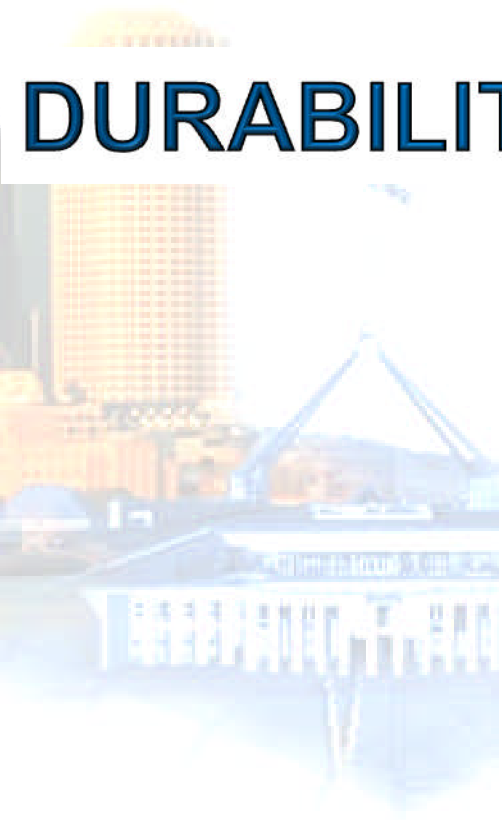
DURABILITY WORKSHOP

CONCRETE INSTITUTE of AUSTRALIA



ACHIEVING DURABILITY IN CONSTRUCTION

CONSTRUCTION & CONTRACTS

Wolfgang Merretz
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promote and develop excellence

in concrete technology

Evolution of Durability Provisions AS 3600 & AS 5100

- 1979 – Beresford & Ho identify durability failures as 10% of expenditure on new structures
- 1979 – Guirguis identifies 69% blgs <15yrs, durability distress
- 1987 – Marosszeky shows 227 cover ~ 5mm in 95 buildings
- Pre 1988 provisions scattered – treated as part of detailing
- 1988 – AS 3600 published – durability provision at front Sect 4
- AS 3600-1988, 1994, 2001 & Draft – essentially no change
- Provisions for durability design essentially static for 21 years
- Repair companies are flourishing more than ever – What's wrong with our codes and/ or construction practices ?

Existing Durability Provisions in AS 3600 & AS 5100

From a Contractor viewpoint existing code provisions are:

- Simple
- Easy to understand and apply
- Compliance test methods are practical
- Test methods are well understood
- Tests performed in short period of time
- Specification clauses are generally helpful and accepted
- Financial risk of non-compliance is manageable
- Therefore, many contractors are wedded to the above

Attainmnt of Adequate Durability

The 4C rule – Constituents (Cement type & w/c)
Cover
Compaction
Curing

This presentation will discuss:

- Understanding need for curing & cover
- The curing conundrum
- Concrete placement & compaction
- Cover to reinforcement
- Relevance of NT Build 443 in contracts
- Durability Plan in construction
- Controllable early-age cracking
- Detailing and Tolerances

Understanding need to Cure

- NPCAA – 2002, 2004, 2008
- Subject of curing understood by few
- Plenty of misconception
- The few had a good technical understanding
- NPCAA embarked on training sessions
- Explained legal obligation in BCA
- Simplified AS 3600 – Section 4 – Restrictive
- Concrete technology has moved on in 15 years
- Supplementary cementitious materials
- Super-workable concrete & Superplasticisers
- Must find technical answers for what is adequate curing

Curing of Concrete

So, what are the practical issues?

- Specifications often require ideal regimes
- Impractical in terms of time & labour
- Cost pressures to save time & money
- Wide range of climatic exposure conditions
- Not recognise link - Strength/Permeability
- Thought to be not necessary
- Ignorance of BCA - AS3600 – AS5100 - B80
- Defiance

To Cure or Not to Cure

- AS 3600 2001 – Cl 4.5 &
- AS 5100 2004 - Cl 4.5 states:

*… shall be initially cured continuously for at least 7 days … OR **cured by accelerated methods** so that the average compressive strength … at completion of curing is not less than 32 MPa …*

- AS 3600 Draft 2007 – Cl 4.4 states:

*… be cured continuously for at least 7 days … OR **have a minimum average compressive strength** of the concrete at the time of stripping of forms … of 32 MPa …*

E.G.
For
Classification C

What's the Fuss all About

The previous slide indicated that …

CURING IS OPTIONAL

CURING IS NOT REQUIRED IF MINIMUM STRENGTHS ARE MET

HOW CAN THIS BE ??

IS THIS THE PATH WE WANT TO FOLLOW ??

SHOULD THE DRAFT BE ALTERED AND HOW ??

Cover to Reinforcement

Cover to reinforcement in AS 3600

- Guirguis 1987 recommends to BD2 committee
- Values based on:
- Water penetration (sorptivity) – A1 & A2
- Carbonation depth – B1
- Chloride diffusion – B2 for $\mathbf{T_o}$ **of 30 years**, 7D moist cure
- Values included +5mm for placement tolerance
- For A1 & A2 (20mm) is minimum value for placement

AS3600-1988 Recommended minimum concrete cover (mm)

Exposure Classification	Characteristic Strength of Concrete f'c (MPa) 20	25	32	40	50
A1	20	20	20	20	20
A2		30	20	20	20
B1			50	40	30
B2				80	65
				60*	50*

* If curing is longer than 7 days, preferably 28 days

BD2 Response to Recommendations

- For more severe exposure B1 & B2 – represented too much change from existing practice
- Increased covers would be difficult to justify and resisted in practice
- Therefore cover values were amended to present AS 3600 values
- Also Curing was relaxed from 7D to 3D moist cure

It is little wonder, that we have a vibrant repair industry today

Cover to Reinforcement

Difficulties under contract arise in differences of interpretation in exactly what is meant by:

- Cover shall be as noted on the drawings
- Minimum cover shall be …
- Minimum cover shall not be exceeded
- Cover is distance between outside surface & reo
- Nominal cover shall be …

Need to eliminate the confusion & develop a single definition for cover that applies in all instances ?

NT Build 443 as QC test in Contracts

The case for not using NT Build 443 as a QC test:

Generally, insufficient time to start of construction

- Special concretes – w/c=0.29, super plasticisers
- Little info exists on long-term resistance to Cl-
- Results dependent on time of exposure 28D to 90D
- Results dependent on degree of hydration
- Relation to ASTM C 1202 not relevant – no correlation
- Steam cured concrete responds more favourably after extended time period
- Should only be used to pre-qualify concrete in time interval external to contract environment
- Discuss steam cured response in Appendix A
- Contractor needs deemed-to-comply concrete rules

28-D Nordtest standard cure diffusion coeff

NORDTEST METHOD: NT BUILD 443 - 1995

Client: Structural Concrete Industries

File No: 410/99

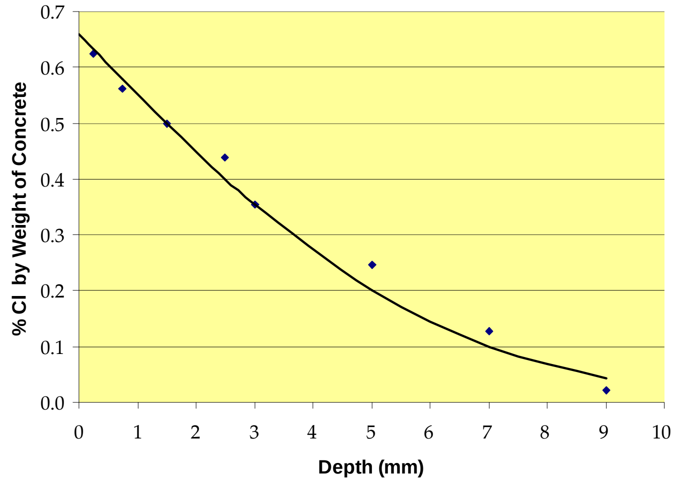
Lab Sample No.		18845	
Sample Number		**SCI 57273-H**	
Date of Casting		19-Oct-99	
Date of Grinding		17-Jan-00	
Background Chloride Content	C_o	0.001	%
Chloride Content at Surface	C_s	0.660	%
Exposure time in Salt Solution	t	28	days
	t	2419200	sec

Depth, mm	% Cl by wt	Macros Eq	Trial Di
0.25	0.625	0.0000	2.91E-12
0.75	0.562	0.0007	3.28E-12
1.5	0.499	0.0001	4.80E-12
2.5	0.439	0.0001	6.87E-12
3	0.355	0.0002	4.88E-12
5	0.246	0.0001	6.48E-12
7	0.127	0.0001	5.93E-12
9	0.022	-0.0001	3.64E-12
		Average D =	4.85E-12 m^2/sec

Best Fit Diffusion Coefficient	**D =**	4.85E-12	**m^2/sec**
Best Fit Chloride Content at Surface	**C_s =**	**0.660**	**%**

Note: 28 days standard water cured then submersed in salt solution for 28 days

28-Day Chloride Profile
Standard Moist Curing



Determination of Chloride Ion

Diffusion Coefficient

Fick's second Law

[Cs – Cx] / [Cs – Co] – [erf (x / 2 x SQRT (De . t)] = 0

28-D Nordtest steam cure diffusion coeff

NORDTEST METHOD: NT BUILD 443 - 1995

Client: Structural Concrete Industries

File No: 410/99

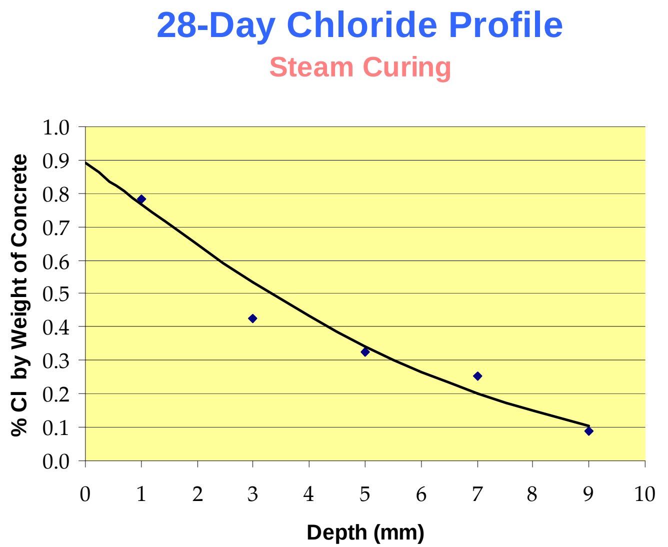
Lab Sample No.		19483	
Sample Number		**SCI N4**	
Date of Casting		24-Nov-99	
Date of Grinding		19-Jan-00	
Background Chloride Content	C_o	0.003	%
Chloride Content at Surface	C_s	0.890	%
Exposure time in Salt Solution	t	28	days
	t	2419200	sec

Depth, mm	% Cl by wt	Macros Eq	Trial Di
1	0.784	0.0001	9.13E-12
3	0.425	0.0005	3.65E-12
5	0.326	0.0002	6.27E-12
7	0.254	0.0001	8.78E-12
9	0.088	-0.0007	6.06E-12

Average D = 6.78E-12 m^2/sec

Best Fit Diffusion Coefficient	**D =**	6.78E-12	**m^2/sec**
Best Fit Chloride Content at Surface	**C_s =**	**0.890**	**%**

Note: 1-day steam + 27-day air curing then submersed in salt solution for 28 days



Determination of Chloride Ion

Diffusion Coefficient

Fick's second Law

[Cs – Cx] / [Cs – Co] – [erf (x / 2 x SQRT (De . t)] = 0

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56-D Nordtest standard cure diffusion coeff

NORDTEST METHOD: NT BUILD 443 - 1995

Client: Structural Concrete Industries

File No: 410/99

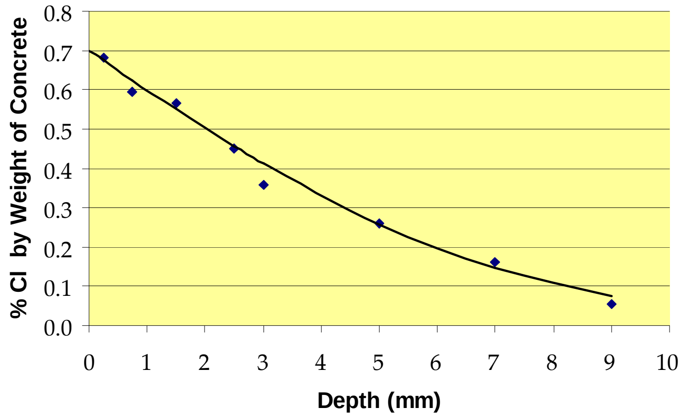
Lab Sample No.		18845	
Sample Number		**SCI 57273 K**	
Date of Casting		19-Oct-99	
Date of Grinding		31-Jan-00	
Background Chloride Content	C_o	0.001	%
Chloride Content at Surface	C_s	0.700	%
Exposure time in Salt Solution	t	56	days
	t	4838400	sec

Depth, mm	% Cl by wt	Macros Eq	Trial Di
0.25	0.685	0.0006	8.44E-12
0.75	0.595	0.0001	1.62E-12
1.5	0.565	0.0007	3.86E-12
2.5	0.451	0.0006	3.01E-12
3	0.359	0.0005	2.16E-12
5	0.275	0.0004	3.52E-12
7	0.163	0.0001	3.54E-12
9	0.055	0.0001	2.68E-12
		Average D =	3.60E-12 m^2/sec

Best Fit Diffusion Coefficient	**D =**	**3.60E-12**	**m^2/sec**
Best Fit Chloride Content at Surface	**C_s =**	**0.700**	**%**

Note: 28 days standard water cured then submersed in salt solution for 56 days

56-Day Chloride Profile
Standard Moist Curing



Determination of Chloride Ion

Diffusion Coefficient

Fick's second Law

[Cs – Cx] / [Cs – Co] – [erf (x / 2 x SQRT (De . t)] = 0

56-D Nordtest steam cure diffusion coeff

NORDTEST METHOD: NT BUILD 443 - 1995

Client: Structural Concrete Industries

File No: 410/99

Lab Sample No.		19483	
Sample Number		**SCI N9**	
Date of Casting		24-Nov-99	
Date of Grinding		16-Feb-00	
Background Chloride Content	C_o	0.003	%
Chloride Content at Surface	C_s	0.800	%
Exposure time in Salt Solution	t	56	days
	t	4838400	sec

Depth, mm	% Cl by wt	Macros Eq	Trial Di
1	0.688	0.0001	3.29E-12
3	0.475	-0.0007	3.25E-12
5	0.361	0.0000	4.51E-12
7	0.121	-0.0001	2.42E-12
9	0.056	-0.0001	2.49E-12

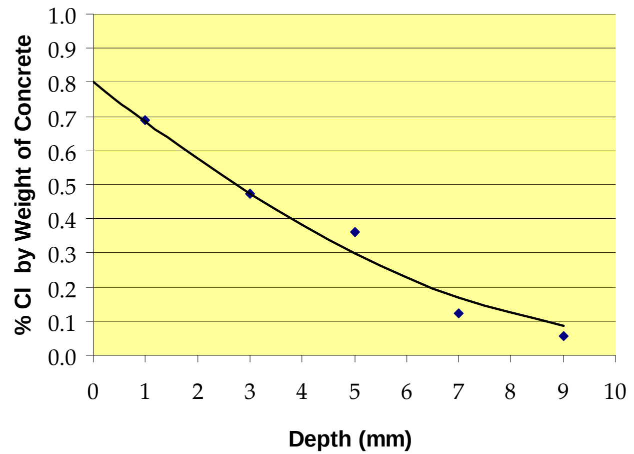
Average D = 3.19E-12 m^2/sec

Best Fit Diffusion Coefficient	**D =**	3.19E-12	**m^2/sec**
Best Fit Chloride Content at Surface	C_s =	**0.800**	**%**

Note: 1-day steam + 27-day air curing then submersed in salt solution for 56 days

56-Day Chloride Profile

Steam Curing



Determination of Chloride Ion

Diffusion Coefficient

Fick's second Law

[Cs – Cx] / [Cs – Co] – [erf (x / 2 x SQRT (De . t)] = 0

Durability Plan for Construction

To ensure conformance, the Durability Plan requires clear instructions to contractors for implementation into project specific construction quality plans that includes:

- Engage in construction planning provisions
- Provision for HOLDPOINTs and WITNESS points
- Documented contractor Inspection and Test Plans
- Identification of construction Special Processes
- Written Technical Procedures and Work Instructions
- Pre-construction strategy consultation with sub-contractors that explains the expected outcomes
- Daily Toolbox Instruction to work teams prior to start
- Minimum requirements for work supervision
- Daily progressive signoff at task completion

Construction Practices

Construction practices will substantially influence the durability life of concrete structures. Most important factors for this workshop to consider include:

- Satisfactory skill of workmanship on site - Training
- Concrete placement procedures - Defined
- Compaction of concrete – Type & Degree
- Curing – early attention to – cover over, aliphatic A
- Environmental variables – heat, rain, wind, humidity
- Finishing – timing of as affected by bleed water
- Crack control awareness and prevention

Controllable Early-age Cracking

Contractor is in control of early-age cracking that will impact on durability of concrete. The following are largely preventable

- Crazing – reduction of concrete quality – increase w/c
- Plastic shrinkage – evaporate faster than bleeding
- Settlement – change of cross section
- Flexural – early removal of forms
- Thermal – heat of hydration – large masses
- Form restraint – differential movement
- Blistered surface – reduction of abrasion resistance

Durability affected by Poor Detailing

Reinforcement detailing is the art of designing and drawing to scale the specified bar shapes and fitment sizes so *that everything will actually fit together* in the construction phase with no clashes with either prestressing strand, penetrations, fittings, embedments, post-tensioning hardware and ensuring the specified cover is met.

Durability affected by Poor Detailing

Good detailing practices create structures which are readily BUILDABLE

Properly detailed structures are always more economical to construct and bring real savings to the project and enhance durability performance

Conversly, poorly / badly detailed structures generally cost all parties more and reduce durability performance

Therefore, expend more effort at detailed design stage

Durability affected by Poor Detailing

Durability affected by Poor Detailing

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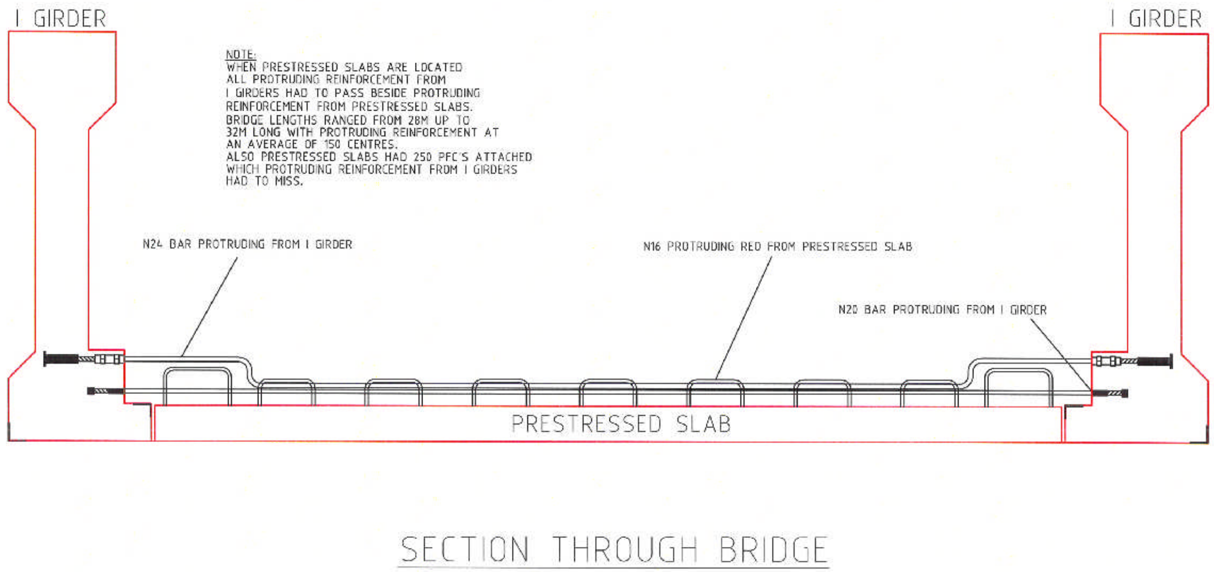
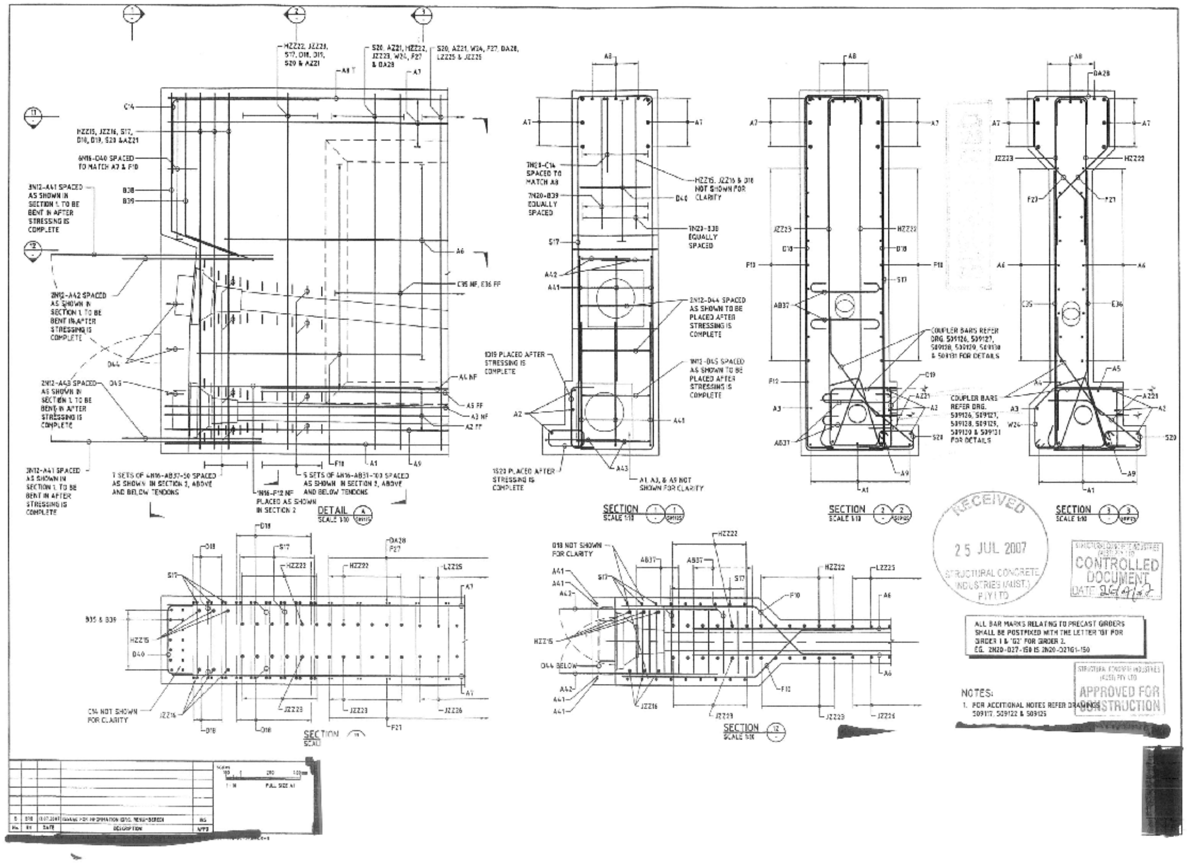


Durability affected by Poor Detailing



Chapter : **Influence of Construction Practice on Durability of Concrete** Lecture: **Codes, Specifications & Contracts**

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Durability affected by Poor Detailing

Chapter : **Influence of Construction Practice on Durability of Concrete** Lecture: **Codes, Specifications & Contracts**

Durability affected by Poor Detailing

Durability affected by Tolerances

All material manufacturers work within allowable tolerances or deviations. The way that various tolerances interact is paramount to successful detailing and enhanced durability performance

ZERO TOLERANCE SOLUTIONS NEVER WORK AND GENERALLY RESULT IN MAJOR DISPUTE

For this presentation, consider RTA specifications for bridgework precast concrete manufacture

Durability affected by Tolerances

RTA Specification B110 / B115 Concrete Profile

- Length: The greater of 0.06% Length or +/- 10mm
- Cross section < 2000mm wide = +/- 4mm
- Cross section > 2000mm wide = +/- 7mm
- Formed holes / openings - location = +/- 7mm

RTA B80 Reinforcement Tolerance

- Cover +5mm, -10mm
- Location (not controlled by cover) +/- 15mm

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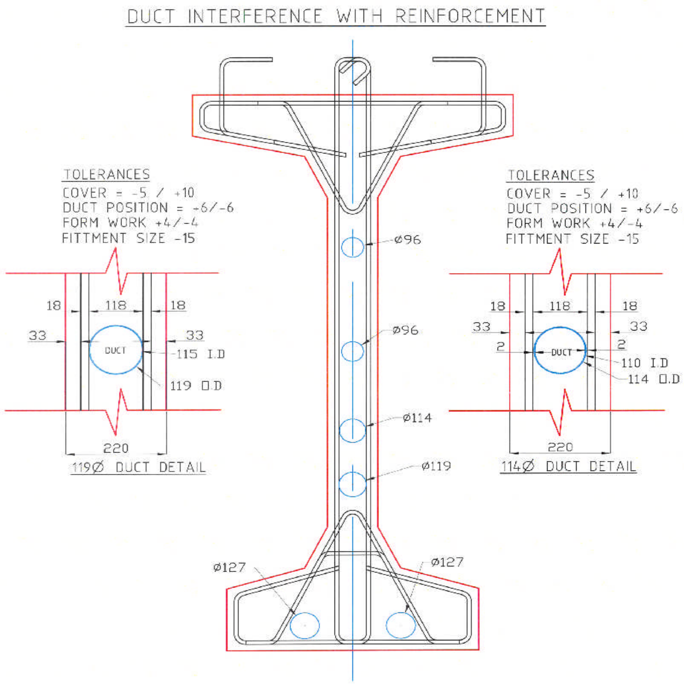
Durability affected by Tolerances

Chapter : **Influence of Construction Practice on Durability of Concrete** Lecture: **Codes, Specifications & Contracts**

Durability affected by Tolerances

Durability affected by Tolerances



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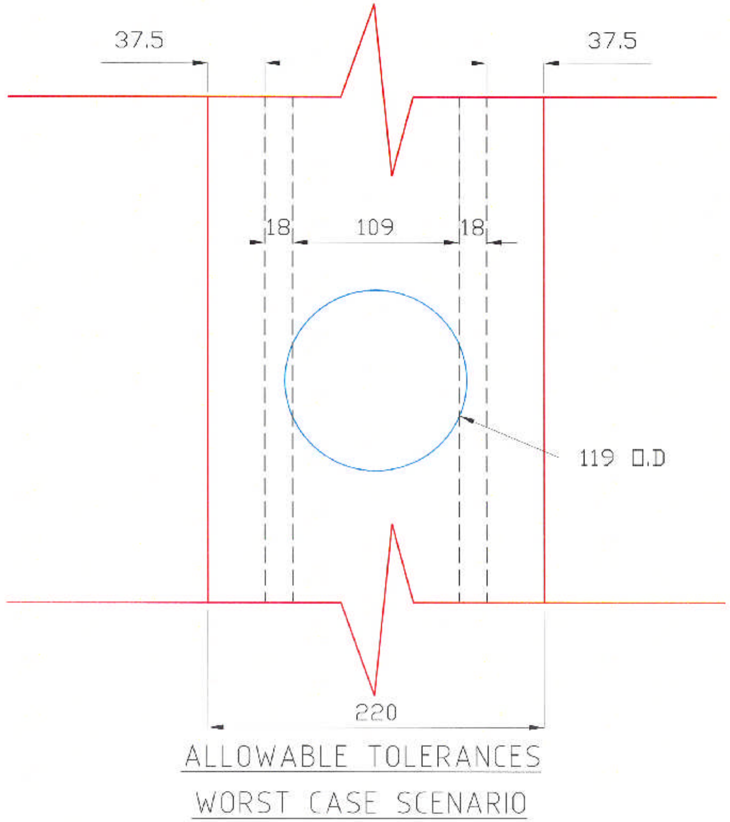
Durability affected by Tolerances



TOLERANCES

COVER = -5 / +10

DUCT POSITION = +6/-6

FORM WORK +4/-4

FITTMENT SIZE -15

Durability affected by Tolerances

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Durability affected by Tolerances

End of presentation