ITU Experience and Lab Support for the Marmaray Project

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ITU Role in Marmaray

General Directorate of Railways, Harbours and Airports Construction

Employer
reports to the Ministry of Transportation

Avrasyaconsult
Representative on the construction sites
engineering and consulting services

Taisei-Gama-Nurol
Contractor
design and construction of the structures

Subcontractors
supply of concrete and concrete making materials

ITU Marmaray Lab
Independent testing agency
ITU Experience

- Evaluation of the project specification
- Special tests required (TI-B, NT BUILD, ASTM..)
  - New test set-ups
  - Technical personnel
  - ISO EN 17025

- A new laboratory with the required infrastructure
- Purchase and calibration of new lab equipment
- Expert visits
- Training of engineers and technicians
- Handbook for quality, procedures, instructions and records/reports
Construction Materials Laboratory

- 2500 m²
- Fresh concrete lab
- Mechanical testing lab
- Curing rooms
ITU Marmaray Lab

February 2005 – restoration of new labs
April 2005 – testing started

~500 m²
Composed of dedicated testing rooms
Towards Accreditation

- Training and certification of technicians
- Calibration, maintenance and spares of equipment
- Procedures and Test instructions
- Traceability of test results
- Measurement uncertainty
- Audits, Corrective/preventive actions
- Coordination meetings
Starting with Aggregates!
Sample Preparation

- **Splitter**
- **Quartering**
- **Crushing**
- **Drying**
- **Sampling and Storage**
Aggregate Testing

- Grading, Fine Materials
- Density, Water Absorption
- Drying Shrinkage
- Los Angeles Abrasion
- Frost Resistance (MgSO₄)
Chemical Analysis

– Chloride, Sulphate, Alkali, pH
– Methylene Blue, Organic Impurities
Alkali Aggregate Reactions with mortar/concrete bars

- Short Term Test ➔ ASTM C1260 Mortar Bar
- 6 Month Test ➔ TI-B 51 Mortar Bar
- Long Term Test ➔ CAN A23.2-14A Concrete Bar
Measurement set-up
Petrographic Analysis

- Macro observations
- Reactive Minerals

fine aggregate macro

dense chalcedony

altered k-feldspar

coarse aggregate macro

chert

porous
Concrete Testing

- Fresh Concrete
- Hardening Concrete
- Hardened Concrete
Fresh Concrete Tests

- Slump, Flow
- U-Box / L-Box
- Air Content
- Density
- Temperature
- Bleeding
- Stiffening Time
Design for Service Life and Cracking Risk

1. Early age cracking

\[
\frac{\text{Cracking stress}}{0.9 \times \text{Tensile strength}} < 0.7
\]

Simulation for crack risk

2. Durability
   - Material quality
   - Permeability
   - Concrete Petrography
Hardening Concrete Tests

- Strength Evaluation
  0.5, 1, 2, 3, 7, 14, 28. days
    - Compressive / Tensile Strength
    - Modulus of Elasticity

100% moisture curing room
Hardening Concrete Tests

- Thermal Expansion
- Activation Energy
Hardening Concrete Tests

• Adiabatic Heat Development
Hardening Concrete Tests

- Shrinkage (TI-B 102)
Hardening Concrete Tests

- Creep
  (TI-B 102)
Design of a Test Report
Simulation for Cracking Risk

Casting sequence

1. Foundation
2. Shear wall
3. Slab

- Casting days and sequence
- Removal day of formwork/insulation
- Environmental temperature and humidity
- Specific heat capacity and heat conductivity of ground
- Formwork/Insulation thickness and heat conductivity
- Structural boundary conditions
- Fresh concrete temperature
- Cooling/heating systems

- E modulus and tensile strength development
- Thermal expansion coefficient
- Poisson’s ratio
- Early age shrinkage and creep
- Adiabatic heat development
- Specific heat capacity and heat conductivity
Max (internal) ve min (surface) temperatures

$\Delta T_{\text{int}} = \text{Difference between the average and surface temps. of member}$

$\Delta T_{\text{out}} = \text{Difference between the av. temps. of the new member and existing member}$
Crack risk = stress/strength

For water retaining structures:
- $T_{\text{max}} < 50^\circ\text{C}$
- $\Delta T_{\text{ iç}} < 15^\circ\text{C}$
- $\Delta T_{\text{ dış}} < 15^\circ\text{C}$
- Risk < 0.7
- Crack width$_{\text{max}}$ < 0 – 0.2 mm
Hardened Concrete Tests

- Compressive Strength
- Density

rock specimen

jet grout specimens
Hardened Concrete Tests

- Rapid Chloride Test
  - Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration
Hardened Concrete Tests

- Chloride Diffusion
Hardened Concrete Tests

- DEF - Delayed Ettringite Formation

Properties at 65°C vs 50°C
1 m³ Trial Casting
Full-Scale Trial Casting
Repair Quality

- Pull-Out
Site Testing

- Crack Depth Investigation
  - impact echo
Concrete Petrography
Concrete Petrography

plane section cup grinder

thin section lapping machine

air void petroplaner
Thin Section Analysis

- mineralogical examination
- cementitious materials

- fluorescence intensity
- capillary porosity (w/c ratio)
- paste homogeneity
- cracks - interface
Cementitous Materials

alite

belite

fly ash
water/cement ratio

relationship between light level – w/c ratio
Paste Homogeneity
Air Content and Distribution
Calcium Hydroxide, Carbonation, Ettringite
Crack Length-Width-Direction
Repair Materials - Concrete Interface
Plane Section Analysis

Aggregate: shape, type, content, distribution
Mortar: homogeneity, segregation
Workmanship: entrapped air voids
Cracks: content, direction, length, width
Surface : bleeding, damage
Rebar : size, interface, corrosion
Repair Material – Concrete Interface
Epoxy Injection
Air Void Analysis

ASTM C457
- Air Content
- Specific Surface
- Spacing Factor

Rapid Air 457 Air Void Analyzer
Conclusion

or Just the Beginning?

• A fully equipped laboratory with a quality system
• Infrastructure for development of new tests
• Experience and knowledge to be reflected upon undergraduate/graduate education
• An example of industry-academia collaboration
• Towards an advanced research center
• Collaborations with international contractors for the quality assurance on site lab of major construction projects
THANK YOU !