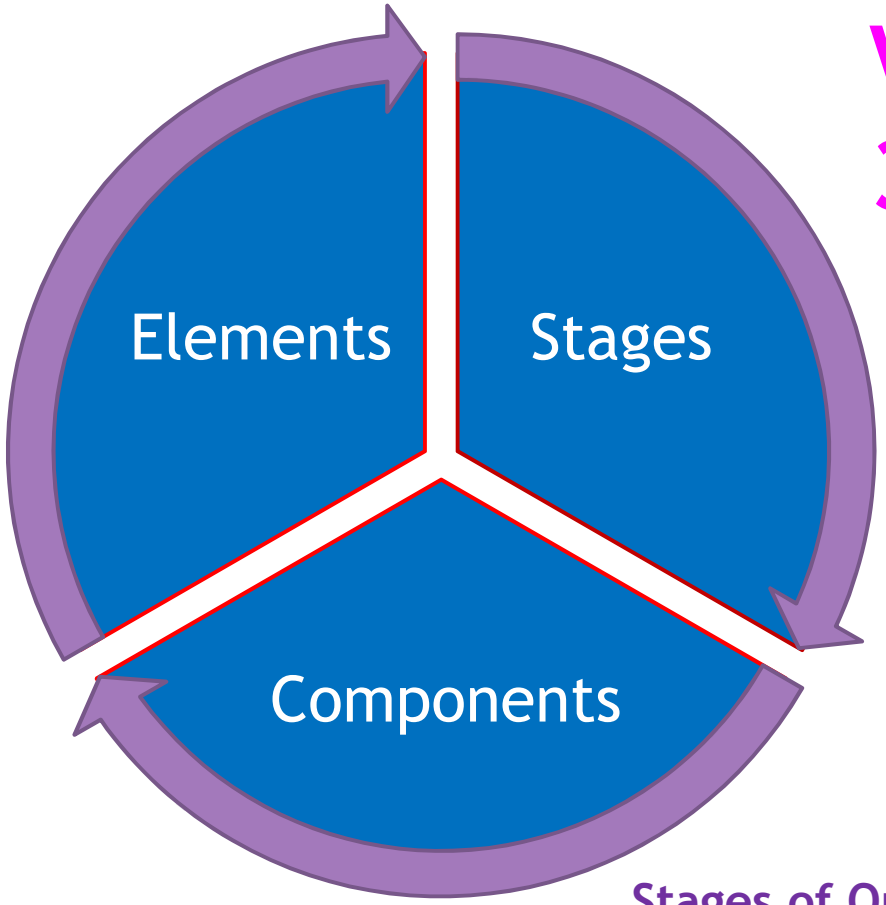
Double Decker Bridge - - Wardha Road, Nagpur : Actual photo

Proposed 4 Tier structure

4 Tier Bridge - - Kampthee Road, Nagpur: Artist Impression

A Project PAR Excellence

Why & What is Quality
360^0 Perspective



Elements of Quality Control

- ✓ Formulation of specifications.
- ✓ Method to be followed (Process Control).
- ✓ Norms of Acceptance (Acceptance Control).

Stages of Quality Control

- ➢ Preconstruction
- ➢ Construction
- ➢ Post construction

Components of Quality ASSURANCE - -

- ❖ Testing
- ❖ Monitoring
- ❖ Documentation
- ❖ Communication
- ❖ Audit
- ❖ Personnel and Training

Importance of QA & QC

- - It encompasses the Construction in 360^0

There is always some way to go to Consistently achieve Durable Concrete structures. ….

We need to address Quality Issues to make that journey Possible. !!!

"I sometimes think that the construction industry is like the person who seeks the wonder cure: the elixir that will provide eternal life with no effort at all on their part. Wouldn't it be wonderful if by the simple expedient of adding ingredient X all would be solved? There would be no need to worry about cover, compaction, curing or even the concrete itself. Life is not that simple..." C.D. Pomeroy

(COIN Project report 22 – 2010 - SINTEF Building and Infrastructure)

(COIN – CONCRETE INNOVATION CENTRE, Norway)

&

THAT'S the REASON why QA & QC is IMPORTANT

What is QA & QC : ? ?

Quality assurance (QA) is essentially the process of planning or forward thinking which is necessary to ensure that the specified quality will be obtained. Thus, the objective of QA is “engineering for quality" rather than "inspection for quality".

Quality control (QC) on the other hand, is the activity which is carried out to verify such compliance with specified requirement.

Testing and inspection of output forms the subject of Quality Control.

Quality assurance (QA)

Quality assurance (QA) can be defined as all those planned activities and systematic actions necessary to provide adequate confidence that a product or service will satisfy the given contract specific requirements.

Quality assurance provides consistency and an assurance that the established Quality Control (QC) procedures have been carried out in full.

Thus, the quality assurance is an “assurance” that the quality of the product is what it should be.

As per ISO 9000:2000, the term Quality Assurance means “ the assurance we give ourselves and others – customers, stakeholders, regulators – that Quality is being provided.

Within an organization, quality assurance serves as a management tool;

Quality control is part of quality assurance. They can also be said to be complimentary to each other.

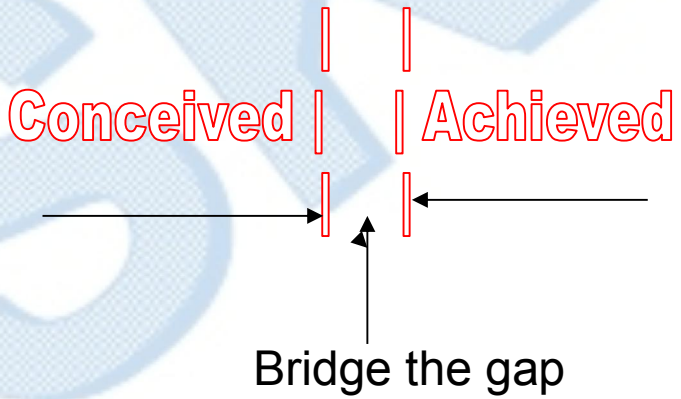
The word “Quality” is derived from the latin word “Qualitas”
which means
“What something is really like”.

ISO 8402 defines “Quality” as :
" The totality of features and characteristic of a product or service that bear on its ability to satisfy stated or implied needs"

Quality control Essentially means ‘Control of variability of Quality’

so that the end product is ‘Uniform’ in behavior.

Quality control means to bridge the gap between ‘what was conceived & designed’ and what is finally ‘achieved’.



Quality . . .

"Quality is never an accident;

it is always the result of

high intention, sincere efforts,

intelligent direction and skillful execution;

it represents the choice of many alternatives."

. . . a thought

GOOD QUALITY . . .

… Gives Satisfaction

What is the first Impression ??

Good Quality, Definitely YES. …

Why ?? ….. Lines are Clean, Perfectly aligned & in Plumb.

Surfaces are true, without bulging or warping without blemishes, and consistent in color.

Formwork carefully constructed.

Philosophy in Maha-Metro

- To adopt a 'First Time Right' approach every time with a 'Zero Defects' culture by Contractor.

- To adopt QMS - Serves to transform client requirements into client satisfaction through the application of processes utilising the 'Quality Cycle' (Plan-Do-Check-Act) model

- Is supported by Quality System Procedures, formats, *work instructions (method statements), checklists* - - so as to deliver to the people at large '**products & services**' by:
  - *Robust* Quality Control (QC)
  - Quality Assurance (QA) practices.

QC Cycle

As per ISO 9001:2015 - - Quality Management System

Review/ Act

P – E – C – R

OR

P – D – C – A

Planning

Checking

Execution/ Do

Quality Management of Maha Metro Rail is derived through:

- The conduct of audits.
- Surveillances and day to day site visits.
- Review of submitted documents and records.
- Inspection & Test Plan (ITP) intervention points, selected from representative or random samples.

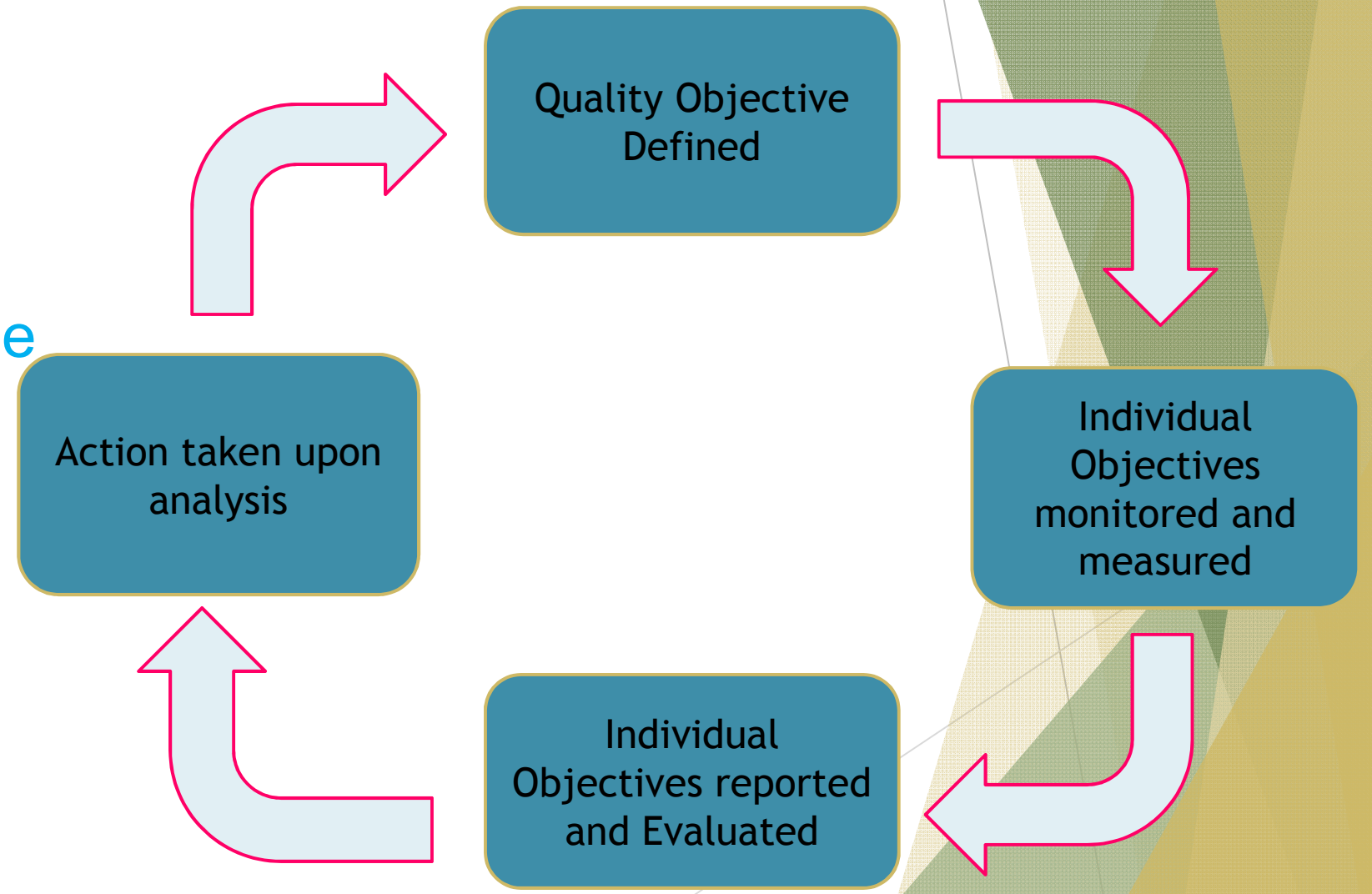
Requirements of Quality

- Quality Managements System (QMS)
- Strategy and Quality Policy
- Legal and Other Requirements
- Key Performance Indicators (KPI's)
- Contractor's Registers
- Contractor's Deliverables

Principle of Establishing KPI

KPI's For:

Continual improvement through the Monitoring and Review of Contractor's performance against objectives and targets during periodic meetings from time to time.



Contractor KPI's for Monitoring Quality

Idx	KPI	Frequency	Calculation Method	Target	
1	Quality Training (QT)	Monthly	Number of Quality training days X Nos of participants / Average Nos of Employees	Green Amber Red	QT > 4 3 ≤ QT ≤ 4 QT < 3
2	Quality Audit Schedule Compliance (QASC)	Monthly	Number of Quality audits conducted/ Number of Quality audits scheduled	Green Amber Red	95% < QASC 95 ≤ QASC ≤ 75 QASC < 75%
3	Timely closure of CARs raised during Quality Audits (CAR)	Monthly	Number of Audit CARs within agreed time-scale / Number of Audit CARs due to be closed	Green Amber Red	95% < CAR 95 ≤ CAR ≤ 75 CAR < 75%
4	Repetition of NCRs (RNCR)	Monthly	Number of repeated Quality NCRs / Total Number of Quality NCRs	Green Amber Red	RNCR < 5% 5 ≤ RNCR ≤ 10% RNCR > 10%
5	Concrete Compressive strength (28 day) Test (CCS)	Monthly	Number of Samples Pass / Total Number of Samples Tested	Green Amber Red	100 < CCS < 99 99 ≤ CCS ≤ 98% CCS < 98%
6	NCR's status (NCR)	Monthly	Number of NCRs Closed within agreed timescale during month / Number of NCRs planned to be closed during the month	Green Amber Red	95% < NCR 95 ≤ NCR ≤ 85 NCR < 85%

Strategy For Quality Policy

Quality policy includes commitment to:

- Embedding a quality culture through active leadership.
- Delivering a Cost, sustainable and energy efficient Metro Rail Project in a short Time-scale (48 months).
- Offering Best-in-Class Services for the Maha metro in respect of modern, safe and high-technology based Transport System.
- Providing adequate resources.
- Training and appointment of competent staff for effective implementation of the QMS to ensure Project requirements are achieved

Works Management

Building Information Modelling (BIM)

- ✓ It is the technique of capturing building and infrastructure design through the use of 3D geometric and information models built up from objects and information databases that represent building elements, components and materials
- ✓ Maha Metro digital platform will be including 5D BIM (3D plus cost plus time).
- ✓ Regulation and monitoring the contractor progress will be through BIM
- ✓ Design management will also be carried out by applying the BIM concept
- ✓ The 5D scheduling will help to better schedule
- ✓ The model can demonstrate planning and movement from site works to operatives

Works Management

- ✓ Building Information Modelling (BIM) : consist of 4 Software Packages

Sr. No.	Software	Used for
1	Bentley	For design/drawing/ Modeling/Documents
2	SAP (System, Application, Product)	Cost/ Activities/Quality Monitoring
3	Primavera – For Scheduling and monitoring	For Scheduling and monitoring
4	RIB (Revolution in Building) - Visualization	Visualization

Works Management

- ✓ Inspect quality records during surveillances and audits at Contractor's, Manufacturer/Supplier's facilities, to confirm compliance with the Quality Plans and procedures.
- ✓ Witness sampling and testing on materials; witness testing on equipment, systems and trial running and review the relevant test reports.
- ✓ Monitor the condition of tools and equipment to ensure that implementation of works is with due quality.
- ✓ Issue Quality Alerts and ensuring that all parties concerned are well informed.
- ✓ Prepare a Quality Monitoring Plan (QMP) in reference to Contractor's QAP and procedures, for sample inspections, audits and verifications to ensure adherence to project requirements.
- ✓ Undertake Competence gap analysis of all individuals for roles affecting quality, identifying any shortfalls and proposing measures.

Practices for Quality

For Continual / Incremental Improvement in QUALITY

- Tests done on Incoming Construction Materials
- Tests for Concrete
- Sensitization Workshops
- Tool Box Trainings
- Quality Circles
- Intra Contractors QC Cluster Meetings
- Site Visits
- Monthly Meetings
- QC Booklets
- Do’s and Don'ts Boards on site

Nagpur Metro Rail Project										
Name of Work: Design and Construction of VIADUCT IN REACH of NAGPUR METRO RAIL PROJECT										
Agreement/Contract No.:						Name of Contractor:				
Summary of Quality Control Tests done on Incoming Construction Materials Cumulative up to 2021										
Sl. No.	Material	Cumulative Quantity Received (MT)	Test Description	No. of Tests		Results received				Results awaited
				Target	Actually done	From Awaited	Cumulative up to month	Conform	Not conform	
1	Cement (MT)		Physical/ Chemical							
2	Steel (MT)		Physical/ Chemical							
3	F.A. (MT)		Physical/ Chemical							
4	C.A (MT)		Physical/ Chemical							
5	Water		Physical/ Chemical							
6	Admixture (MT)		Physical/ Chemical							
7	VMA (MT)		Physical/ Chemical							
8	Micro Silica (MT)		Physical/ Chemical							
9	Inhibitor Solution (MT)		Physical/ Chemical							
10	Sealing Solution (MT)		Physical/ Chemical							

Contd....

Summary of Quality Control Tests done on Incoming Construction Materials Cumulative up to 2021

List of Materials Tested		
Wedges (Nos.)	HT Strands (MT)	Geo strap 25 KN (Nos.)
Protective coating (Paint) lit	HDPE pipe (m)	Geo strap 50KN (Nos.)
S.S rails 38 mm dia (MT)	HDPE Rain Water Pipe (m)	Geo textile (SQMT)
S.S rails 19 mm dia (MT)	Fly Ash (MT)	EDPM rubber pads (Nos.)
S.S rails 16 mm dia (MT)	Mould Release Agent (MT)	M.D.D (cum)
Non0Shrink grout (Kg)	PPE Fiber (MT)	F.D.D (cum)
Epoxy grout (Kg)	Curing Compound (MT)	Gradation (cum)
Segmental Glue (KG)	Anchor Cone (Nos.)	Plasticity Index (Cum)
Lifting Anchor (Nos.)	Anchor Head (Nos.)	Direct Shear (cum)

Summary of Quality Control and Quality Monitoring carried out by up to 2021 end for Reach- for Concrete.

Sr. No.	Grade of Concrete	Total Qty. (Cum)	Sample required as per Frequency	Sample taken	Results Received			Standard Deviation	Coefficient of Variance	Result Awaited
				Nos.	Nos.	Confirming	Non-Confirming			
1	M-15									
2	M-25									
3	M-35									
4	M-40									
5	M-45									
6	M-50									
7	M-60									
8	M-70									
Grand Total										

Nagpur Metro Rail Project										
Name of Work: Design and Construction of VIADUCT IN REACH of NAGPUR METRO RAIL PROJECT										
Agreement/Contract No.:					Name of Contractor:					
Summary of Quality Control Tests done on FINISHED PRODUCT					Cumulative up to 2020					
Sl. No.	TEST	Cumulative Quantity Executed	Test Description	No. of Tests		Results received				Results awaited
				Target	Actually done	From Awaited	Cumulative up to month	Conform	Not conform	
1	WPT									
2	NDT									
3	PIT									
4	RCPT									
5	CHSL									
6	WPT									

Toolbox; Quality Circle & Quality Cluster (Intra Civil Contractors)

Sr. No.	Reach	Toolbox		Quality Circles		Quality Cluster	
		Total no. of trainings	Total no. of trainees	Total no. of trainings	Total no. of trainees	Total no. of trainings	Total no. of trainees
NMRP							
TOTAL		1310	15265	183	1815	34	399

Toolbox; Quality Circle & Quality Cluster (Intra Civil Contractors)

Cumulative data

Reach	Toolbox		Quality Circles		Quality Cluster	
	Total no. of trainings	Total no. of trainees	Total no. of trainings	Total no. of trainees	Total no. of trainings	Total no. of trainees
PMRP						
TOTAL	5109	80182	226	2348	29	236

Practices in Maha-Metro

- Tool Box Trainings

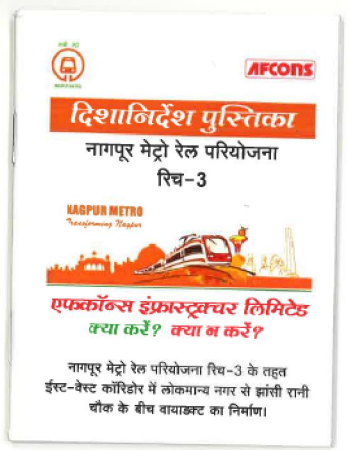
Practices in Maha-Metro

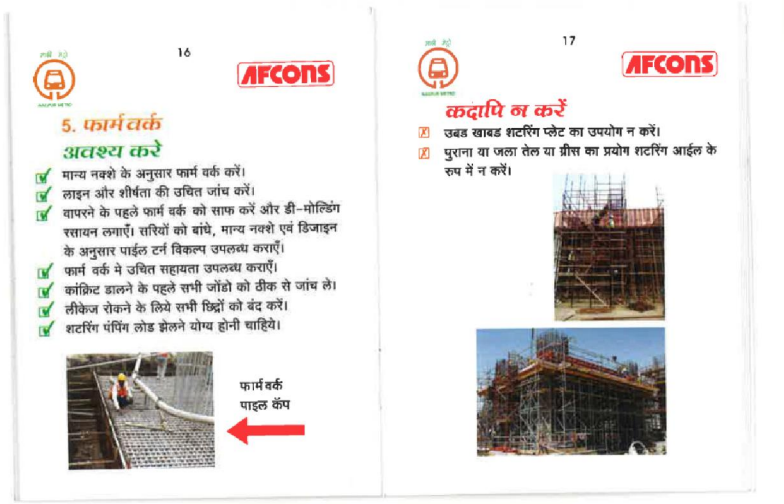
- Quality Circles

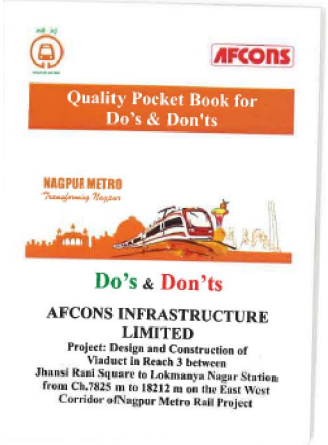
- Quality Clusters

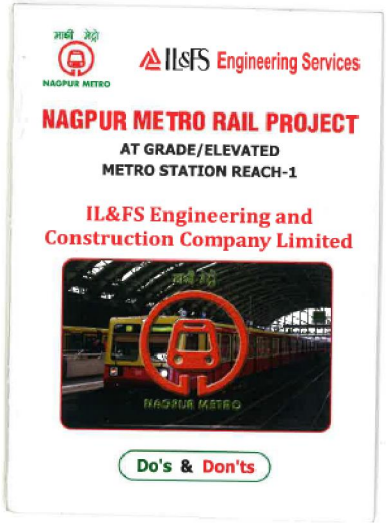
Practices in Maha-Metro

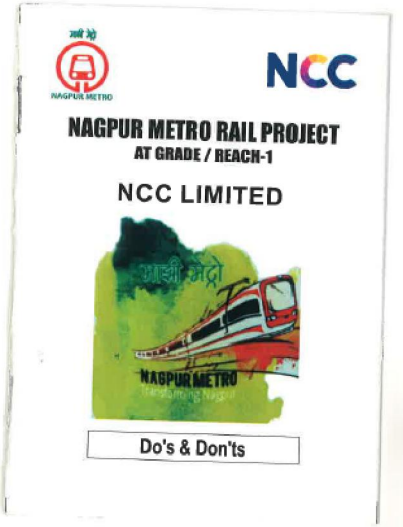
Quality Control Booklets

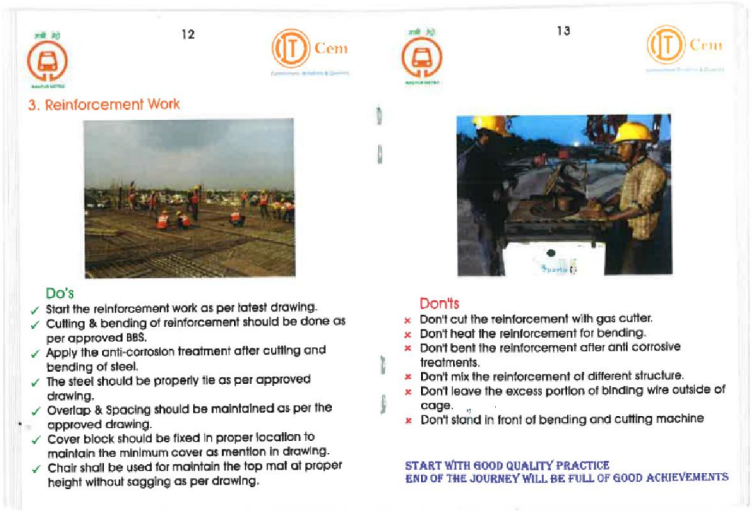












Practices in Maha-Metro

- Do’s and Don’ts Boards displayed at site

Maintaining Quality - Good Practices

- Application of curing compound – Properly & Evenly.
- Hessian cloth covering all the surfaces & tightly wrapped.
- Proper training of site engineers
- Cubes covered after curing.
- Proper precautions taken during de-shuttering of segments.
- Proper bending of stirrups
- Providing proper & Uniform cover
- Precautions to avoid cracks
- Proper concreting to avoid Honeycombing/Bugholes
- Proper marking on cubes
- Proper sampling
- Proper stacking of reinforcement on site

Adopting the
KAIZEN Way
in
Project Execution

Maintaining Quality - Good Practices

- Proper formwork erection.
- Proper tying of knots of reinforcement.
- Random Check of Materials at site and at source.
- Re-verification of concrete Mix Designs.
- Strict enforcement of Use of RMC within three hours after its production.
- Water Tank of TM sealed before dispatch.
- Pouring height not to exceed1.5m in case of concreting by chute.
- Proper protection/filling/of cubes filled at site.
- Foam rubber/sheets to be used to avoid leakage of concrete slurry from form work.
- Proper housekeeping at site, disposal of waste.
- Timely testing by 3rd party for material received at site.
- Proper assertive closures of NCR's, OBV's, Site Visit Notes.

Our AIM

Incremental Improvement

Maintaining Quality - Good Practices . . .

GOOD FORM WORK

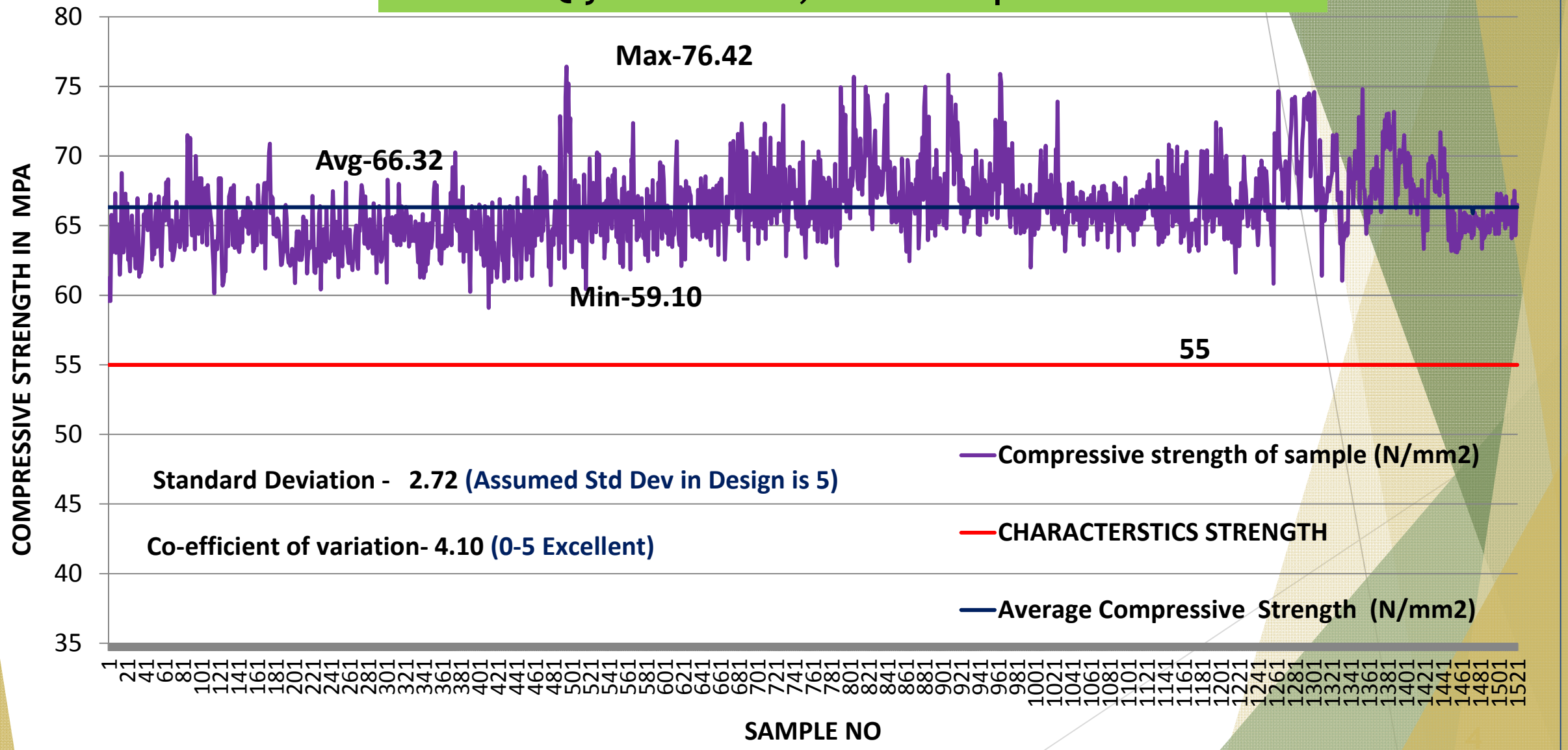
*Remember that :*The starting point for high quality in concrete construction is the **formwork**

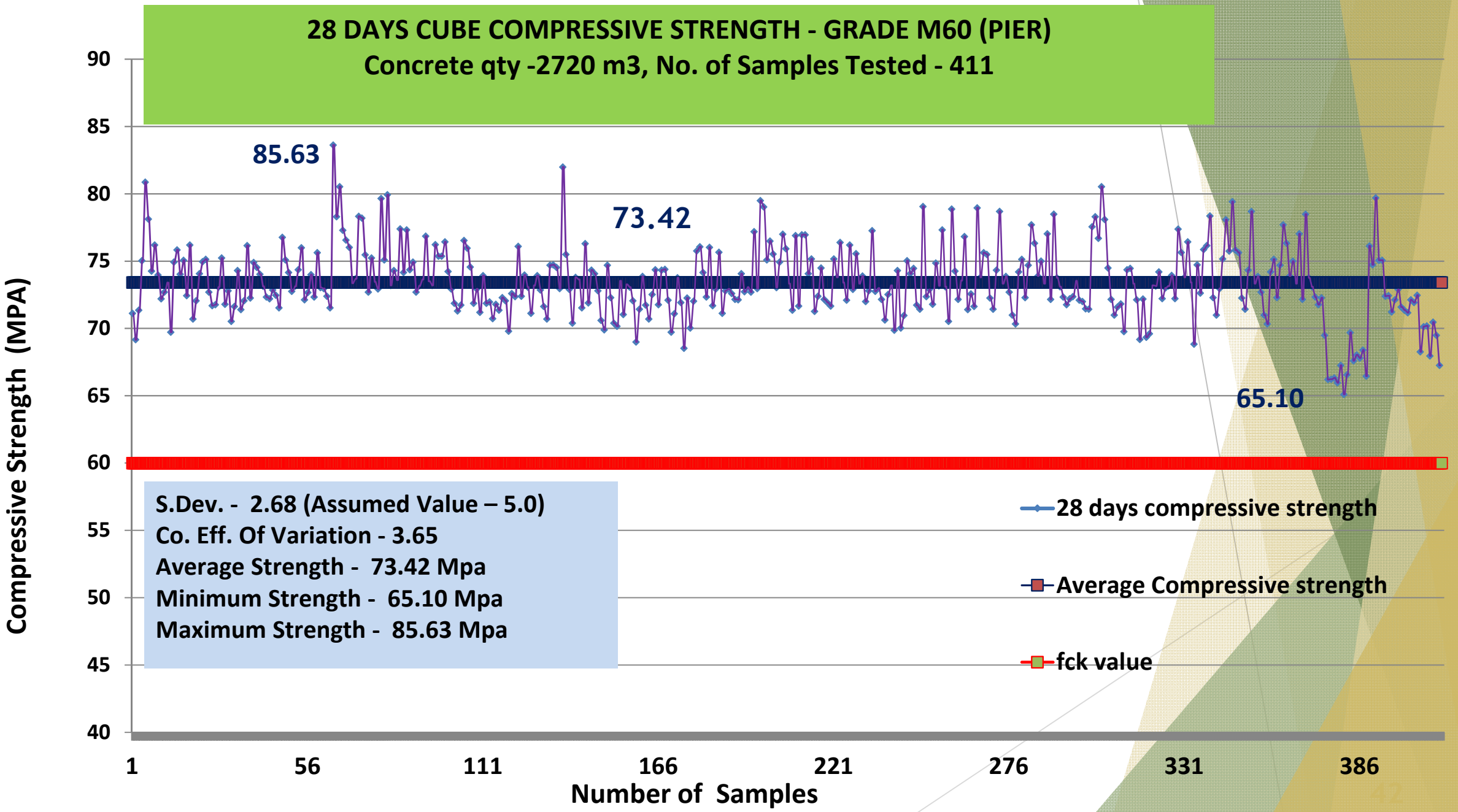
GOOD FORM WORK
Results in

Good Finish

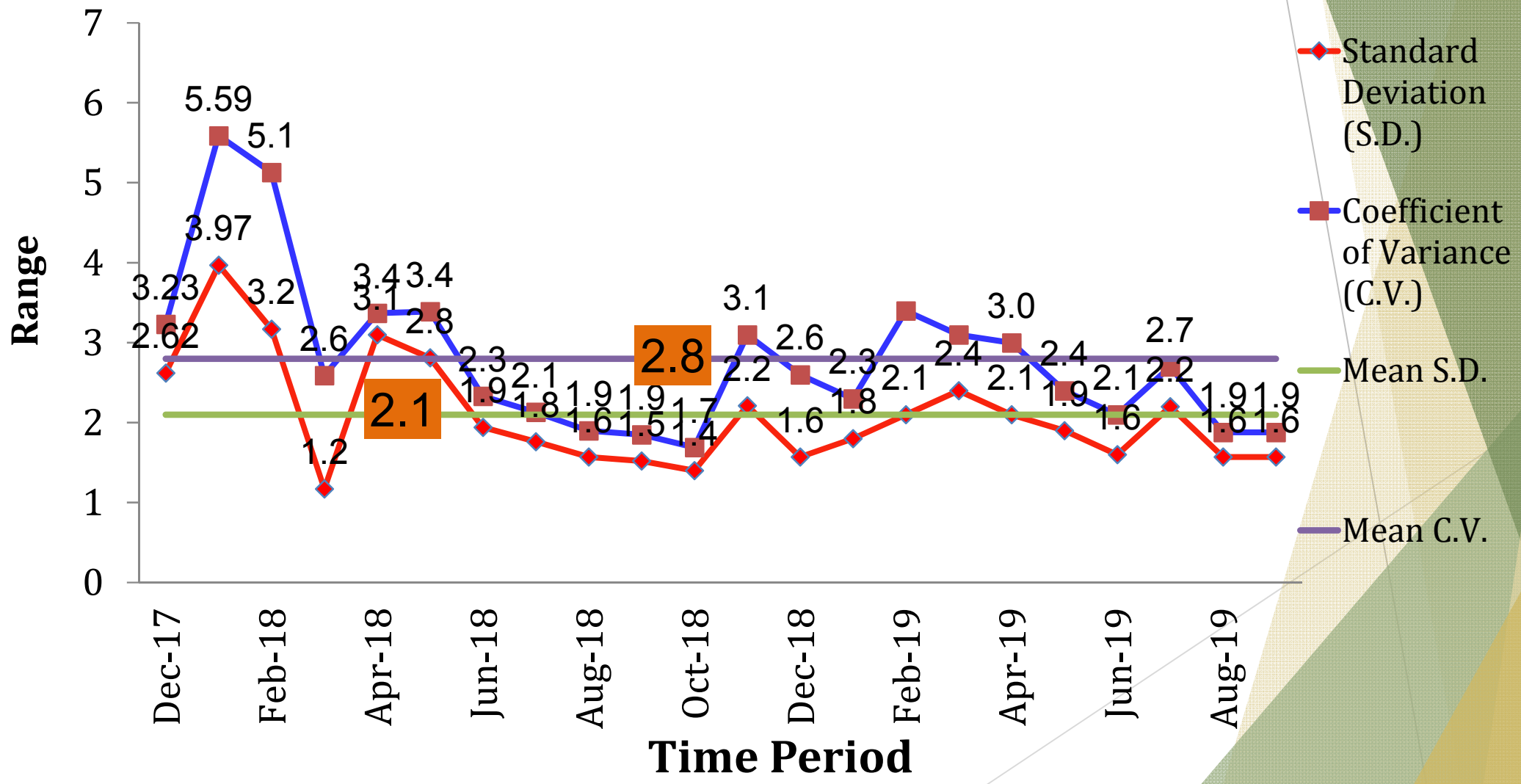
Good Lines and Levels

CUBE COMPRESSIVE STRENGTH TEST -M55 Grade
Qty - 17244 m3, No. of samples 1521

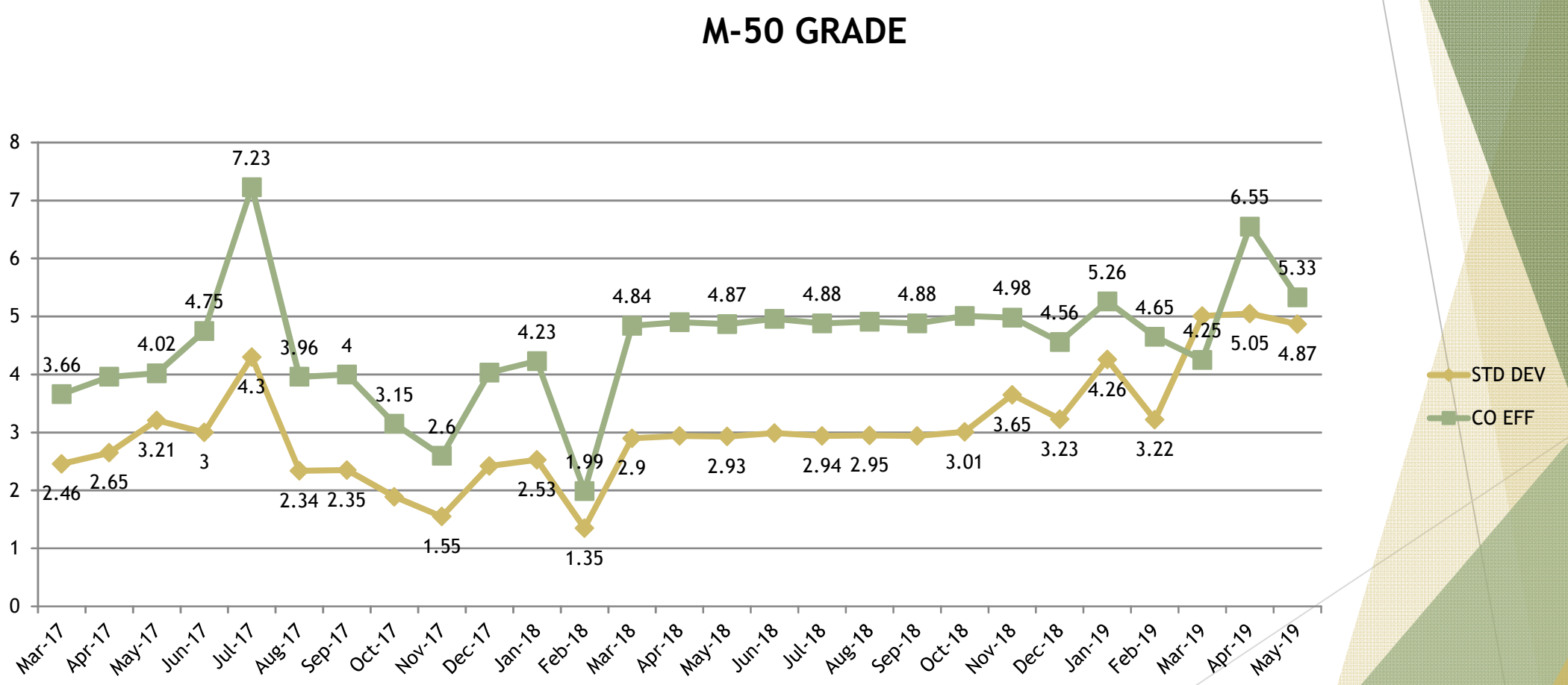



28 DAYS CUBE COMPRESSIVE STRENGTH - GRADE M60 (PIER)
Concrete qty -2720 m3, No. of Samples Tested - 411
85.63
73.42
65.10
S.Dev. - 2.68 (Assumed Value – 5.0)
Co. Eff. Of Variation - 3.65
Average Strength - 73.42 Mpa
Minimum Strength - 65.10 Mpa
Maximum Strength - 85.63 Mpa
28 days compressive strength
Average Compressive strength
fck value
Compressive Strength (MPA)
Number of Samples
90
85
80
75
70
65
60
55
50
45
40
1
56
111
166
221
276
331
386

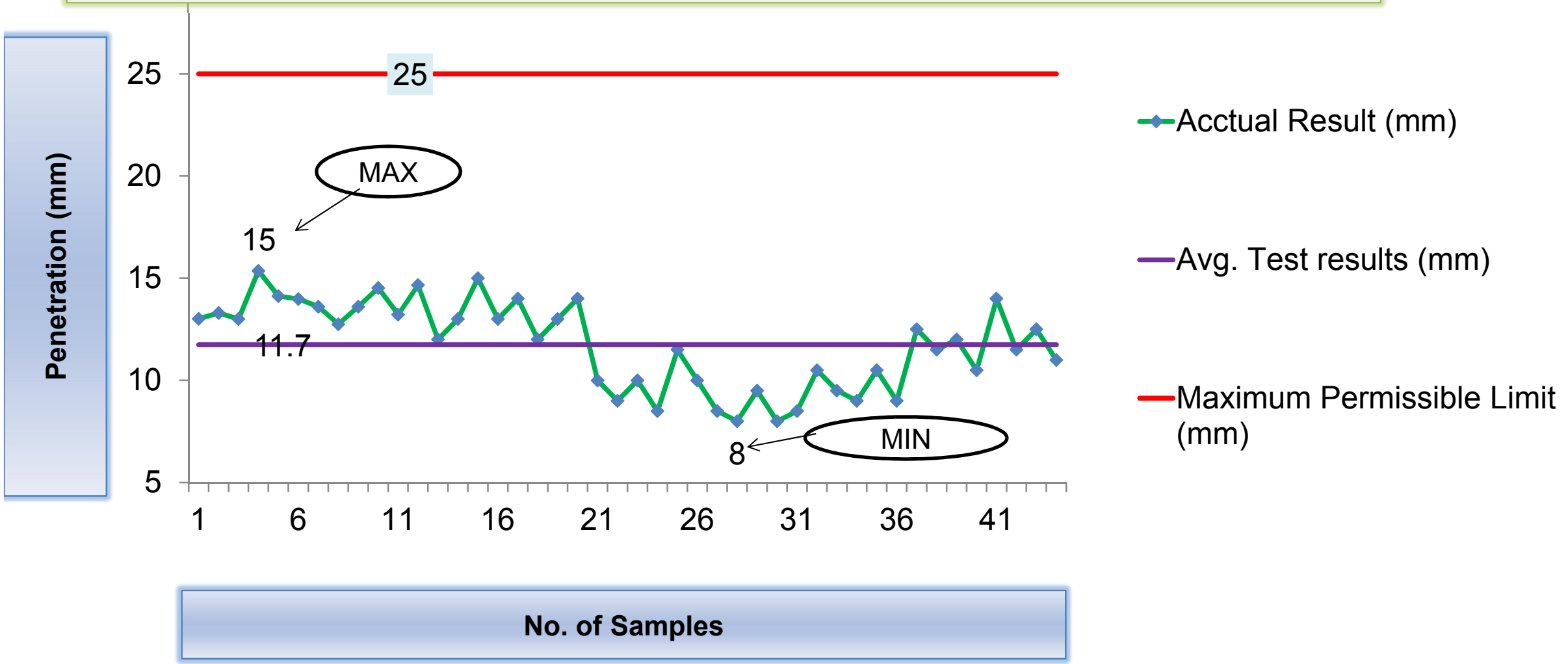
Grade month wise Standard Deviation & Coefficient of Variance



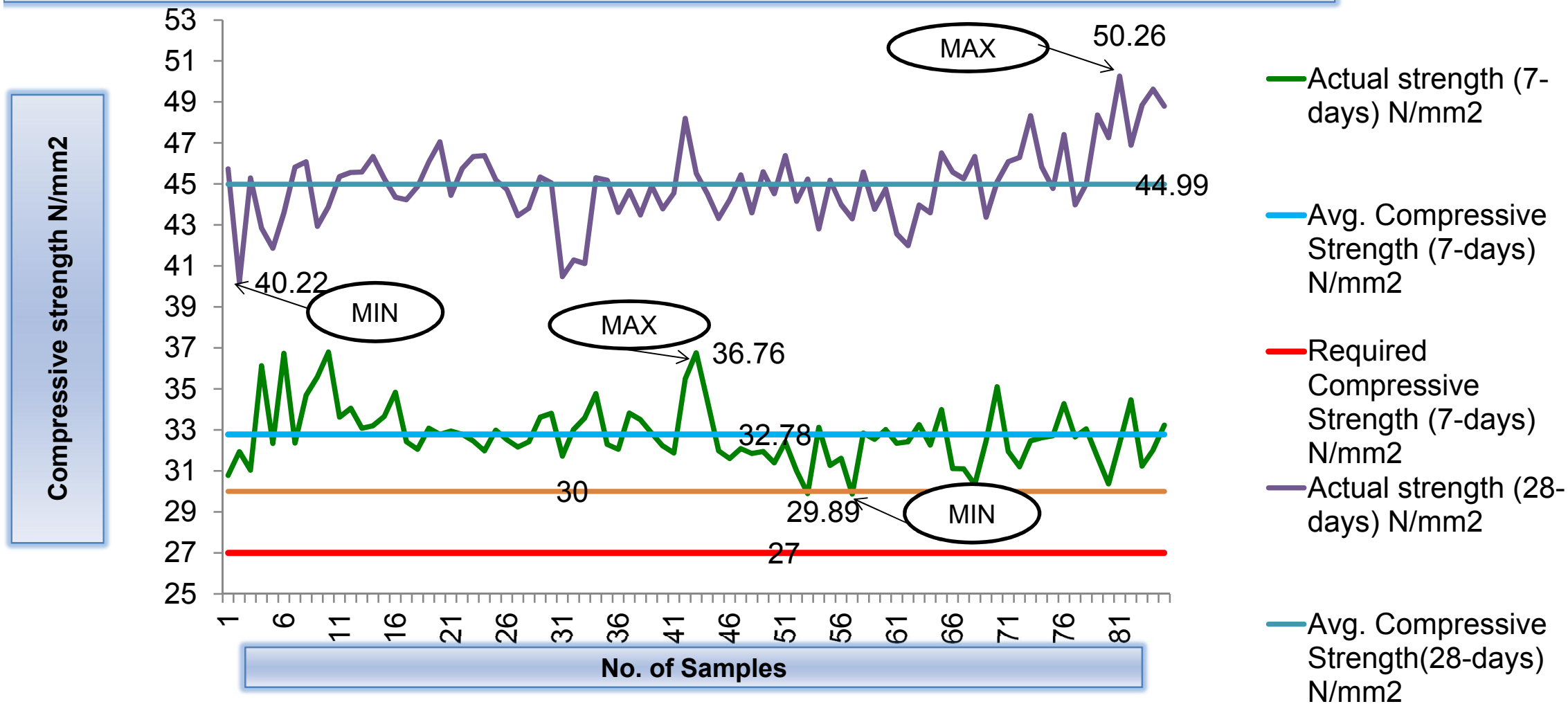
Standard Deviation & Coefficient of Variance

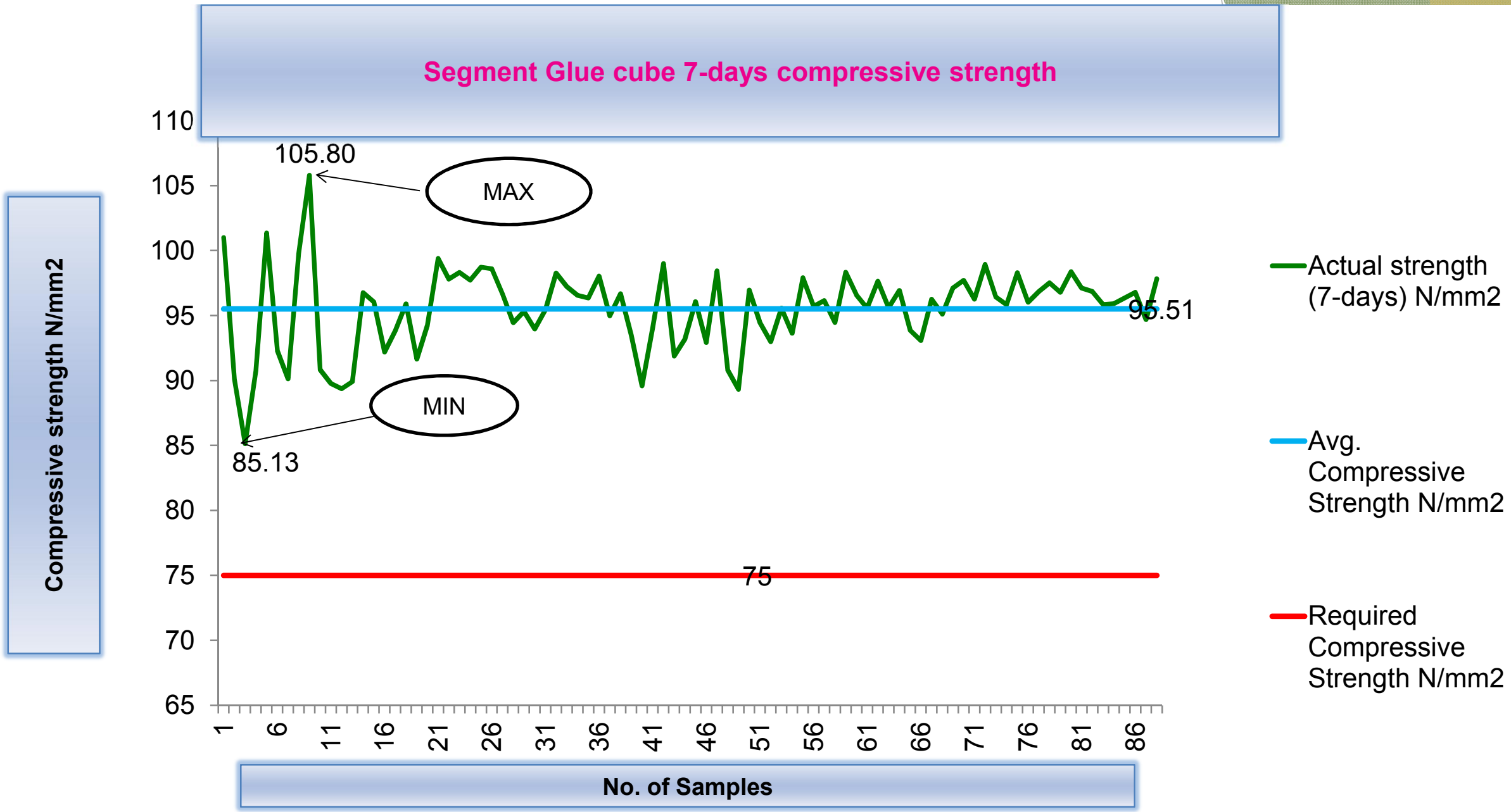


Permeability test results of M40 Grade Concrete for Pile & Pile cap



P.T. Cable Grout cube 7 & 28-days compressive strength in Mpa




Segment Glue cube 7-days compressive strength
Compressive strength N/mm2
110
105
100
95
90
85
80
75
70
65
105.80
MAX
MIN
85.13
95.51
75
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
No. of Samples
Actual strength (7-days) N/mm2
Avg. Compressive Strength N/mm2
Required Compressive Strength N/mm2

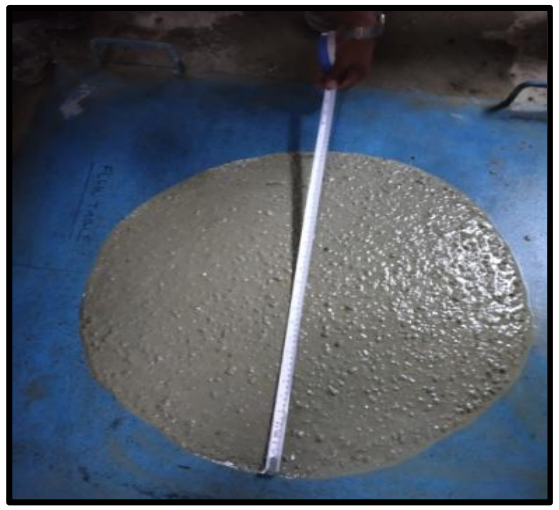
New Initiatives for Improving Quality

- Use of Self Compacting Concrete (SCC)
- Use of Secondary Cementatious Materials (SCM) – Flyash & GGBS & Micro silica.
- Use of PP Fibrillated Fibres in Segments.
- Use of Curing Compound.
- Use of Colored concrete
- Use of Flyash Bricks, AAC blocks, Paver blocks.
- Use of ice in concreting.
- Sprinklers on aggregate stocks.
- Covering TM's by double layer wet hessian cloth.
- Thermal Monitoring of Temperature rise in Concrete by embedding Thermo Couples.

SCC used in NMRP & PMRP Projects

- **Used in M60 Grade in Cast In-situ Highly Congested Reinforcement Structure Of Vierendeel Concrete Truss at interchange Station of Nagpur Metro.**

- **Used in NATM Overt Secondary Lining : M40 grade in Pune Metro.**



Slump flow Test

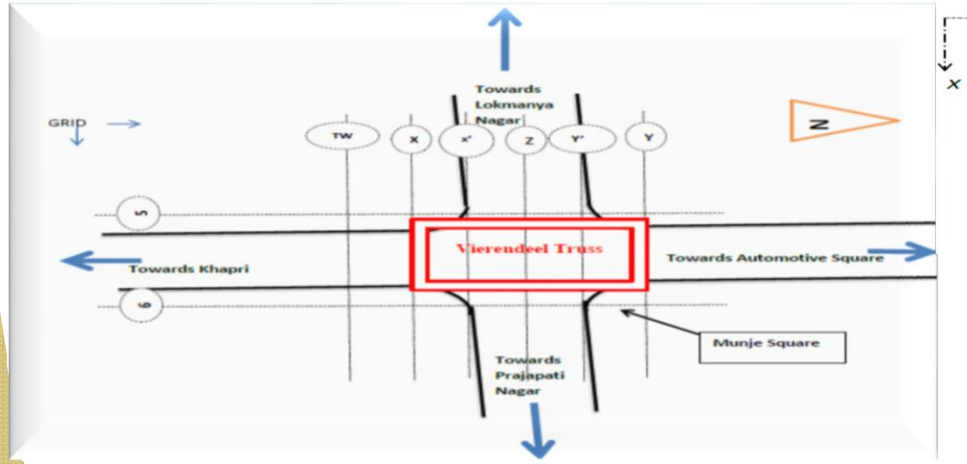
L-Box Test

U – Box Test

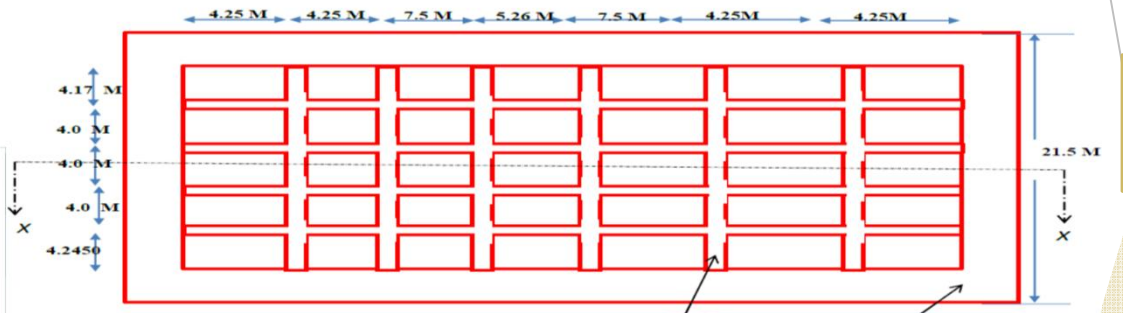
V Funnel Test

Details of final selected SCC mix design trial mix - NMRP
Concrete Grade M-60 (12.5MSA)

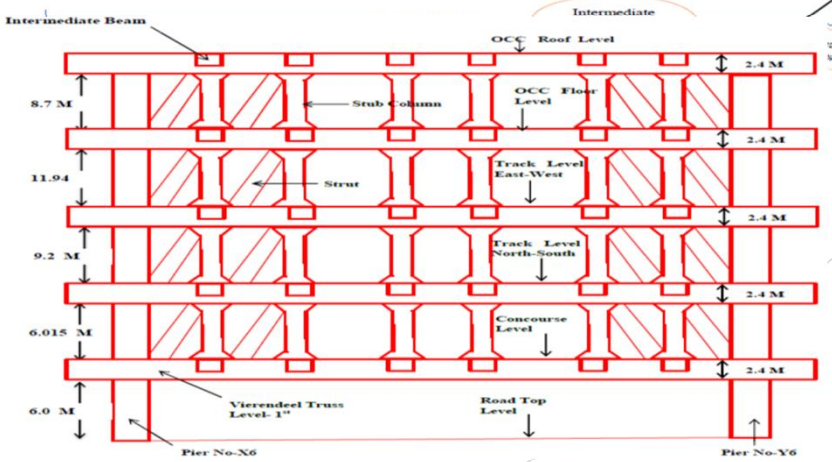
Cementitious (Kg)		Water (Kg)	River Sand (kg)	Coarse aggregate (12.5 MSA) (Kg)	HWRA (Kg)	VMA (Kg)
Cement OPC 53 grade (%)	Fly ash (%)	174	811	830	4.03	1
450 (72 %)	170 (28 %)					



Layout plan of Sitabuldi Interchange Station



Plan-Vierendeel Truss



SECTION XX – Showing Vierendeel Truss (5 layers) with vertical Columns and inclined Struts

Actual site photographs

Cube Compressive Strength of Trial Mix no TR-5 for M60 grade of Concrete in N/mm2 – In laboratory.

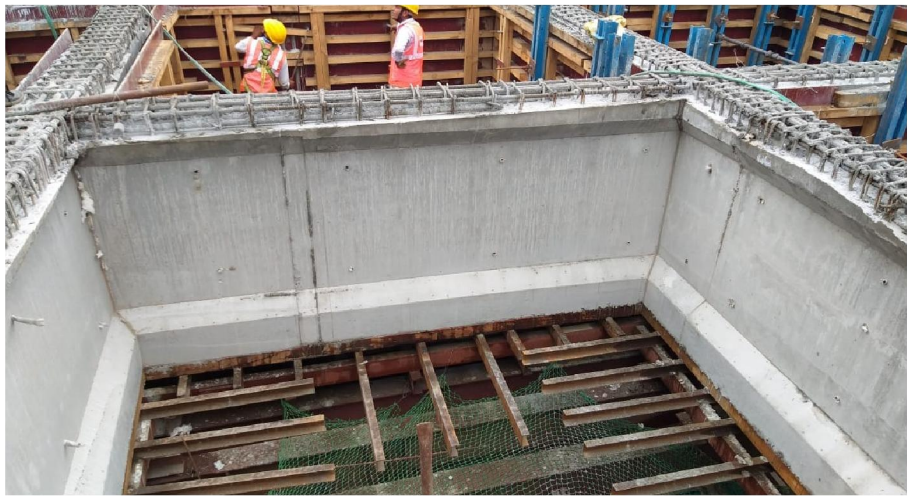
Sr. No	7 days	28 days	56 days
1	54.65	71.34	78.88

The Compressive Strength at site casted cubes for M60 grade of Concrete (in N/mm2)

Sr. No	Age of Cube	No. Samples Tested	Avg. Strength of Samples (N/mm2)	Standard Deviation (N/mm2)	Coefficient of Variation (%)
1	7 days	9	54.09	1.8	2.6
2	28 days	34	70.22		
3	56 days	9	78.04		

Observation

- SCC mix design was accurate - No bleeding, No segregation & No Clogging.
- SCC has been placed successfully in formwork without any break downs and obstacles due to proper planning and systematic arrangement.
- After De-shuttering of beams, concrete surfaces found smooth without any defects.

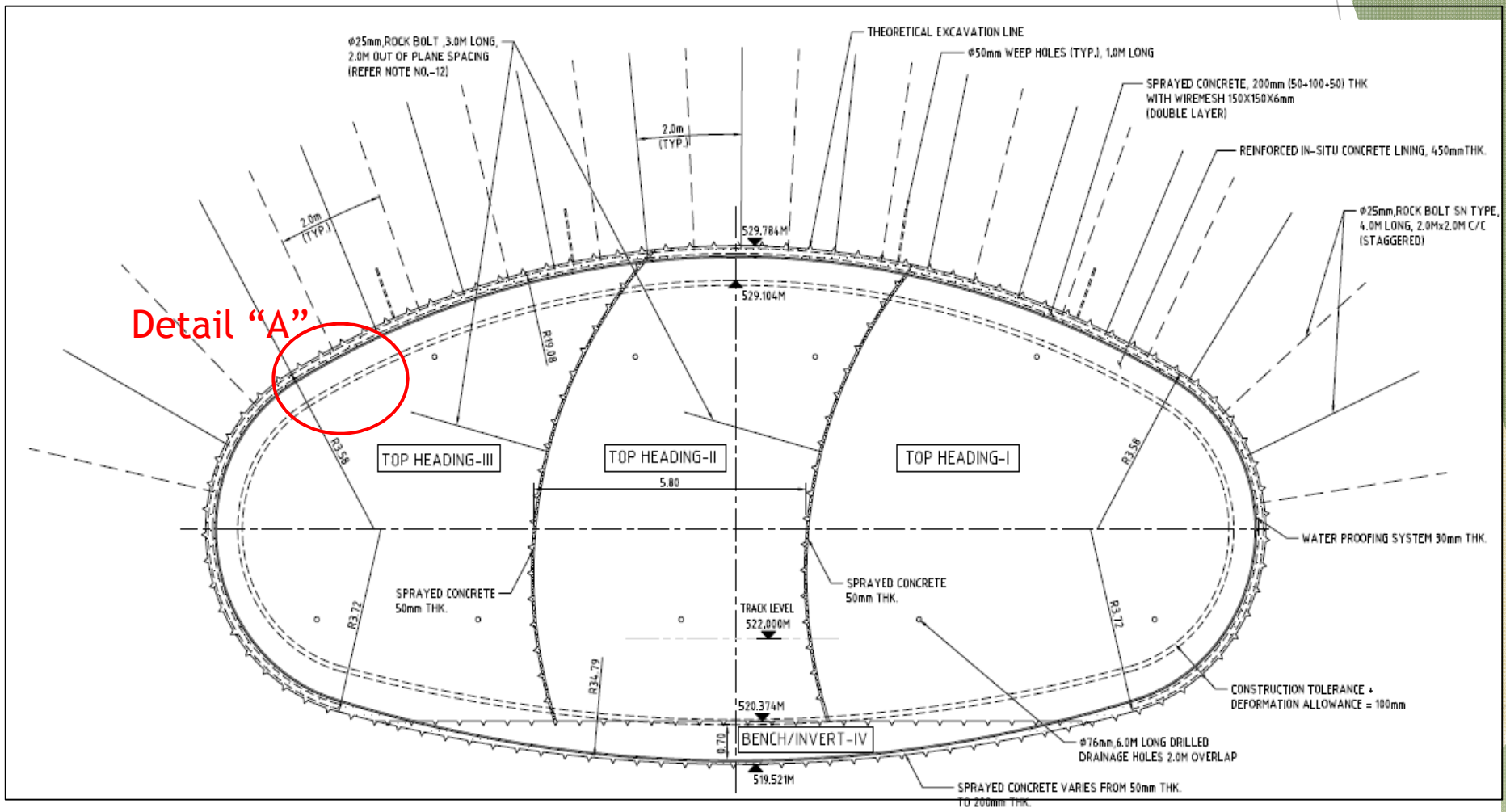


Smooth surface observed after de-shuttering

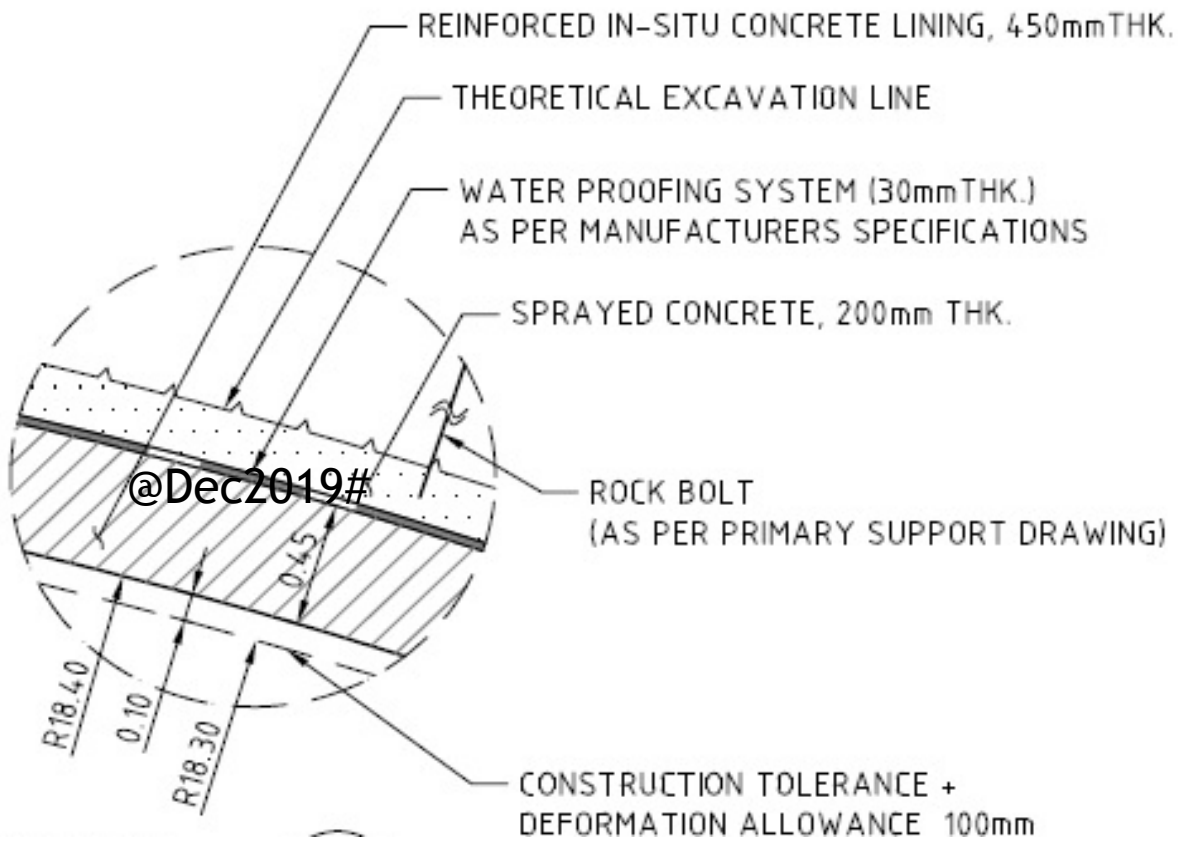
PMRP: Self Compacting Concrete (M40)- Overt Secondary Lining

S.No.	Description	Overt Lining
1	Overt Thickness (mm)	450
2	Concrete Grade	M40 (SCC)
3	Total Scope Concrete Quantity (Cum)	9311
4	Total Concrete Poured Till Date (Cum)	1546
5	Flow (mm)	650 - 800
6	Temperature (°C)	25 to 32
7	Formwork Demoulding Criteria	Min. 15 Mpa

NATM Crossover Support drawing

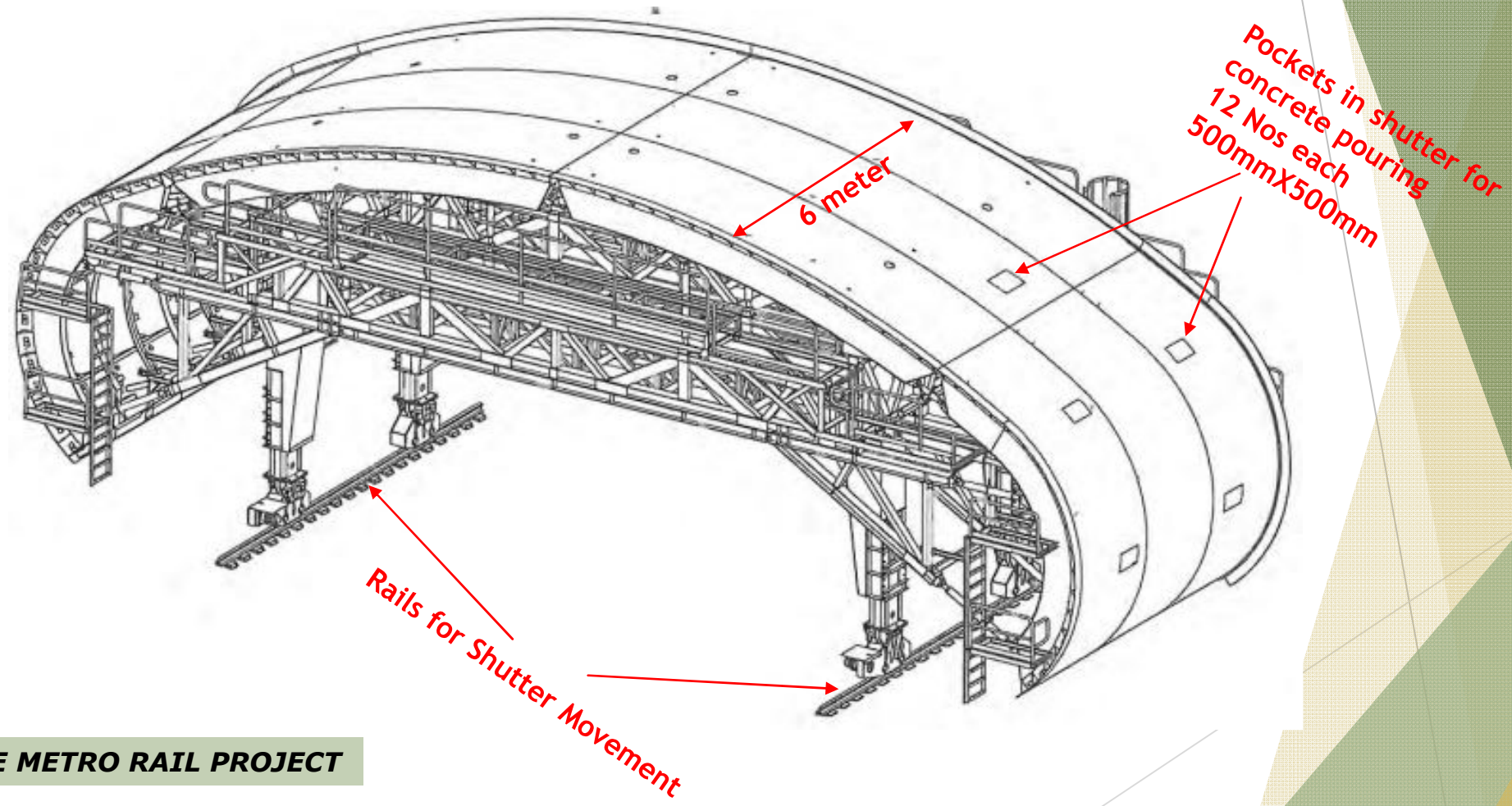


NATM Crossover Support drawing



Detail "A"

Secondary/Permanent Concrete Lining- Overt Shutter



Overt Concreting Photographs

Photograph After Primary lining

Photograph After Secondary lining (SCC)

Use of Fly-Ash & GGBS
In
Cement Concrete

HOW FLYASH & GGBS HELPS ?

FRESHCRET

- Reduces water demand
- Increases workability
- Improves rheology of mix
- Enhances water retentivity
- Increases cohesivity & pumpability
- Reduces internal bleeding and segregation
- Reduces plastic shrinkage

HOW FLYASH & GGBS HELPS ??

HARDENED CONCRETE - Hardcrete

- Converts Ca(OH)2 to C-S-H Gel
- Contributes to long term strength
- Enhanced uniformity and homogeneity
- Reducing thickness of transition zone and eliminating the week link in
- Concrete micro structure is Improved
- Reduces permeability of concrete
- Reduced volume changes
- Enhanced cover quality
- Increases durability

FIBRES In CONCRETE

- IS 456:2000 Amendment No.3 August 2007,which specify the use of Fibre in Concrete by referring to specialist literature i.e. - - ASTM C-1116-03 and ACI COMMITTEE REPORT 544.1R-42.
- Fibres can be Steel, Synthetic (Polymeric – Nylon, Polypropylene, Polyester), Glass, Carbon, Aramide, Basalt
- Polypropylene Fibers (PP)are the most used synthetic fiber, & most researched.
- Polyesters, polyethylene etc. are not suitable for concrete, as these are not stable in alkaline environment of concrete. These causes increase in porosity & permeability in service life & reduces the durability.
- PP Fibres have - - Excellent dispersion providing three-dimensional reinforcement

- Improves concrete cohesiveness – requires no mix design changes
- Easily mixes into concrete – does not ball or tangle
- Non-corrosive, non-toxic, rust-proof, inert material

Fibers Shapes

- Fibers can be mono-filament or fibrillated.
- Fibrillated fibers have flat section, thus have higher surface area & hence better bond.
- Collated fibrillated fibers attached to each other, contribute to mechanical anchorage. While mixing in concrete, fibers twist giving improved bond thus result in better performance, compared to monofilament.
- Refer ACI report 544.1R (2002). Clause 4.3.7.7.

  “Researchers [4.70] have also shown that composites reinforced with collated **fibrillated polypropylene** fibers displayed **excellent** post first cracking behavior if produced under certain optimized conditions. Mechanical bonding properties of the polypropylene fibers were found to be greater for twisted collated fibrillated polypropylene fibers or for -- -- .”

PP Fibrillated Fibres in Concrete.

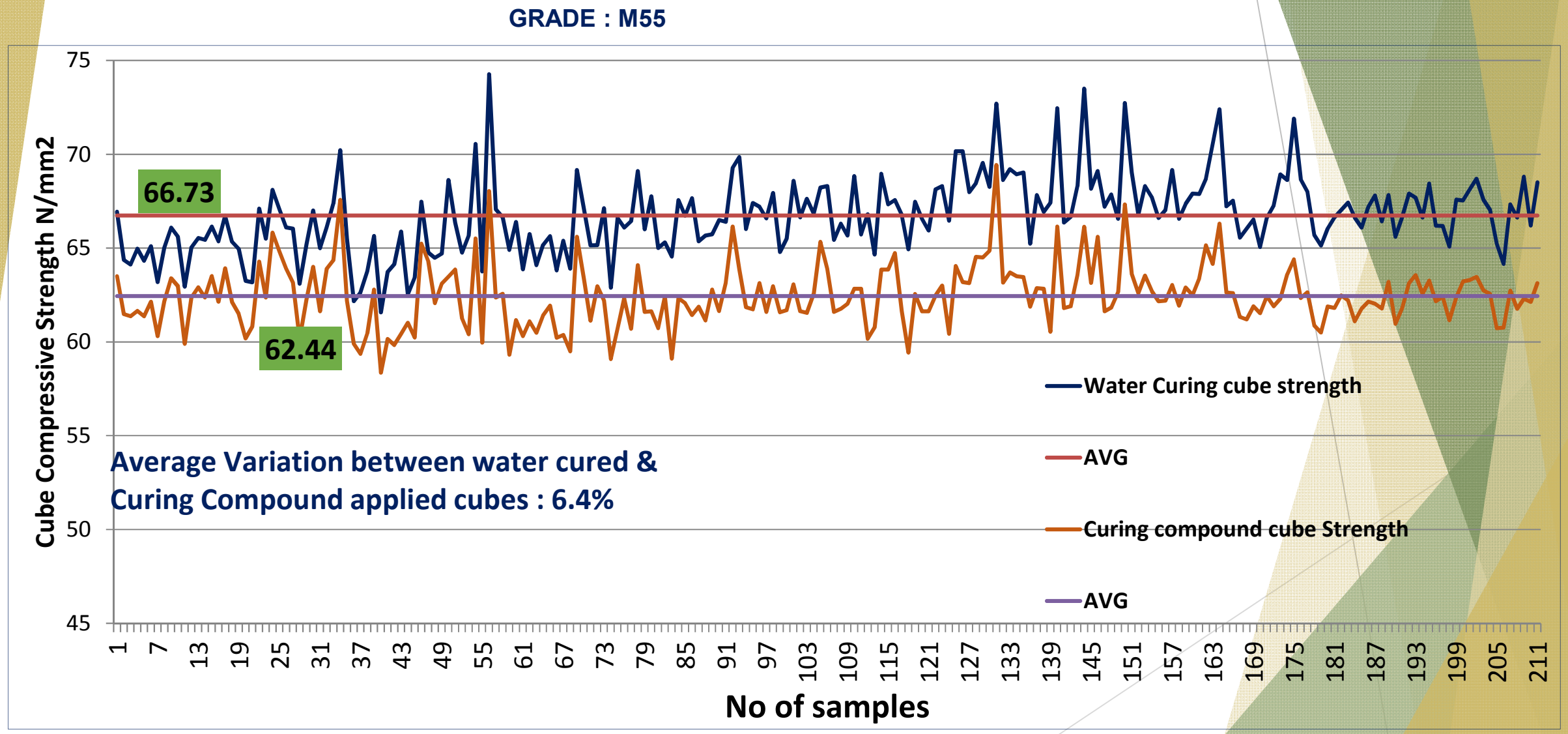
Polypropylene fibers when used in concrete prevents/reduces Plastic Shrinkage cracks.

USE OF CURING COMPOUND

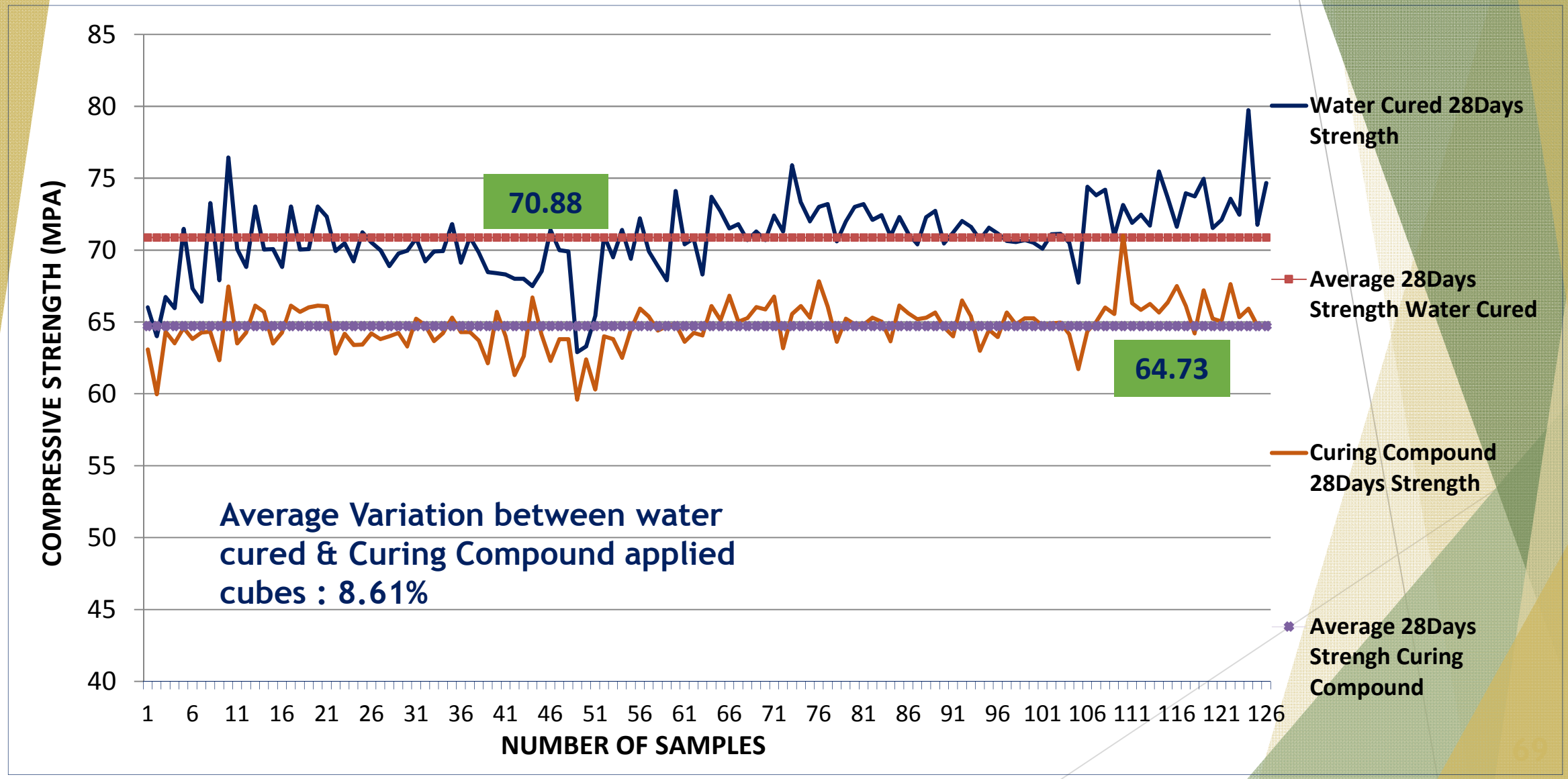
Compressive Strength Test Comparison

Water Cured Cube Samples
Vs
Samples Cured using Curing Compound

Water curing Vs Curing Compound - Concrete Cube Strength Comparison -

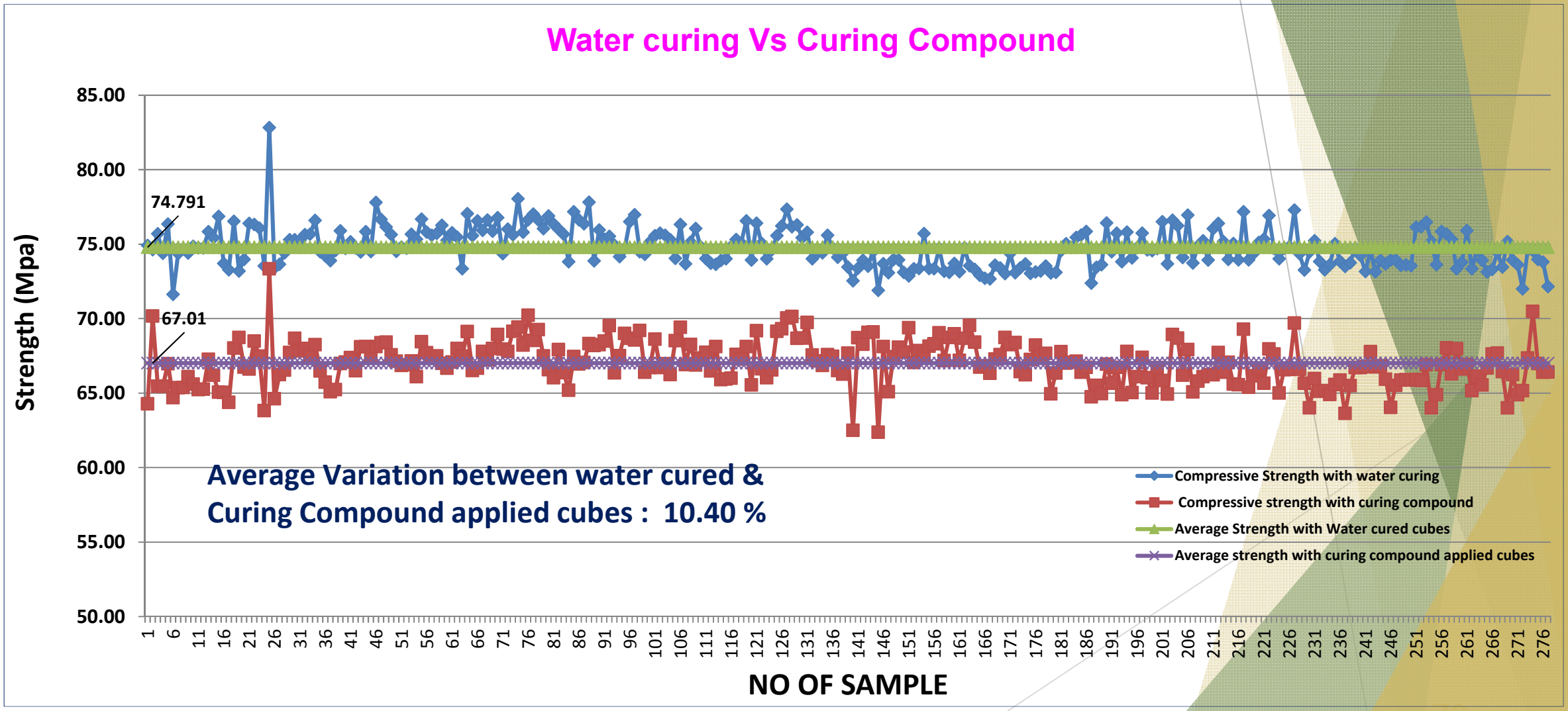


Water curing Vs Curing Compound - Concrete Cube Strength Comparison -



Water curing Vs Curing Compound - Concrete Cube Strength Comparison

GRADE : M50



Temperature Control in Concrete – MEASURES.

Spraying water on Aggregates stock piles.

Covering by double hessian cloth of TM drum.

Mixing Chilled water In Concrete.

Use of ICE in Concrete

Use of Curing Compound

Properly & Evenly applied Curing Compound on Concrete surfaces. …

Use of Colored Concrete.

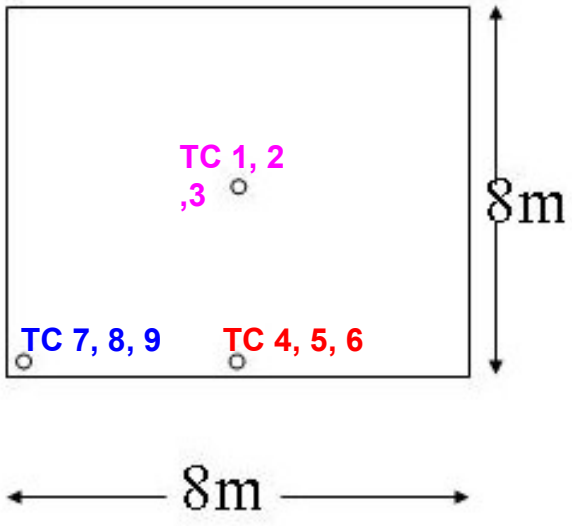
Thermal Monitoring of Temperature rise in Concrete by embedding Thermo Couples.

HEAT OF Hydration & Temperature Control of Concrete.

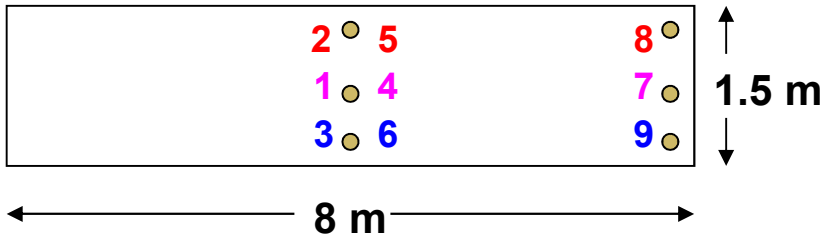
- Tendency to select Higher grade of cement, and to often assume that the higher the grade of cement; the better.
- Neglect consideration of heat of hydration.
- Neglect to consider shrinkage characteristics.
- To Ignore specific surface of the cement & its setting times.

KEEP YOUR CONCRETE COOL …

….. SO THAT YOUR HEAD REMAINS COOL.

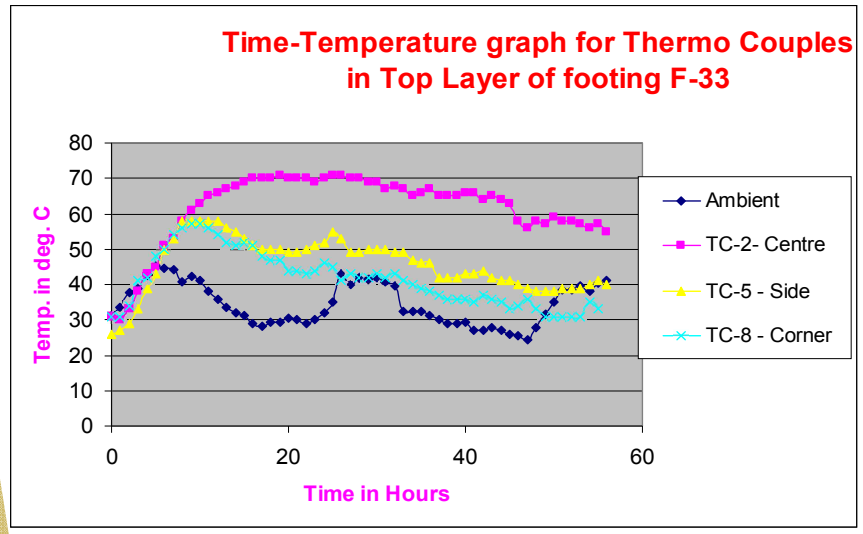


(Not to Scale)



Side Elevation of Footing

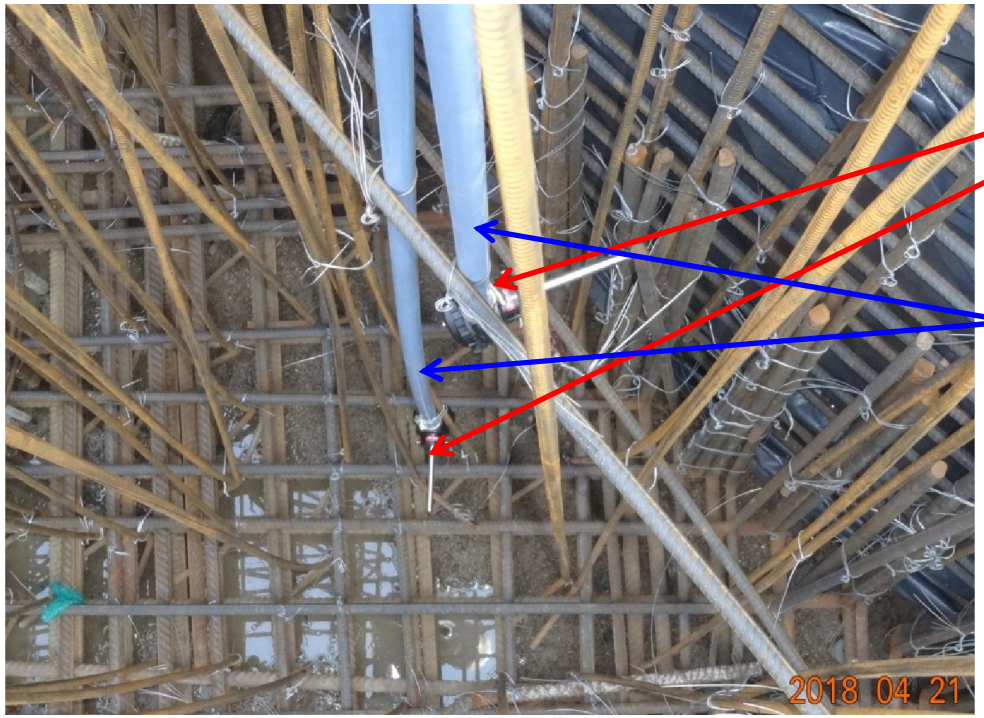
(Not to Scale)



Temperature profile in Horizontal plane – At Top

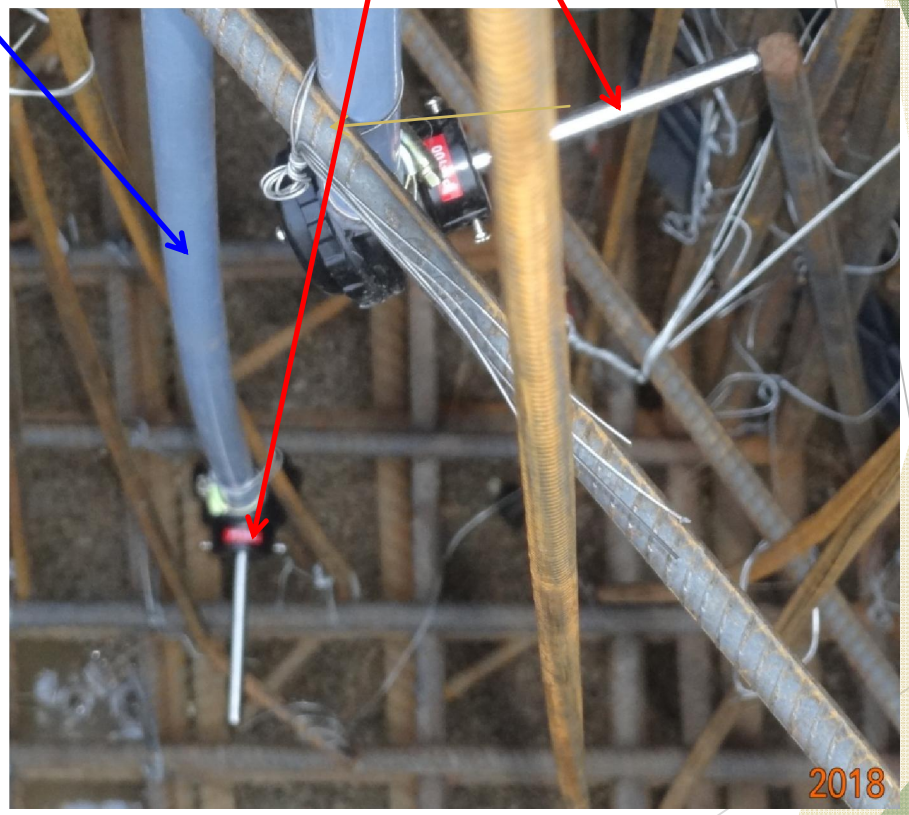
Sr. No.	TC No.	Location		Ambient Temperature (^{0}C) - Ta	Maximum Temperature (^{0}C) - Tm	Time Elapsed in Hours	Difference (Tm-Ta) in ^{0}C
		In Plan	In Elevation				
1	2	Centre	Top	29.5	**71**	19	**41.5**
2	5	Side	Top	38.1	**58**	11	**19.9**
3	8	Corner	Top	38.1	**57**	10	**18.9**

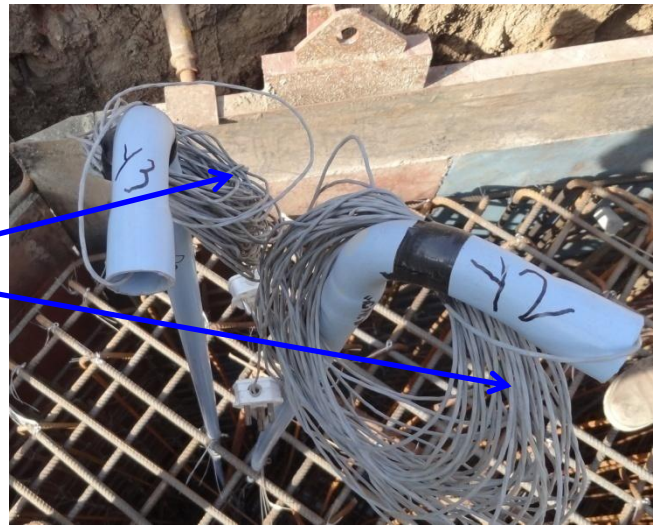
Difference in temperature of concrete in the plane: **14^{0}C**



Thermo Couples

PVC Casing Pipes



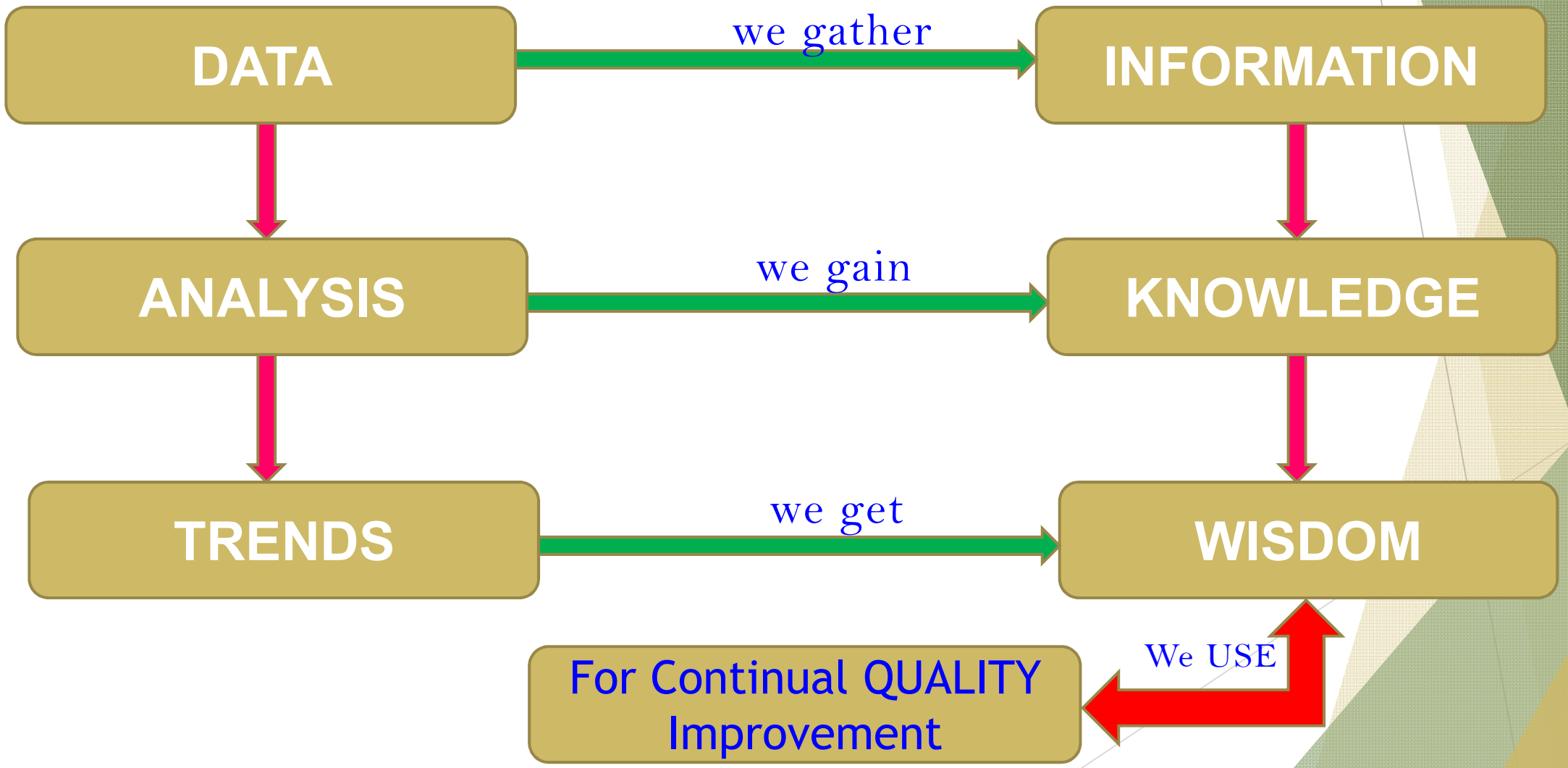


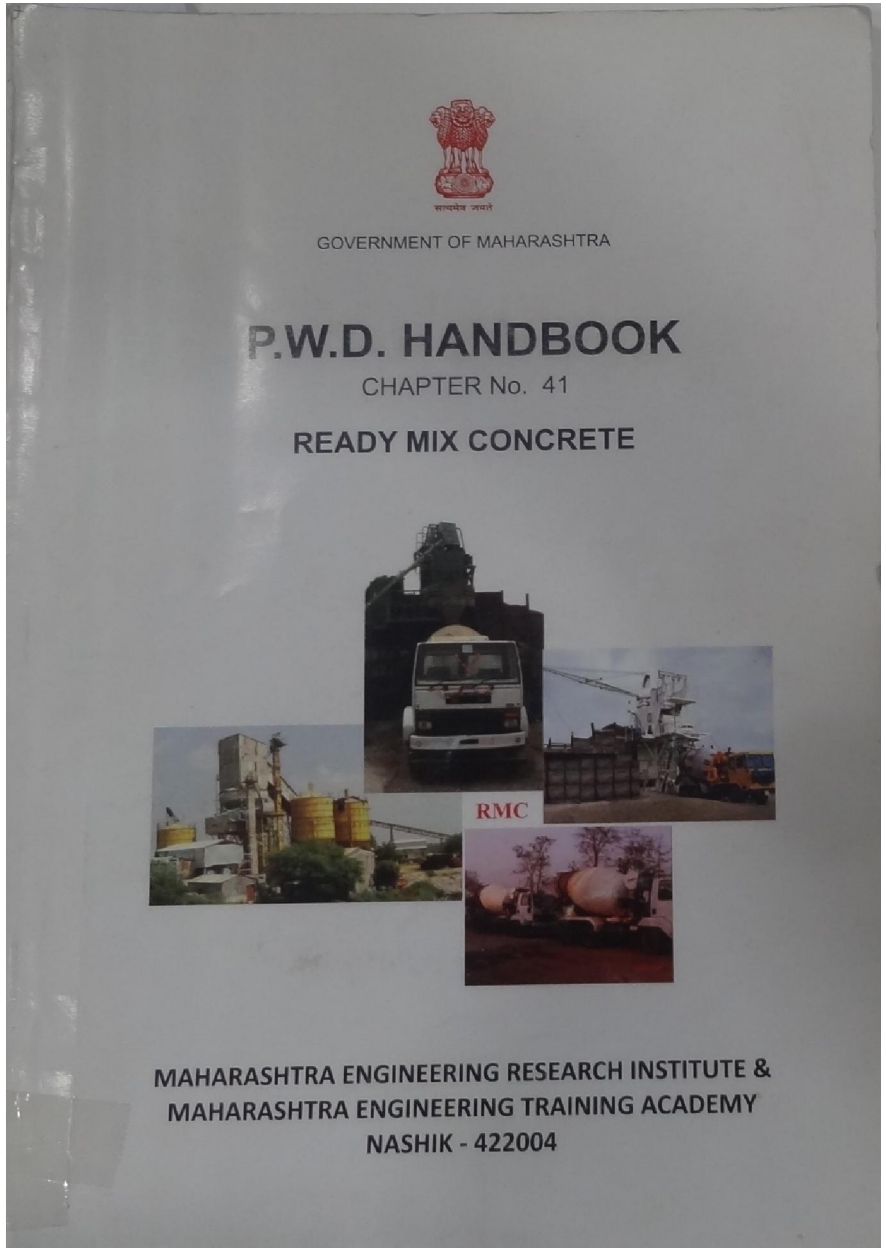
Lead Wires

Actual photos of structure with Thermo couples Fixed

What we do for QA & QC in Maha-Metro?

How we get Benefitted





CONTENTS

R M C Chapter is divided into 16 Sub-chapters, 3 Annexures and 8 Checklists and includes:

Sub-Chapters :

- ❑ Introduction & Scope
- ❑ References
- ❑ Terminology
- ❑ Material Storage & Handling
- ❑ Batching & Mixing Control Equipments
- ❑ Transport Of Concrete
- ❑ Laboratory
- ❑ Monitoring Quality Of Ingredients
- ❑ Sampling & Testing Of Concrete
- ❑ Quality Control
- ❑ General Requirements Of R M C
- ❑ General Information About R M C Facility
- ❑ Properties Of Fresh Concrete
- ❑ Properties Of Hardened Concrete
- ❑ Quality Audits & Q C Techniques
- ❑ Environmental Concerns & Site Safety

Referances for RMC Chapter

- **Total no. of I.S. referred --------- 25 (List annexed in Annex B)**
- Important I.S. referred : – 456:2000, 457:1957, 4925:1968, 4926:2003, 9103:1999, 10262:2009 ,

Other Codes

1) ASTM Designation :
C94/C94M-09a-Dec'09

Standard specification for Ready Mixed Concrete.

2) British Standard
BSEN 206-1:2000

Concrete-Part I- Specification, Performance, production and conformity

LITERATURE

1.Building Materials and Technology Promotion Council, New Delhi and Quality Council of India, New Delhi (BMTPC-QCI) (Draft-2012) "Criteria for RMC Production Control"

2.Indian Railway "Guidelines on use of Ready Mixed Concrete"

3.Ready Mixed Concrete Manufacturer's Association(RMCMA) (2008) , "Guidelines on Quality control and Quality Assurance of Ready Mixed Concrete"

4 RMC Research and Education Foundation of National Ready Mixed Concrete Association (NRMCA), U.S.A. "Sustainable concrete plant Guidelines"

सत्यमेव जयते

GOVERNMENT OF MAHARASHTRA

WRD HANDBOOK CHAPTER NO. 3

SELF COMPACTING CONCRETE

MAHARASHTRA ENGINEERING RESEARCH INSTITUTE,

WATER RESOURCE DEPARTMENT, NASHIK-04

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