Special Construction Considerations in the Middle-East
Outline

• Origin
• Middle-East Construction Challenges and special considerations
• Case Study 1: Kuwait International Airport Project
• Case Study 2: King Abdulaziz International Airport Project
• Conclusions
Origin

- Fast development and growth of the demand for construction starting year 1970 with several planning for large scale projects. The construction industry adopted the available information and used it.

- This information was in several instances not relevant (MEA is well outside the range of earlier hot weather experience and can be classified as "Severely Hot" or "Hyper-arid")

- Workmanship restrictions created many deficiencies especially in durability.

- Some of the structures surveyed on or near the coast would reach a terminal condition as early as 12 to 15 years.
Origin

Population of the UAE, 1960 to 2016 (in millions)

Source: worldbank.org

Demographics of Saudi Arabia, Data of FAO, year 2005; Number of inhabitants in thousands.

HISTORICAL BENCHMARK OIL PRICES
Realized USD/barrel - data by OPEC Group
Middle-East Construction Challenges

- Severe Environment
- Lack of Quality Materials
- Lack of competent workmanship and quality control
- Nature of surface soils and groundwater
- Large Scale and Fast Track Projects
Environmental Challenges

- High Temperatures with high daily and seasonal temperature range
- Evaporation has led to a substantial buildup of salts in the ground.
- Salt Contamination in coastal regions and some inland areas.
- Windborne Contaminated dust
- Fluctuating high humidity
- High rate of evaporation
- High solar radiation
Environmental Challenges

- Stringent hot weather concreting practices
- Workmanship comfort
- Durability requirements
Some natural materials are contaminated (sulfate chloride) or unsuitable for concrete: Poorly graded sands, soft aggregate particles, high dust content, high water absorptions, and variations of the properties from one single source.

Groundwater is contaminated with salt that are aggressive to the concrete and potable water is expensive.

Expensive transport of aggregate and good materials.

Major variations in clinker and cement properties.
Materials Quality

Bedrock geology of the Arabian Peninsula (after Fookes and Higginbottom, 1980a).
Materials Quality
Lack of Competent workmanship and Quality Control
QCS Large Scale and Fast Track Projects

- Constituent Materials Assessment
- Batching Plant Quality Control
- Field Testing and Evaluation
- Post-placing inspections and Evaluations

Concrete Mix Design Development and Testing
- Formwork and Reinforcing Steel Inspection
- Site Monitoring and Contribution
- Hardened Concrete Testing and Evaluation

Reliable Laboratory Testing

Qualified Concrete Technology Consultancy

Synchronization
QCS Large Scale and Fast Track Projects

Developing Online Quality Control Applications
Durability Design

Precision

Prescriptive Based Specifications
- Limits on: w/c, Cement Content, cementitious material type, strength

Performance Based Testing
- Limits on specific laboratory durability testing

Modeling
- Degradation models based on concrete properties

Complexity
Durability Design

Chloride Diffusion Coefficient - Different Models

Regression of the Average Values
\[ y = 7E-13e^{6.1705x} \]
\[ R^2 = 0.9839 \]
Durability Design

\[ D_c = D_{c,\text{ref}} \cdot f_1(T) \cdot f_2(h) \cdot f_3(x) \cdot f_4(CA, Hy) \cdot f_5(C3A) \cdot f_6(Cs) \cdot f_7(Mi) \cdot f_8(CW, w/c) \]

- Environmental input parameters
  - Temperature
  - Age
  - Relative humidity
- Concrete properties input parameters
  - Water-cement ratio
  - Cementitious materials content
  - Cementitious materials replacement percentage (Fly ash, silica fume, slag)
  - Cement Density
  - Cement Surface Area
  - Alite Percentage in Cement
  - Belite Percentage in Cement
  - Aluminate Percentage in Cement (C3A content)
  - Ferrite Percentage in Cement
  - Aggregate content and properties
  - Hydration Coefficient
- Workmanship input parameters
  - Curing time
  - Initial Mixing Time
  - Consolidation Degree
- Post-placing input parameters
  - Crack Width
Case Study 1: Kuwait International Airport Project
Kuwait International Airport Project
Kuwait International Airport Project
Kuwait International Airport Project
Kuwait International Airport Project
Kuwait International Airport Project
Kuwait International Airport Project

- Five site batching plants
- One sand washing plant
- Hot weather concrete practices
- Precast concrete design
- Self-consolidated concrete is used
- Online platforms for laboratory testing and Quality control
- Concrete durability design
Kuwait International Airport Project
Kuwait International Airport Project

Mock-up

White Concrete

Casted
Kuwait International Airport Project
Kuwait International Airport Project
Kuwait International Airport Project
Kuwait International Airport Project
Case Study 2: King Abdulaziz International Airport Project (Jeddah)
King Abdulaziz International Airport Project (Jeddah – KSA)

Phase 1: Volume of Concrete 6,000,000 m³

- The terminal will include 46 additional departure gates, 96 airway bridges 200 new counters.
King Abdulaziz International Airport Project (Jeddah – KSA)
King Abdulaziz International Airport Project (Jeddah – KSA)
King Abdulaziz International Airport Project (Jeddah – KSA)

SCC – Self Compacted Concrete / Viaduct Arches

- Volume (60,135 m³)
King Abdulaziz International Airport Project (Jeddah – KSA)

Concrete Poured per Month (All Concrete Grades)

TOTAL CONCRETE Poured (m³) = 5,313,224

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
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<tbody>
<tr>
<td>Qty, per Year</td>
<td>39,354 m³</td>
<td>1,765,452 m³</td>
<td>1,604,140 m³</td>
<td>1,368,033 m³</td>
<td>785,945 m³</td>
<td>161,659 m³</td>
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King Abdulaziz International Airport Project (Jeddah – KSA)

No. of Aggregates Test per Month (All Batch Plants)

| Month | 09 | 10 | 11 | 12 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 01 | 02 | 03 |
|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Year  | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Test per Year | 2,100 | 33,388 | 39,811 | 53,799 | 45,568 | 18,786 | 3150 |

TOTAL NO. OF TEST=213,580
King Abdulaziz International Airport Project (Jeddah – KSA)

No. of Cylinders per Month

TOTAL NO. OF CYLINDERS=942,591

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<th>Total No. of Cylinders per Year</th>
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<tr>
<td>10</td>
<td>123,783</td>
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Conclusions

- The special construction considerations in the Middle East are related to the severe environment, lack of quality materials, lack of quality control, and large-scale fast track projects.

- These considerations include additional schemes for hot weather concrete practices, laboratory testing, concrete quality control, and durability design.

- These schemes were successfully applied in large scale projects in the Middle-East, notably KIA and KAIA.
Thank You

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