SCCT Annual Concrete Seminar 2005

Durability of Reinforced Concrete Structures

Durability assurance of concrete in marine environments

HK Shenzen Western Corridor

Tony Read

Ove Arup & Partners Hong Kong Ltd

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Design life has options

- **Design life first life**
- **Design life first life + maintenance**
- **Design life first life + maintenance + repair**
- **Design life first life + replacement**

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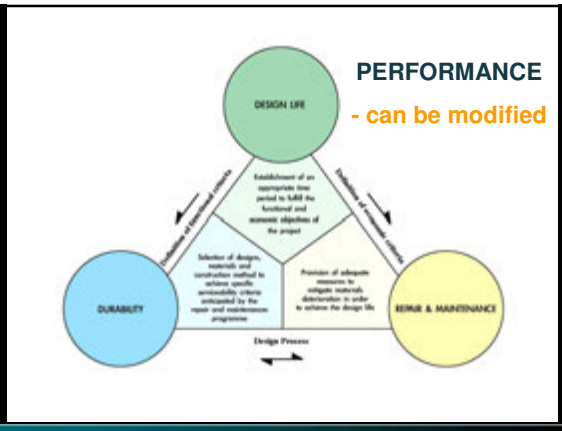

PERFORMANCE

- can be modified

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What does design life mean?

- **Certainty of project requirements**
- **Track record of performance**
- **Understanding of technical development**
- **Economic consequences**

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Durability design - elements

- Piles
- Pilecaps
- Piers
- Bridgedecks
- Towers
- Secondary structural elements
- Materials
- Form
- Structural performance
- Access
- Durability requirements
- Constructability

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Durability design - environments

- Buried
- Buried and submerged
- Buried and aerated
- Partially submerged
- External atmospheric
- Internal
- Aggressivity
- Rate of deterioration
- Effect on performance
- Mitigation measures
- Maintenance
- Cost effectiveness

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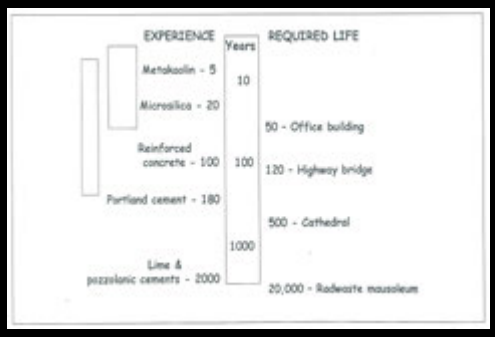
Design life and experience



ex Prof. Nick Buenfield

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Approach to durability assessment

- Traditional approach
- Carbonation
- Chlorides
- Variability
- Durability safety factors

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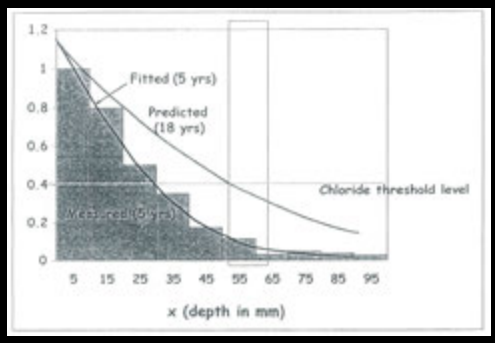
Chloride profiles



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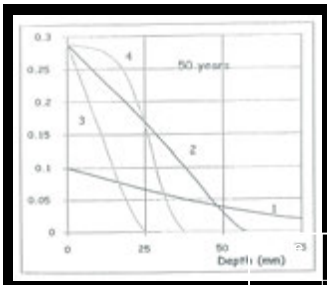

Chloride profiles depend on assumptions

	Diffusion coeff (m^2/s)	Binding	Pressure head (m)
1	10^{-12}	No	0
2	10^{-12}	Yes	O
3	10^{-12} 10^{-13}	Yes	O
4	10^{-12} 10^{-13}	Yes	12

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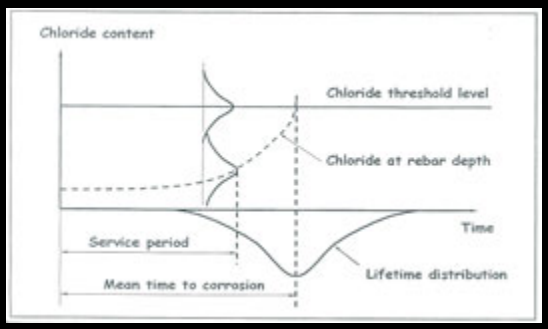
Probabilistic modelling of corrosion initiation by chloride



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'Normal' Concretes

- **Durability determined by cover**
- **Durability design and structural design in conflict**
- **Durability factor of 40 60 years**
- **Performance then determined by environment**

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'High Performance' Concretes

- Low w/c ratio
- Secondary cementitious materials
- microsilica
- Low bleed, good consolidation and good curing
- Durability factor of 70-120 years

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Performance reliability

- Manufacture
- Placement
- Curing
- Environment

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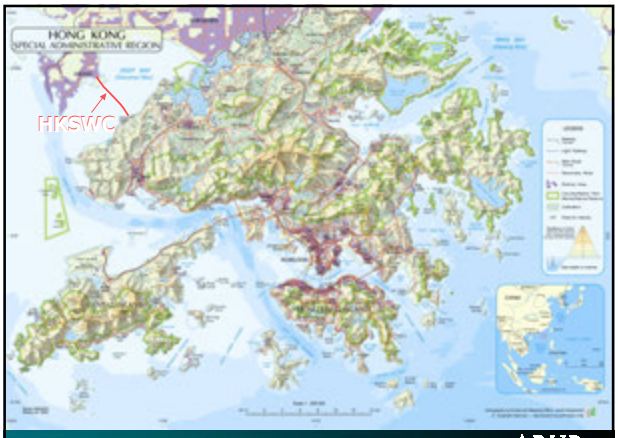

LOCATION ARUP

Shenzen Western Crossing Overview

- Fourth vehicular boundary crossing between HKSAR and the Mainland
- Total length : 5.5km (Divided by Boundary of HKSAR)
- HKSAR section : 3.5km, Shenzhen section : 2km
- Dual 3-lane elevated carriageway with hard shoulders
- Cable-Stayed Bridge at navigation channel
- Jointly invested BUT separately designed (using unified design standards & regulations)

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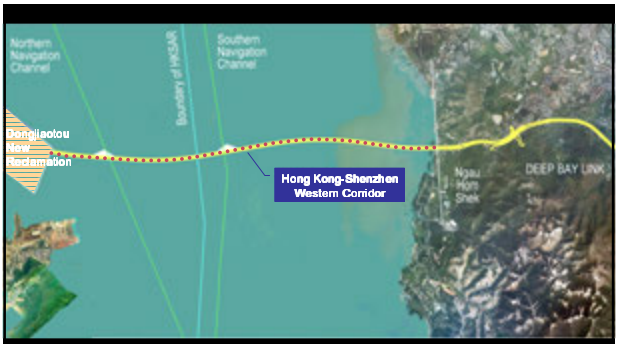
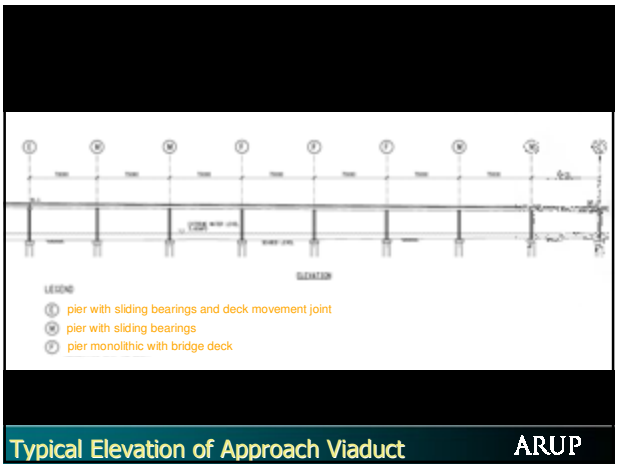


Highest Score → Option B : 247.8
Curved Bridge Option, Landing at Ngau Hom Shek

Preferred Option ARUP

- Approach viaducts have long spans (75m typical) to reduce the bridge pier numbers
- Pile caps are submerged below seabed
- Bridge piers are streamline-shaped to reduce friction to tidal flow

Environmental Friendly Approach ARUP



Typical Elevation of Approach Viaduct ARUP

Approach Viaduct ARUP

- 8 Continuous Spans
- (Internal : 75 m ; External : 70 m)
- Depth : 3.8 m
- Deck weight : 34 tonnes per meter

Approach Viaduct: Elevation & Section

Cable-stayed Bridge ARUP

- Main Span : 210 m
- Back Span : 99 m
- Height of Tower : 158 m
- Navigation Clearance : 146 m x 23 m
- Cables : 26 strands (160 mm to 315 mm dia.)

(total length 3.5 km ; total weight 3.8 tonnes)

- Deck Weight : 21 tonnes per metre

Cable-stayed Bridge: Elevation & Section

Durability Design - Foundations

- Piles Cast insitu bored piles
  Grade 40
  PFA 40%
  max w/c 0.4
  75mm
- Pilecaps Cast insitu concrete
  as above but with G45 and 50mm cover
  plus bituminous coating in above tidal positions

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Durability Design - Prestressed deck

- Precast concrete segmental units
  - Grade 50/60
  - PFA 35%
  - max w/c 0.35
  - 50mm

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Durability Design - Piers

- Below l/water and above splash zone
  - Cast insitu concrete
  - Grade 60
  - PFA 35% and 8% microsilica
  - max w/c 0.35
  - 75mm cover
- In slash zone
  - as above but with the use of stainless steel rebar for the outer layers

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Hong Kong portion of SWC ARUP

Hong Kong portion of SWC ARUP

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Thank you
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Options for better reliability

- Non ferrous rebar
- Galvanised rebar
- Epoxy coatings
- Stainless steel

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Stainless steel reinforcement

Chemical designations included in BS 6744:2001

Designation to BS EN 10088-1	Chromium (%min/max)	Nickel (%min/max)	Molybdenum (%min/max)	Approx equivalent to 'old' designation
1.4301	17.0/19.5	8.0/10.5		304
1.4436	16.5/18.5	10.5/13.0	2.5/3.0	316
1.4462	21.0/23.0	4.5/6.5	2.5/3.5	Duplex

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Stainless steel reinforcement

Tensile properties of BS 6744:2001 grades

Grade	0.2% proof stress (MPa)	Stress ratio (min %)	Elongation at fracture (min %)	Total elongation at max force (min %)
200	200	1.10	22	5
500	500	1.10	14	5
650	650	1.10	14	5

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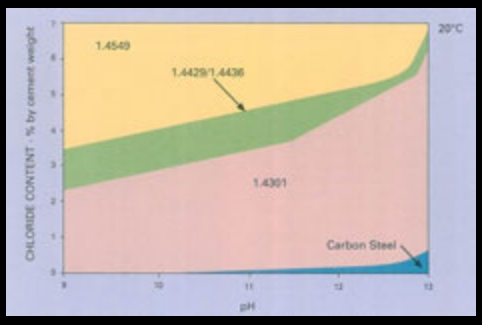
Passivity of carbon and stainless reinforcing steel in chloride contaminated concrete



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Performance

- **60 year track record in tropical marine environment (Progreso pier, Mexico)**
- **Correctly specified stainless steel reinforcement should prevent chloride attack for the full design life of any structure** ***UKHA Design Manual BA 84/02***

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Galvanic Corrosion

- Passivity in alkaline environments
- Inefficient cathode in chloride contaminated concrete
- Similar corrosion rate in carbonated concrete
- Increased corrosion rate in carbonated *and* chloride contaminated concrete

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