



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



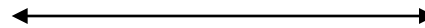
Taisei-Gama-Nurol

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

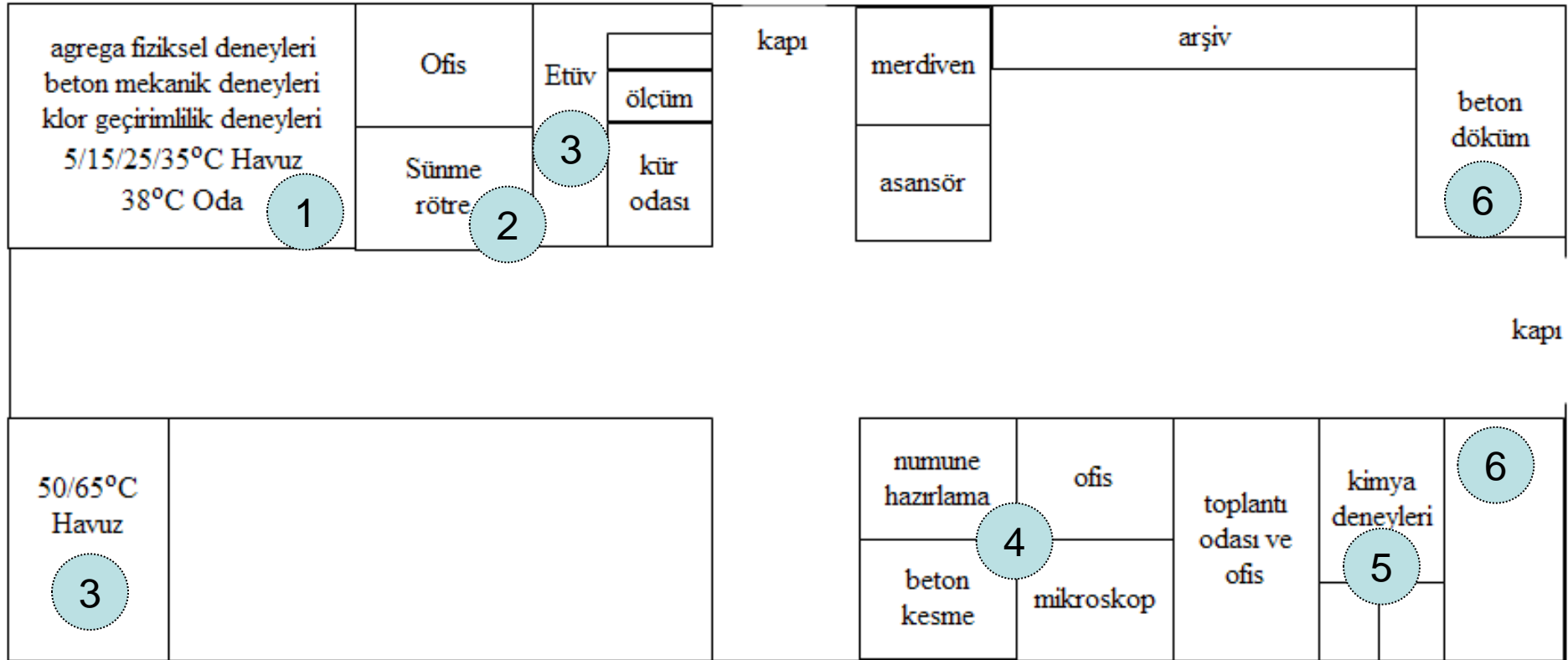
 - A new laboratory with the required infrastructure
 - Purchase and calibration of new lab equipment
 - Expert visits
 - Training of engineers and technicians
 - Handbook for quality, procedures, instructions and records/reports

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 Preperation



splitter



quartering



crushing



drying



Sampling and storage

Aggregate Testing

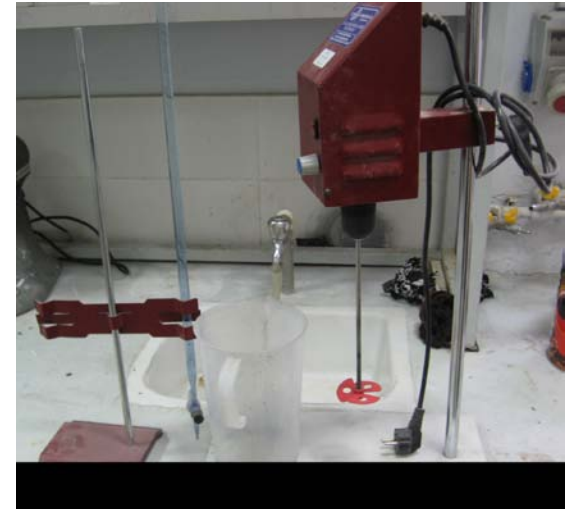
- Grading, Fine Materials
- Density, Water Absorption
- Drying Shrinkage
- Los Angeles Abrasion
- Frost Resistance (MgSO_4)



sieves

Chemical Analysis

- Chloride, Sulphate, Alkali, pH
- Methylene Blue, Organic Impurities



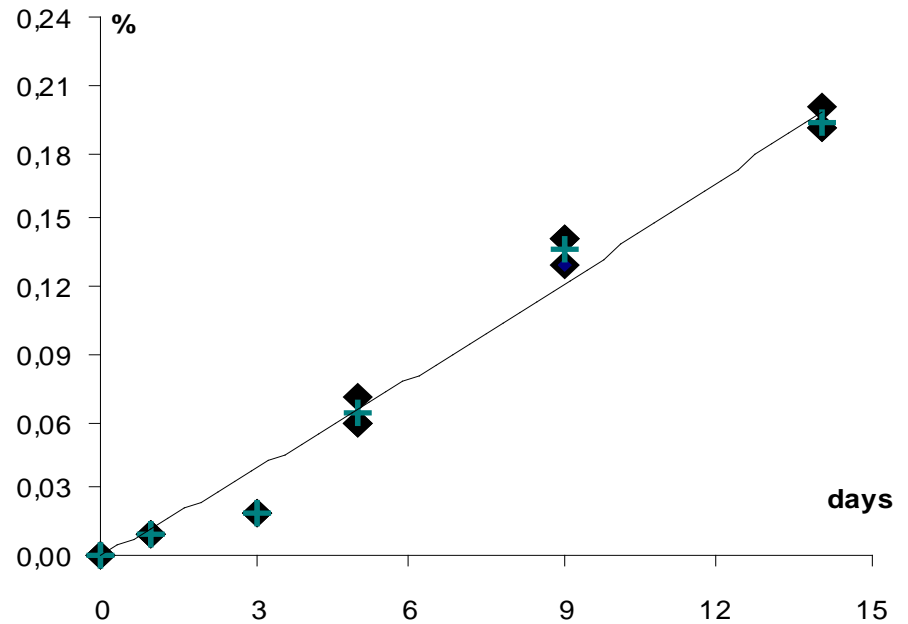
Alkali Aggregate Reactions with mortar/concrete bars



- Short Term Test → ASTM C1260 Mortar Bar
- 6 Month Test → TI-B 51 Mortar Bar
- Long Term Test → CAN A23.2-14A Concrete Bar

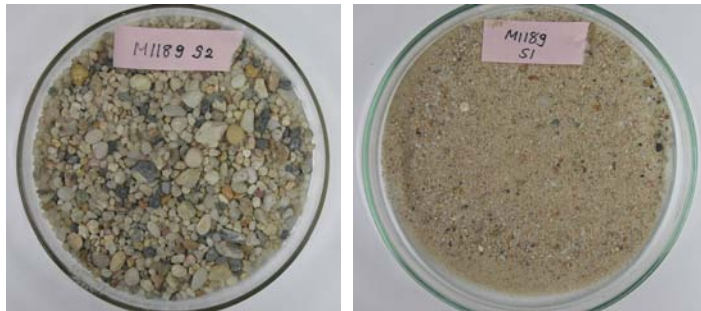


Measurement set-up



Petrographic Analysis

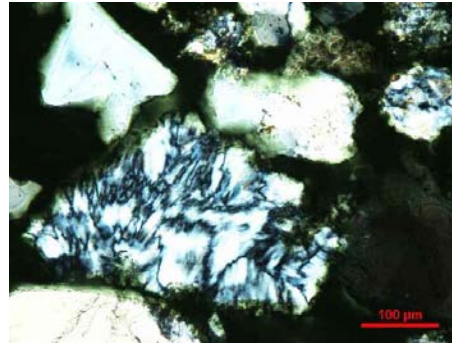
- Macro observations
- Reactive Minerals



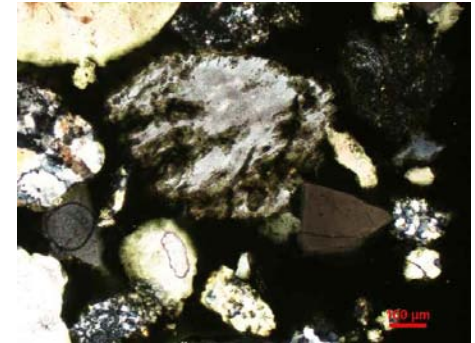
fine aggregate macro



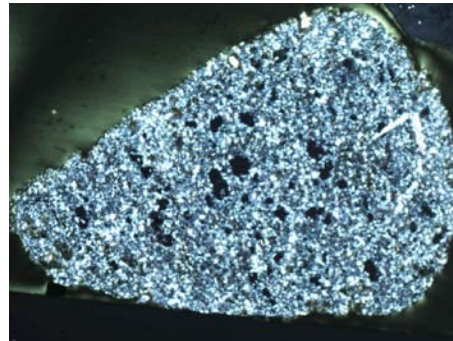
coarse aggregate macro



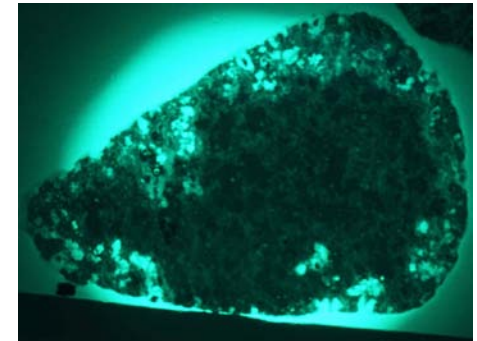
dense chalcedony



altered k-feldspar

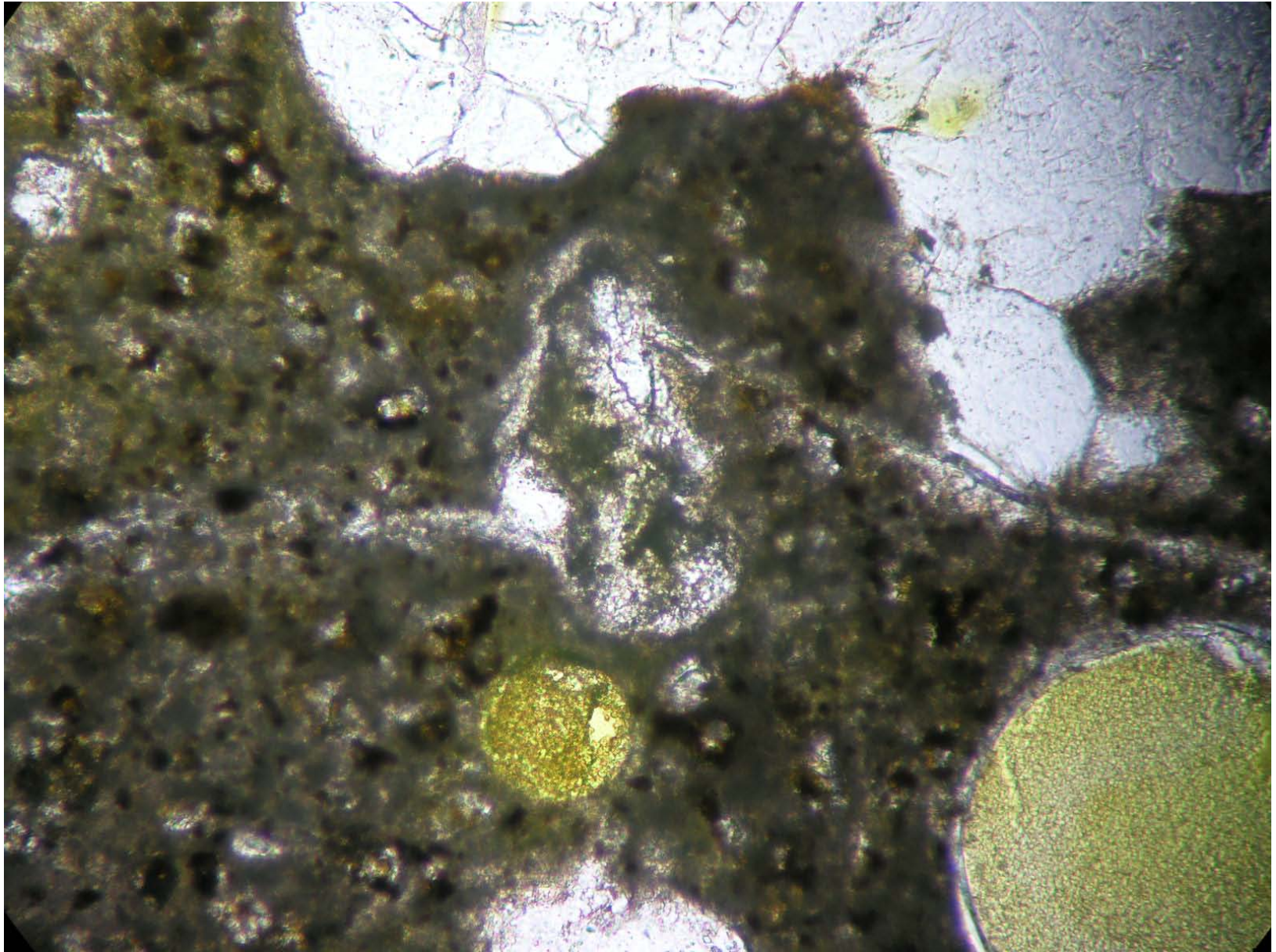


chert



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

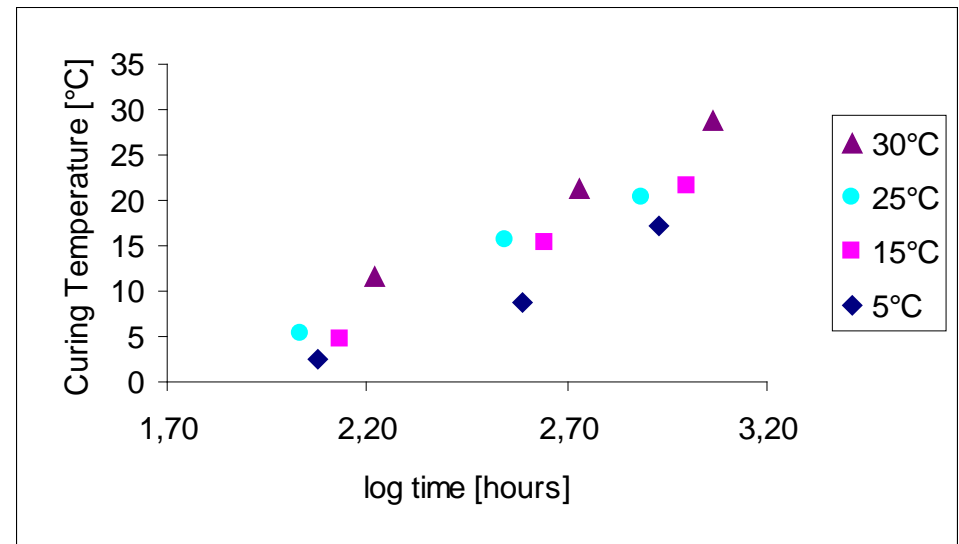


100% moisture curing room



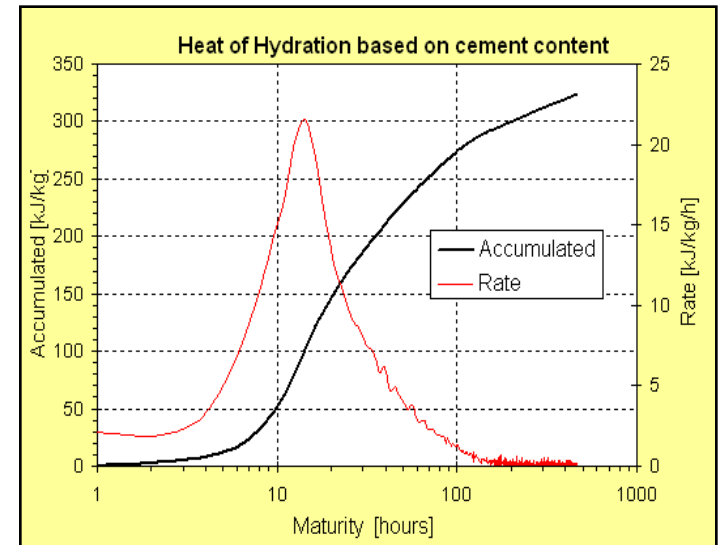
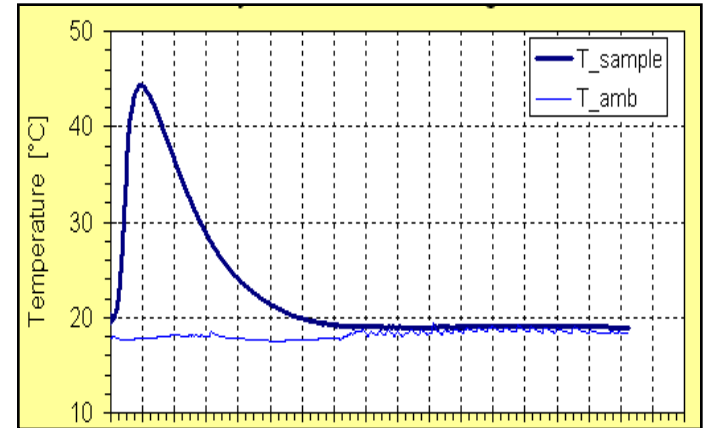
Hardening Concrete Tests

- Thermal Expansion
- Activation Energy



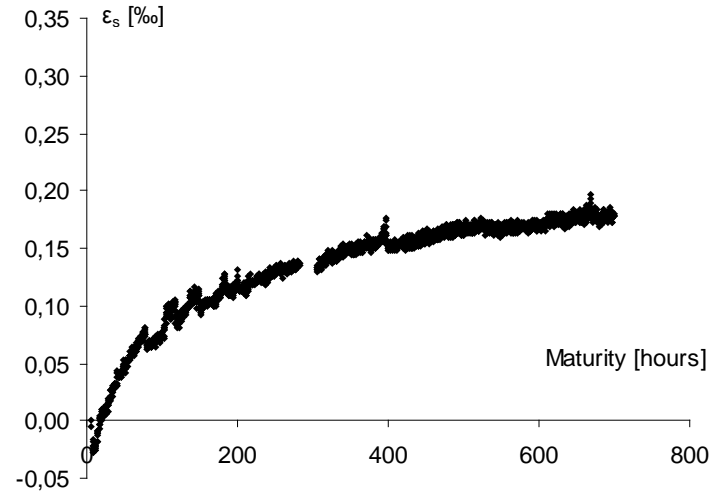
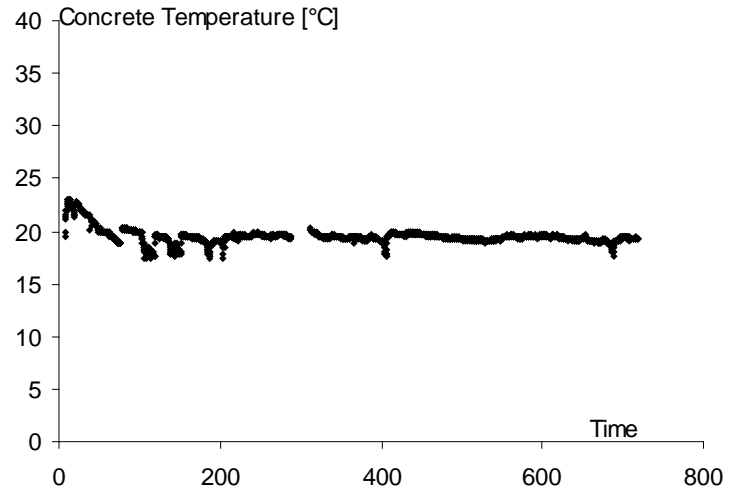
Hardening Concrete Tests

- Adiabatic Heat Development



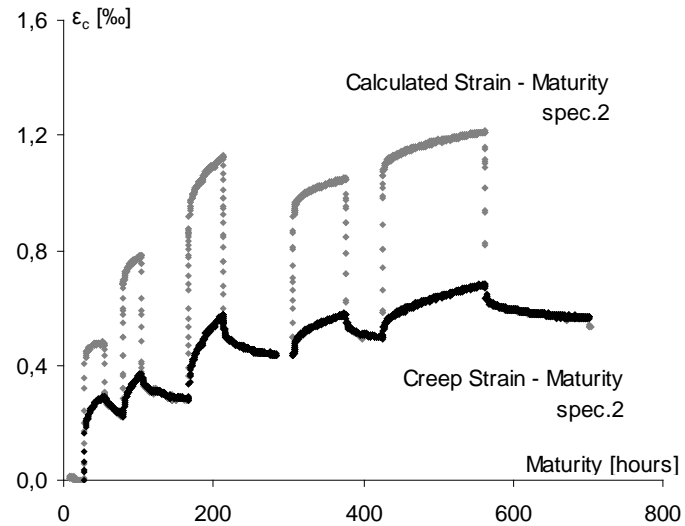
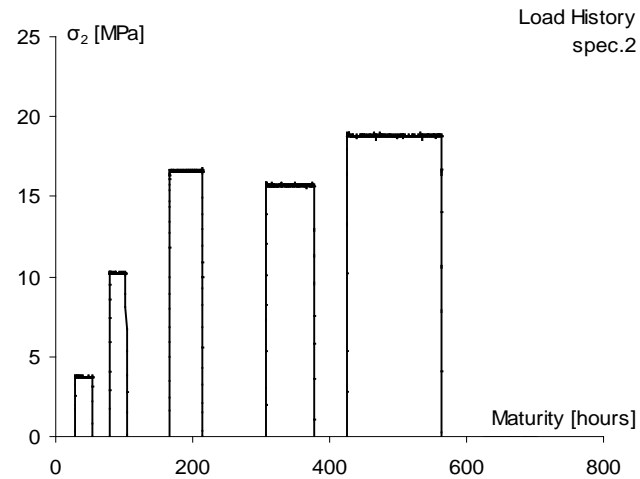
Hardening Concrete Tests

- Shrinkage (TI-B 102)



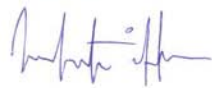
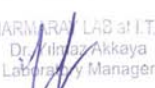


Hardening Concrete Tests

- Creep (TI-B 102)

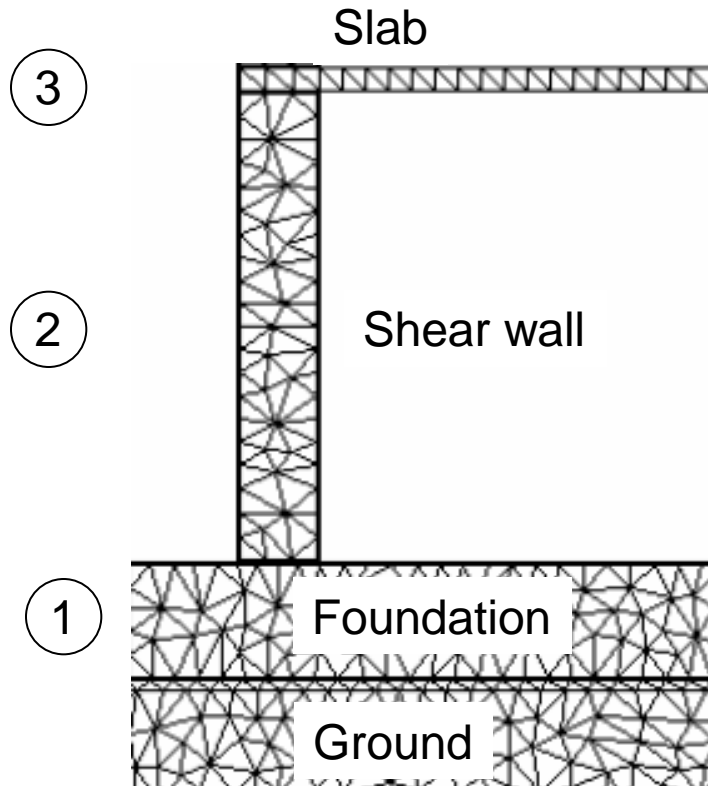


Design of a Test Report

ISTANBUL TECHNICAL UNIVERSITY CIVIL ENGINEERING FACULTY CONSTRUCTION MATERIALS MARMARAY LABORATORY Maslak/Istanbul-Turkey										Report No : HGR-015 Rev. Report Date : 20.02.2007 Report Page : 1/1												
Hardening Concrete Test Report																						
Client/Project Concrete Mix Design Code Mix Design Report No Request No / Date Fresh Concrete Report No Aggregate Report Nos					TGN JV Marmaray Project BC 1 / IMM AAB18 MDR-017 TR-012 / 05.12.2006 FCR-019 AG-199 / AG-200 / AG-201 / AG-202																	
Test Period Dates		Property / Item		Temp. [°C]		Testing Time [h]				Av. Strength [MPa]				k		EJ/mol	CJ/mol	E(±20) [J/mol]				
05.12.2006 23.12.2006		Activation Energy		5		22		44		67		89		112		0,9	4,1	8,0	13,8	17	0,19	36759
				15		13		26		39		52		65		0,7	5,4	9,3	14,2	19,4	0,34	34758
				20		13		27		41		55		69		-	2,6	8,4	16,8	21,1	25,9	-
		Test Standart: TI-B 103		25		10		21		31		42		53		1,9	7,9	12,9	17,8	25,1	0,53	28766
				30		10		20		31		41		52		2,8	11,1	19,5	24,1	27,7	0,70	34698
35		9		18		26		35		44		2,9	10,4	18,6	22,0	26,1	0,73	26006				
750		29823																				
Test Period Dates		Property / Item		Temp. [°C]		Testing Time [h]				Av. Strength [MPa]				k		EJ/mol	CJ/mol	E(±20) [J/mol]				
05.12.2006 23.12.2006		Activation Energy		5		22		44		67		89		112		0,9	4,1	8,0	13,5	17	0,18	40634
				15		13		26		39		52		65		0,7	5,4	9,3	13,9	19,2	0,33	43710
				20		13		27		41		55		69		-	2,6	8,1	15,6	20,9	26,2	-
		Test Standart: TI-B 103		25		10		21		31		42		53		2,2	8,2	15,5	21,4	25,2	0,62	48136
				30		10		20		31		41		52		2,9	11,1	19,3	22,4	24,3	0,65	26976
35		9		18		26		35		44		2,9	10,2	18,6	21,4	25,5	0,71	23337				
1350		32816																				
Test Period Dates		Property / Item		Temp. [°C]		Testing Time [h]				Av. Strength [MPa]				k		EJ/mol	CJ/mol	E(±20) [J/mol]				
05.12.2006 23.12.2006		Activation Energy		5		22		44		67		89		112		0,8	4,1	7,9	13,5	18	0,19	35752
				15		13		26		39		52		65		0,8	5,2	10,0	12,8	19,2	0,31	39175
				20		13		27		41		55		69		-	2,6	8,3	16,4	21,8	25,4	-
		Test Standart: TI-B 103		25		10		21		31		42		53		2,2	8,3	15,8	21,4	24,3	0,54	37705
				30		10		20		31		41		52		2,8	10,3	18,3	20,5	26,1	0,59	26139
35		9		18		26		35		44		2,9	10,2	19,2	21,1	24,4	0,71	27055				
1069		30300																				
Property Development		Max Load [kN]		Compressive Strength [MPa]			Tensile Strength [MPa]				Modulus of Elasticity E _c [GPa]				Modulus of Elasticity E ₀ [GPa]							
Applied Standard		TS EN 12390-3						TS EN 12390-6				NT BUILD 205				NT BUILD 205						
Test Date	Maturity Days	1	2	3	1	2	3	Av.	1	2	3	Av.	1	2	3	Av.	1	2	3	Av.		
01.12.2006	0,5	51	50	51	3,0	3,0	3,0	3,0	-	0,40	0,35	0,40	15,5	11,5	16,5	14,5	2,5	1,5	3,5	2,5		
01.12.2006	1	200	203	194	11,5	11,5	11,0	11,3	-	1,35	1,35	1,35	28,0	29,5	28,5	28,7	13,5	20,0	14,5	16,0		
02.12.2006	2	375	394	377	21,0	22,5	21,5	21,5	2,35	2,40	2,35	2,35	29,0	31,5	31,0	30,5	23,0	26,0	27,0	25,5		
03.12.2006	3	525	508	533	29,5	28,5	30,0	29,5	2,90	3,25	2,85	3,00	29,5	33,5	33,0	32,0	25,0	27,5	30,0	27,5		
07.12.2006	7	739	749	758	42,0	42,5	43,0	42,5	3,75	3,70	3,70	3,70	36,0	37,0	37,0	36,5	34,5	34,0	34,5	34,5		
14.12.2006	14	890	910	904	50,5	51,5	51,0	51,0	4,55	4,45	4,85	4,60	39,0	37,5	37,5	38,0	38,0	37,5	37,0	37,5		
28.12.2006	28	1102	1112	1122	62,5	63,0	63,5	63,0	5,20	4,55	5,60	5,10	41,5	42,5	41,0	41,5	40,5	39,5	37,5	39,0		
Thermal Exp. Coeff. Test Standart: TI-B 101		Age (day)		Average x10 ⁻⁶ /°C																		
Test Record No:		Test Period Dates:		1	5,66																	
IMM-EXP-18-01		01.12-08.12.2006		3	7,27																	
				7	6,52																	
Specific Heat Capacity Calculation [kJ/kg°C]		Record No: 18-00-SHC-01		1,05																		
Notes:																						
- Specimens (H=300 mm , D=150 mm) were sulphur capped and surface dried for Compression, Tension and E modulus tests.																						
- A quasi-adiabatic calorimeter was used for the Adiabatic Heat Development test according to NT Build 388.																						
- supersedes HGR-015.																						
performed by							reviewed by							approved by								
																						
Mehmet Ali KÜÇÜK							Başar Necdet ÜLKER							Yılmaz AKKAYA								
Civil Engineer											Assoc.Prof.Dr.											
without permission and test reports without original signatures are not valid.											Laboratory Technician Reproduced test report:											

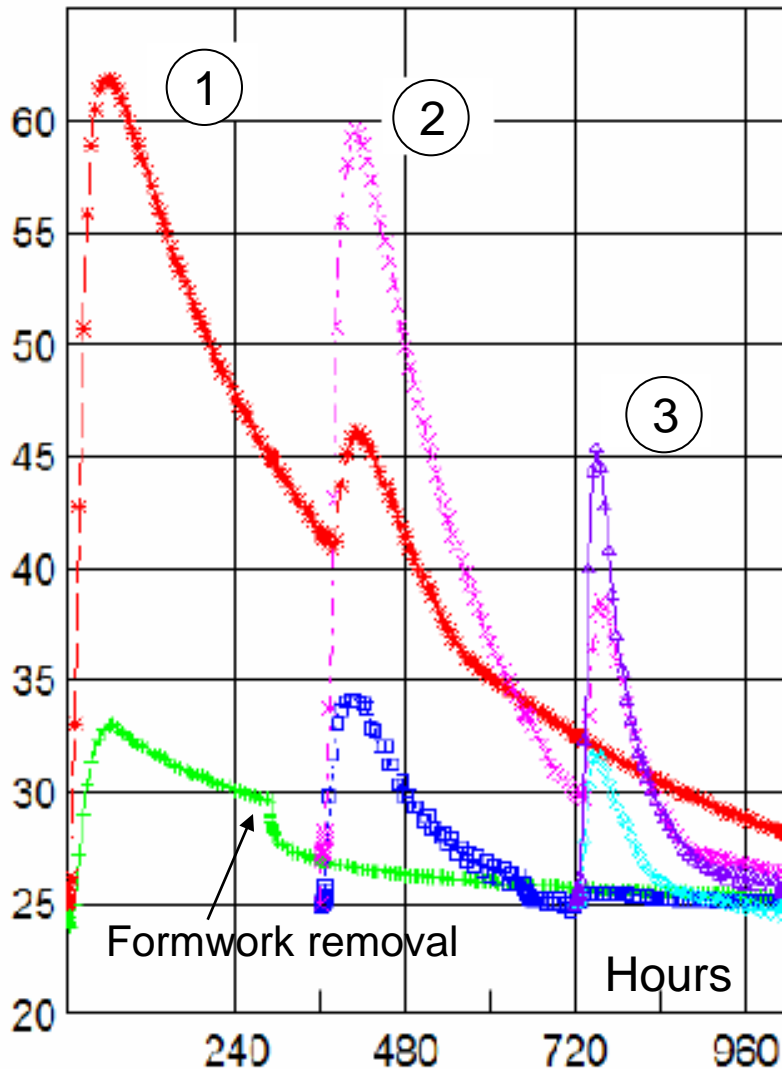
Simulation for Cracking Risk

Casting sequence



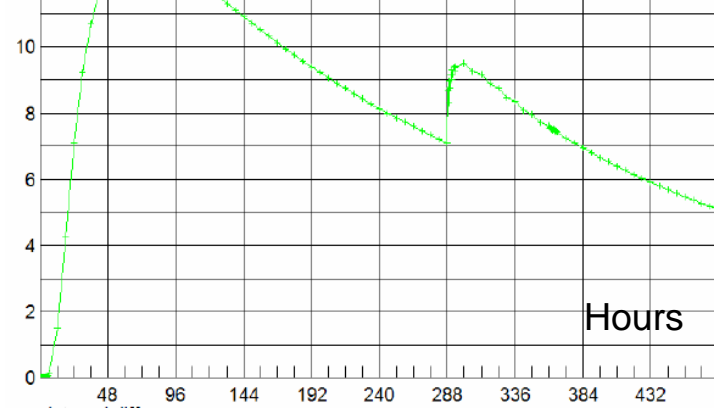
- Casting days and sequence
 - Removal day of formwork/ insulation
 - Environmental temperature and humidity
 - Specific heat capacity and heat conductivity of ground
 - Formwork/Insulation thickness ve heat conductivity
 - Structural boundary conditions
 - Fresh concrete temperature
 - Cooling/heating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

Temperature (°C)



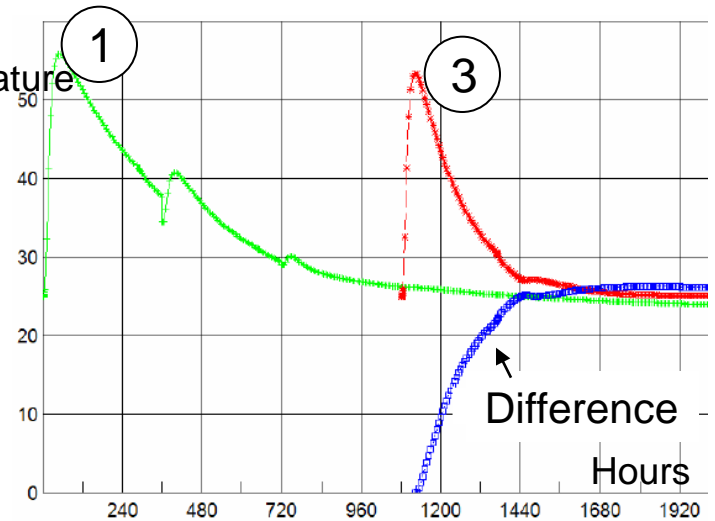
Max (internal) ve min (surface) temperatures

Temperature (°C)



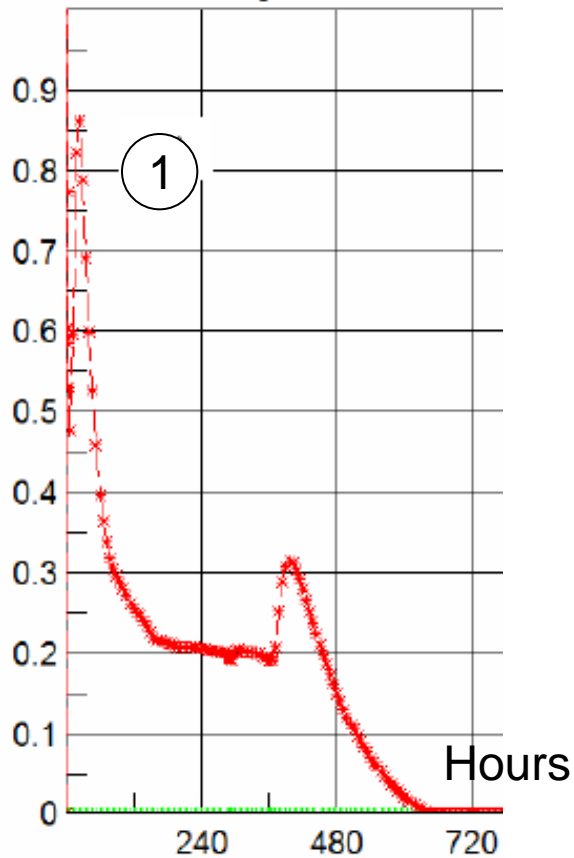
ΔT_{int} = Difference between the average and surface temps. of member

Temperature (°C)



ΔT_{out} = Difference between the av. temps. of the new member and existing member

Crack risk = stress/strength



For water retaining structures:

$$T_{\max} < 50^{\circ}\text{C}$$

$$\Delta T_{i\check{c}} < 15^{\circ}\text{C}$$

$$\Delta T_{dış} < 15^{\circ}\text{C}$$

$$\text{Risk} < 0,7$$

$$\text{Crack width}_{\max} < 0 - 0,2 \text{ mm}$$

Hardened Concrete Tests

- Compressive Strength
- Density



rock specimen



jet grout specimens



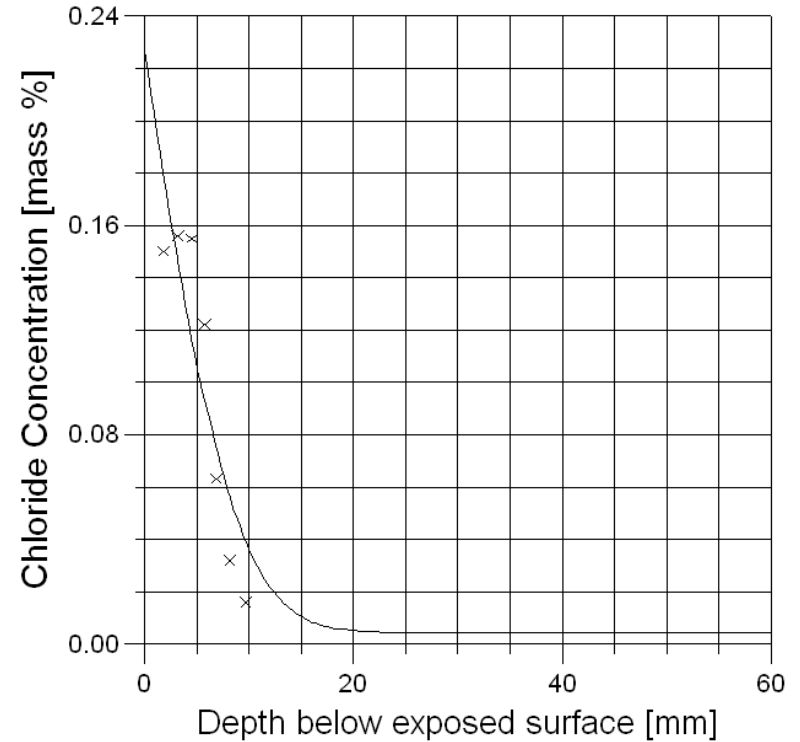
Hardened Concrete Tests

- 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



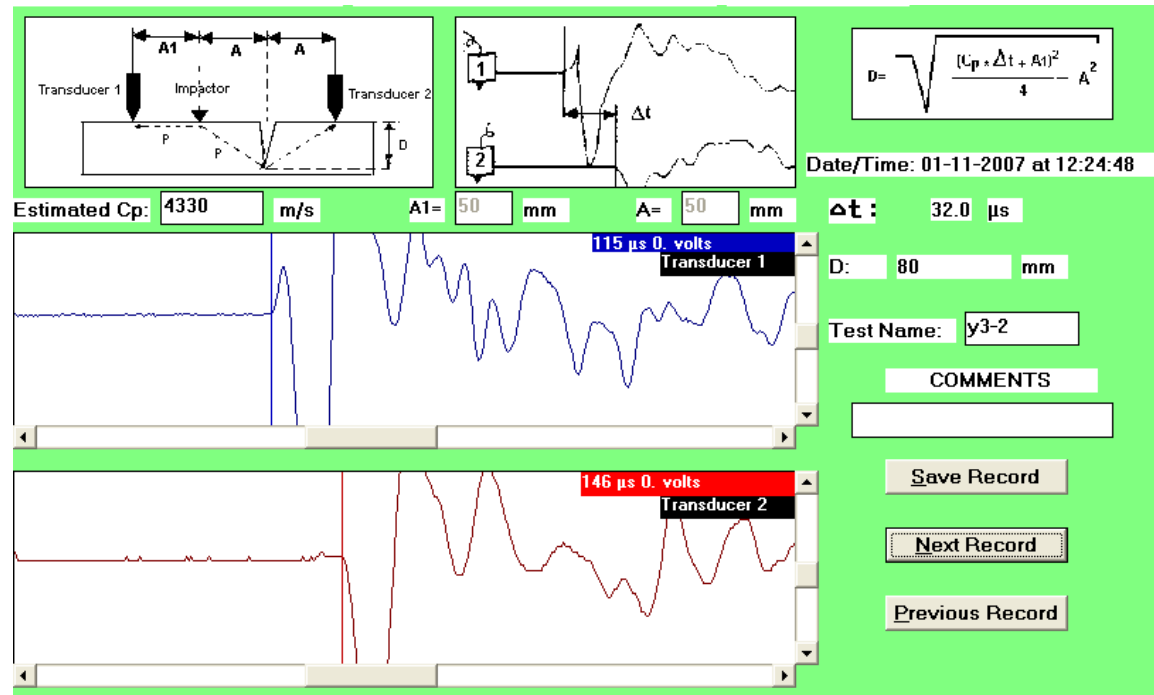
Repair Quality

- Pull-Out



Site Testing

- Crack Depth Investigation
- impact echo



Concrete Petrography



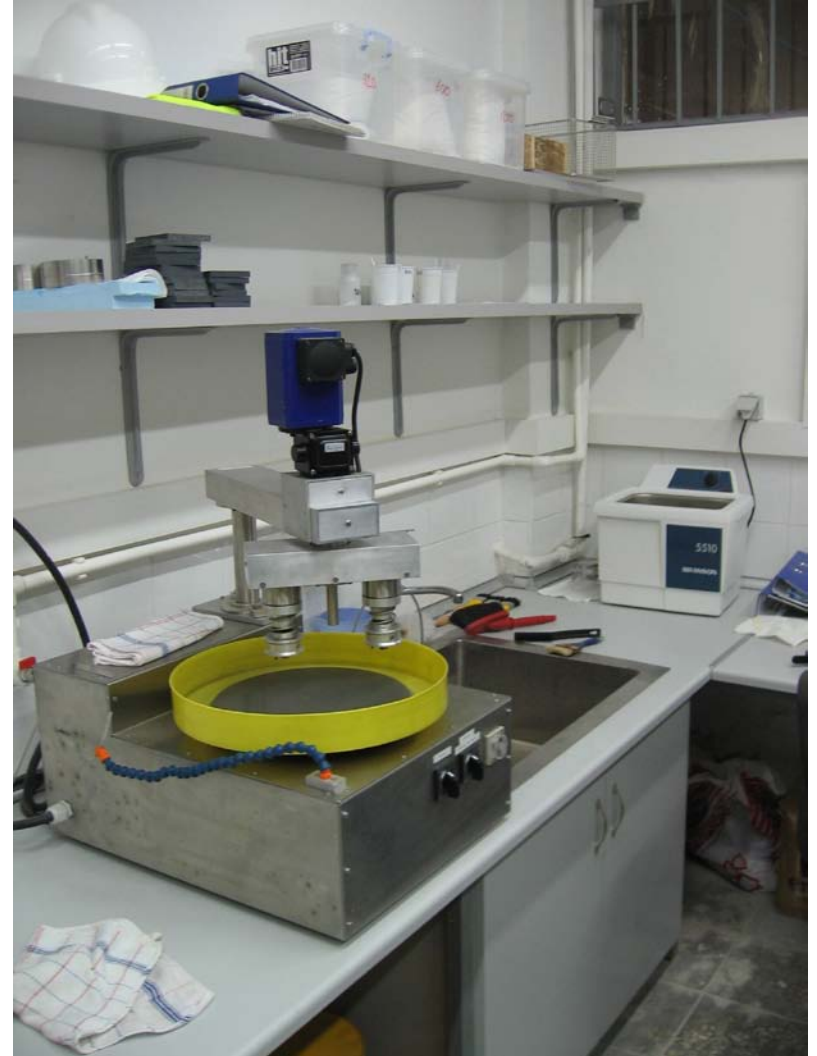
Concrete Petrography



plane section cup grinder



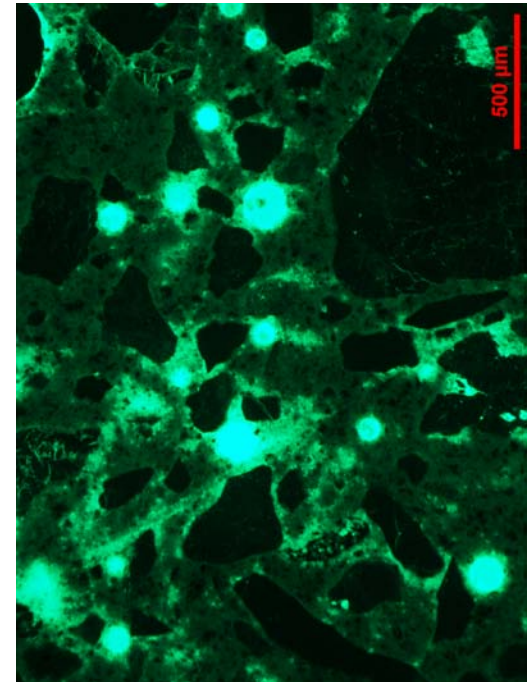
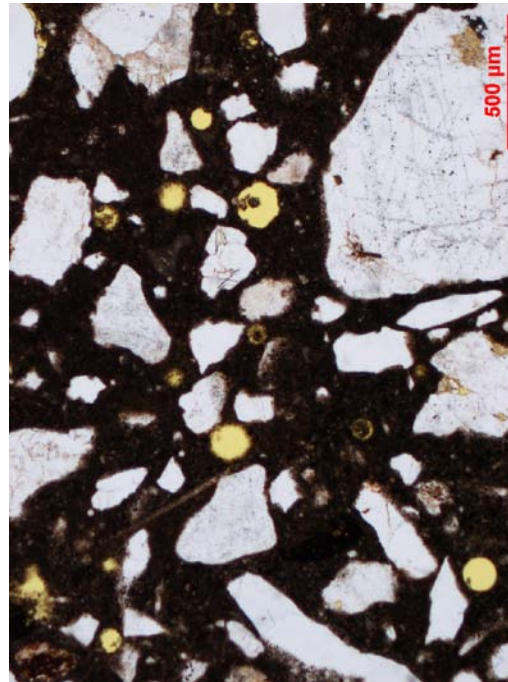
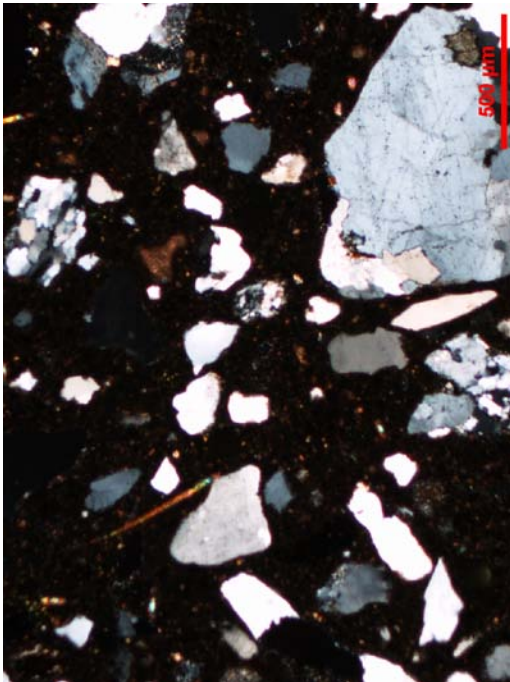
thin section lapping machine



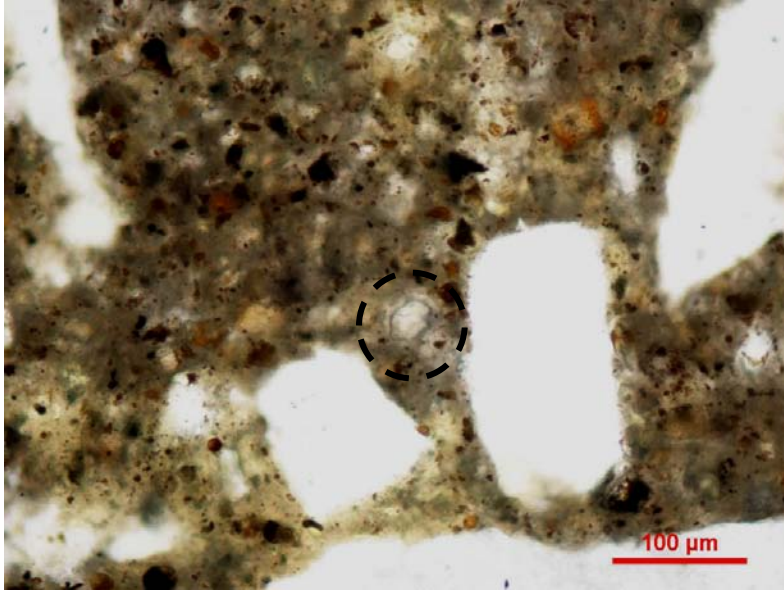
air void petroplaner

Thin Section Analysis

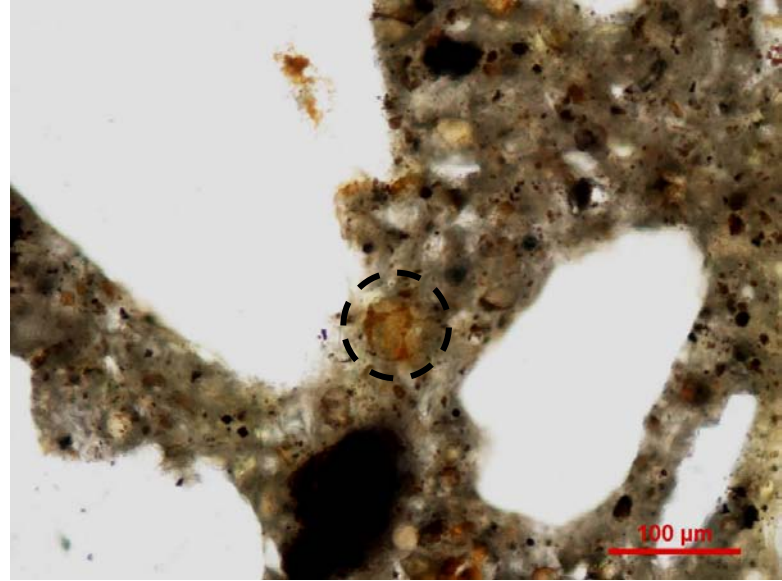
- mineralogical examination
- cementitious materials
- fluorescence intensity
- capillary porosity(w/c ratio)
- paste homogeneity
- cracks - interface



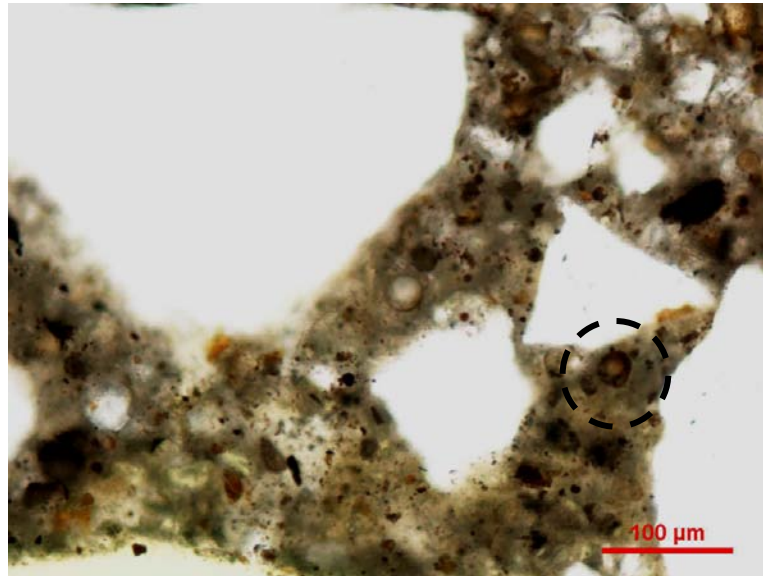
Cementitious Materials



alite

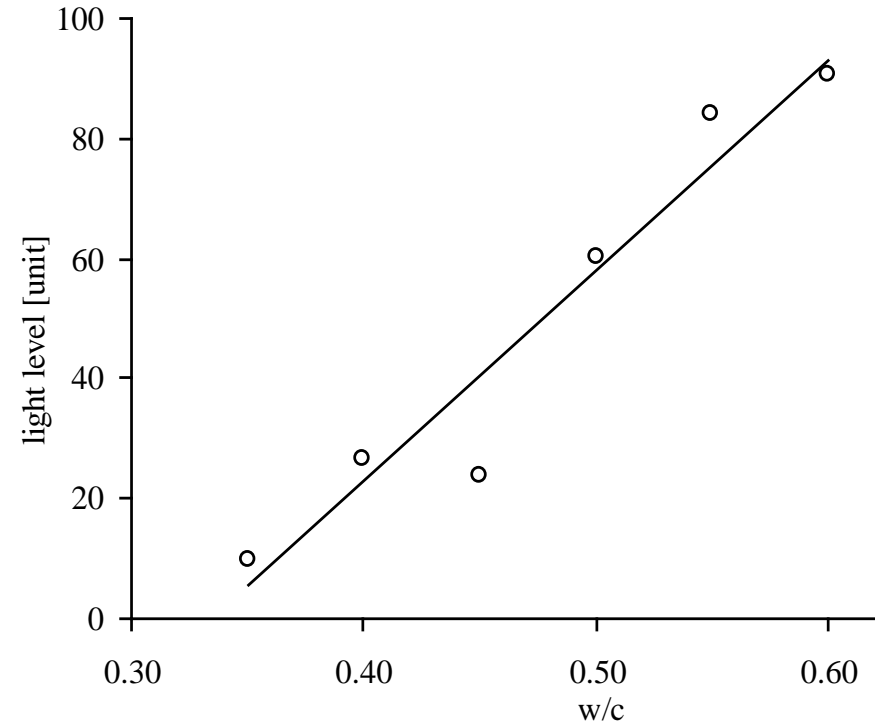
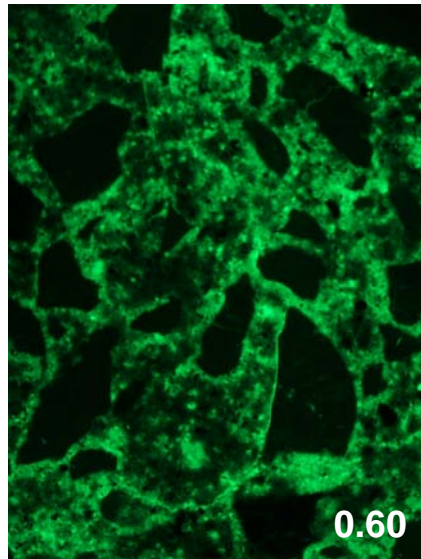
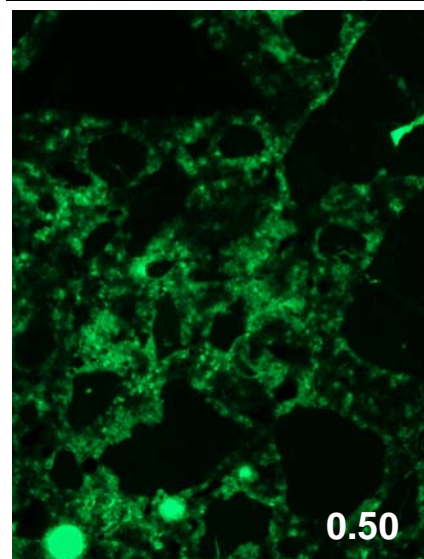
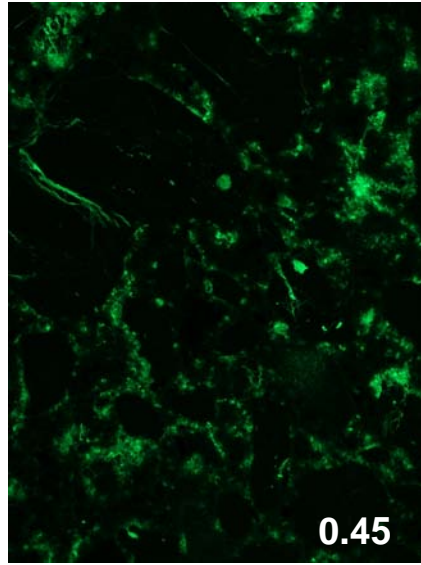
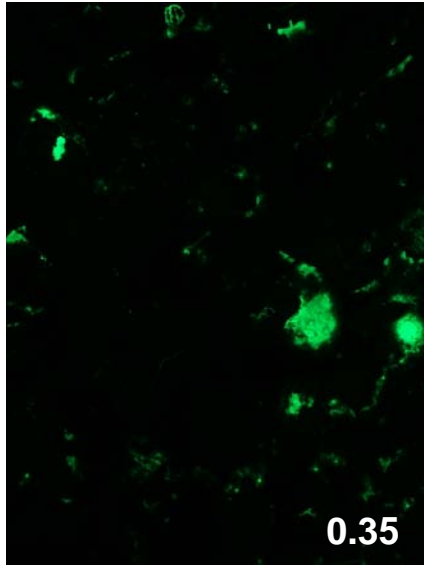


belite



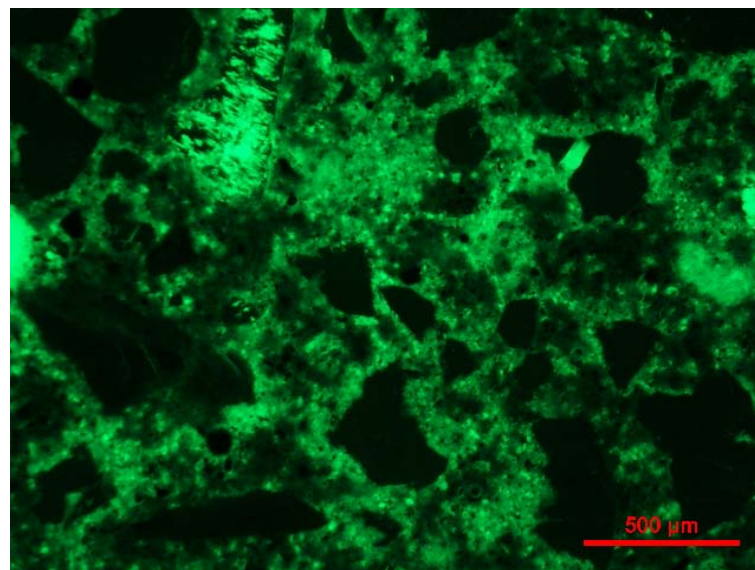
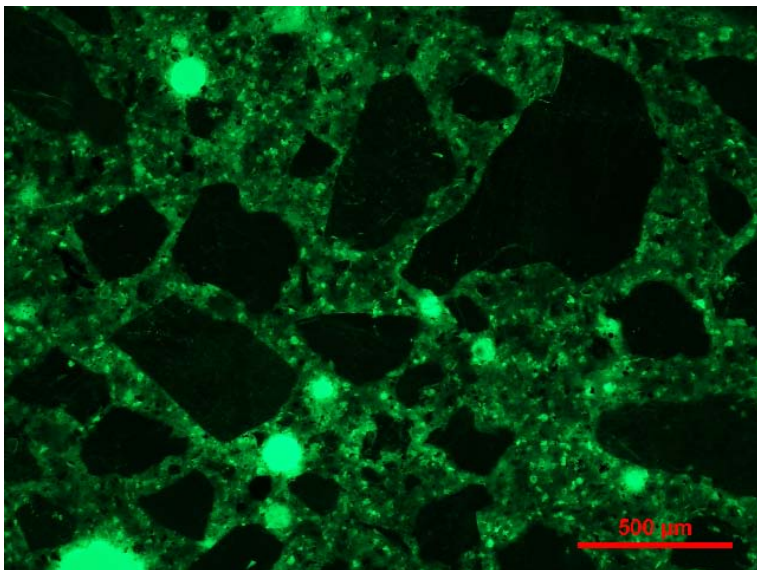
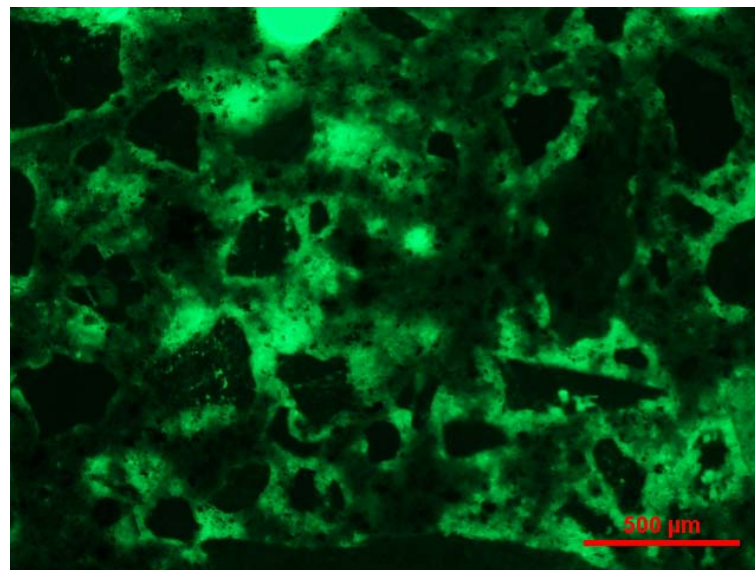
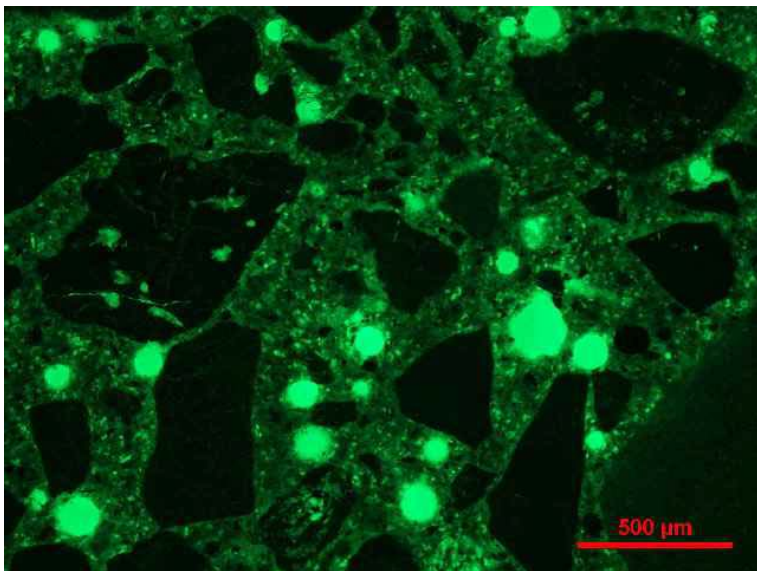
fly ash

water/cement ratio

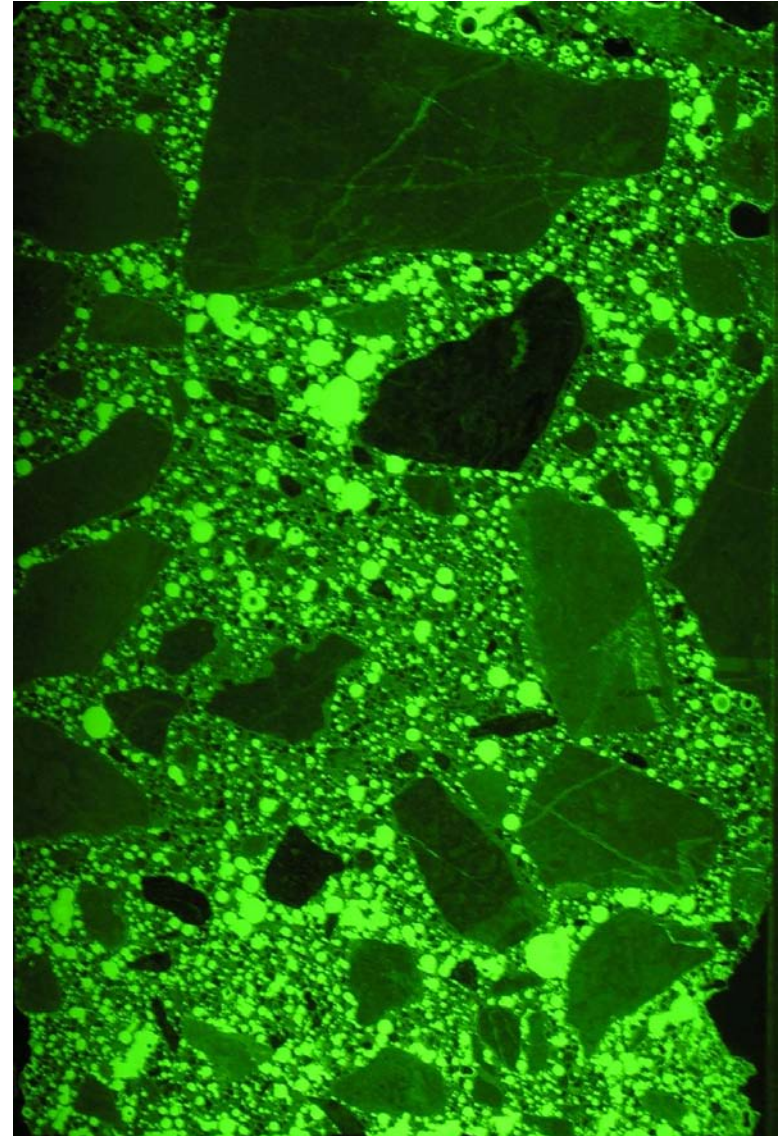
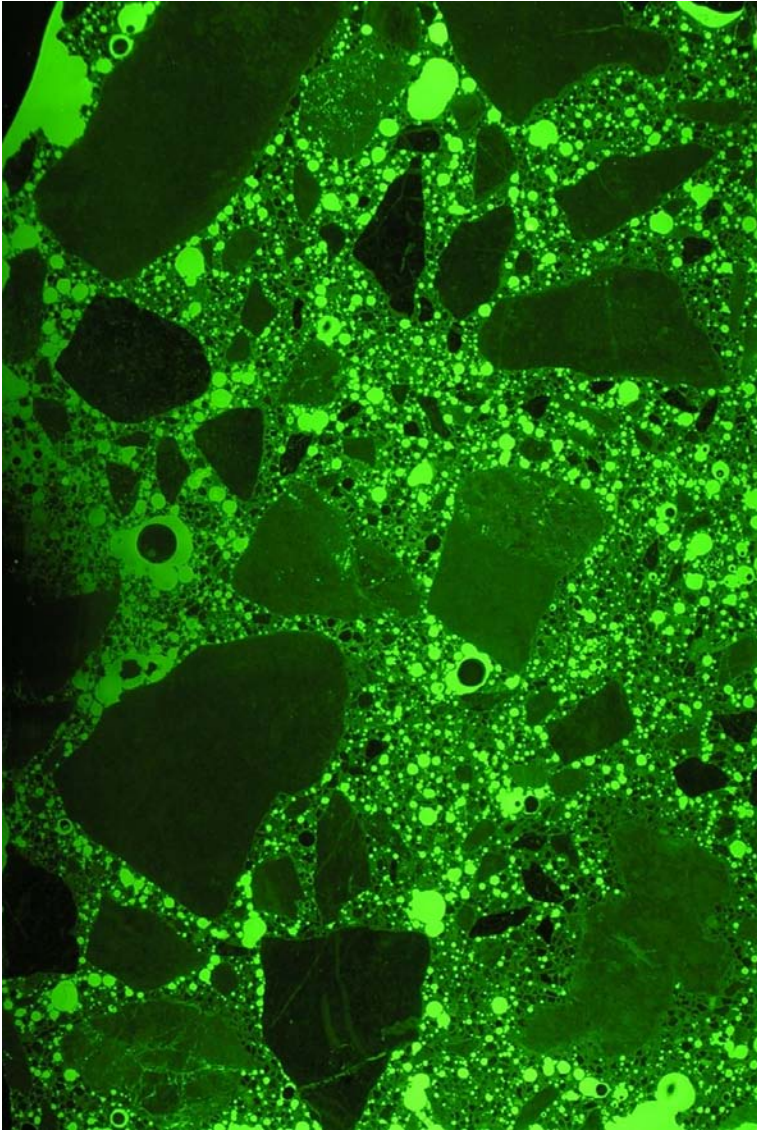


relationship between light level – w/c ratio

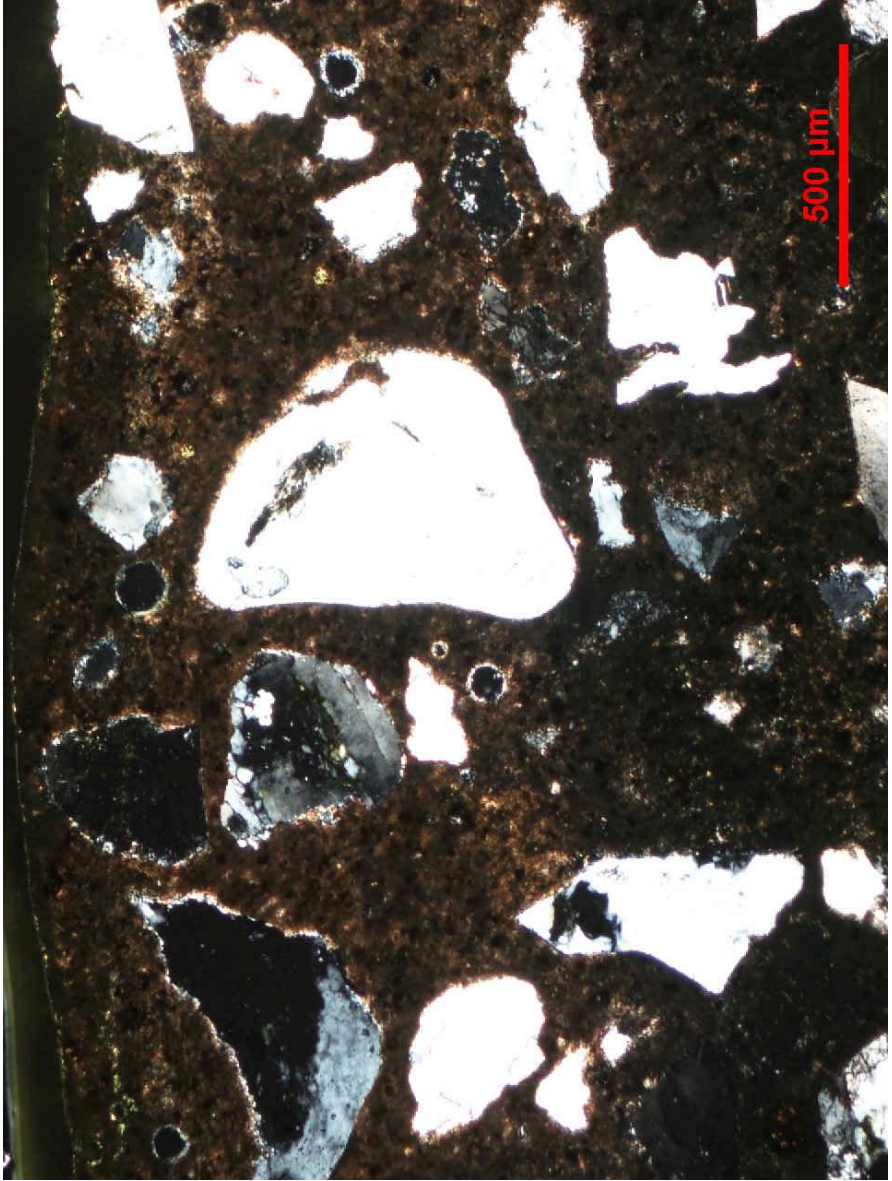
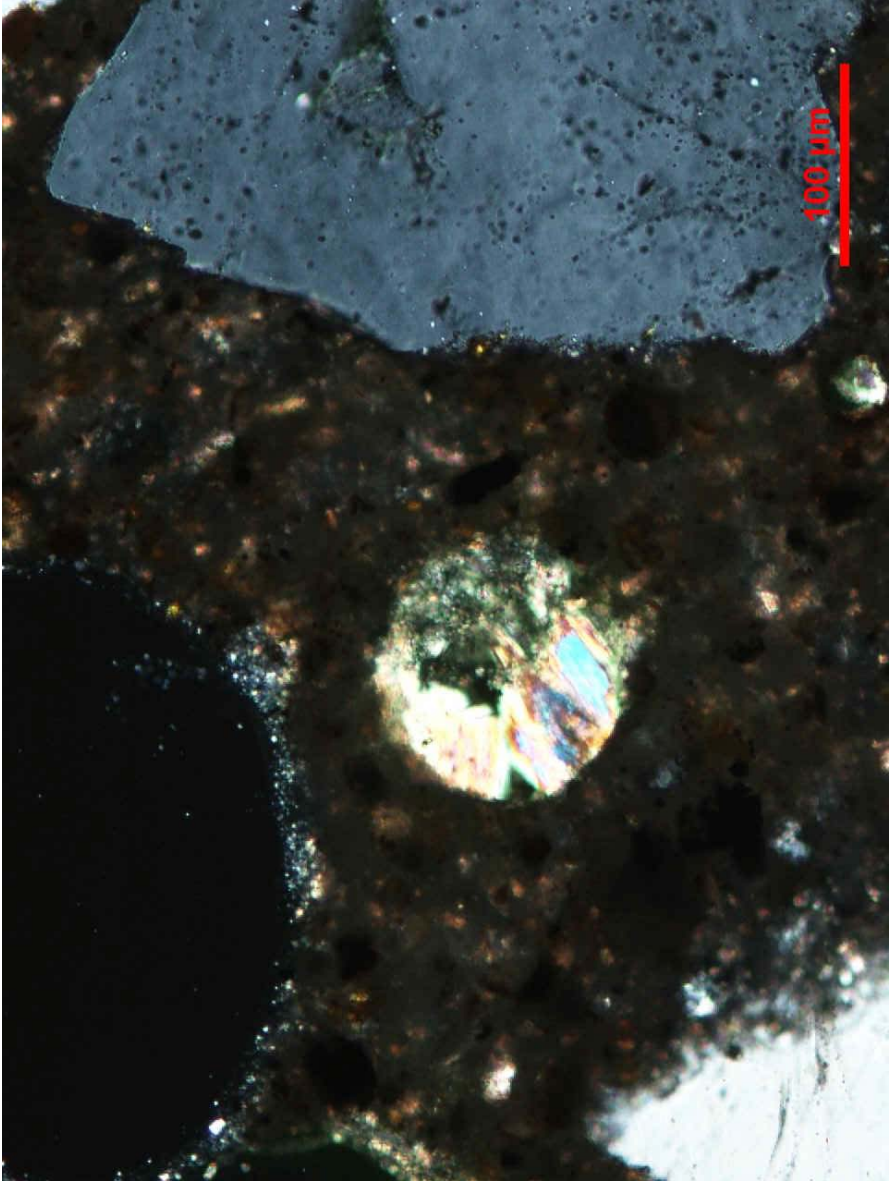
Paste Homogeneity



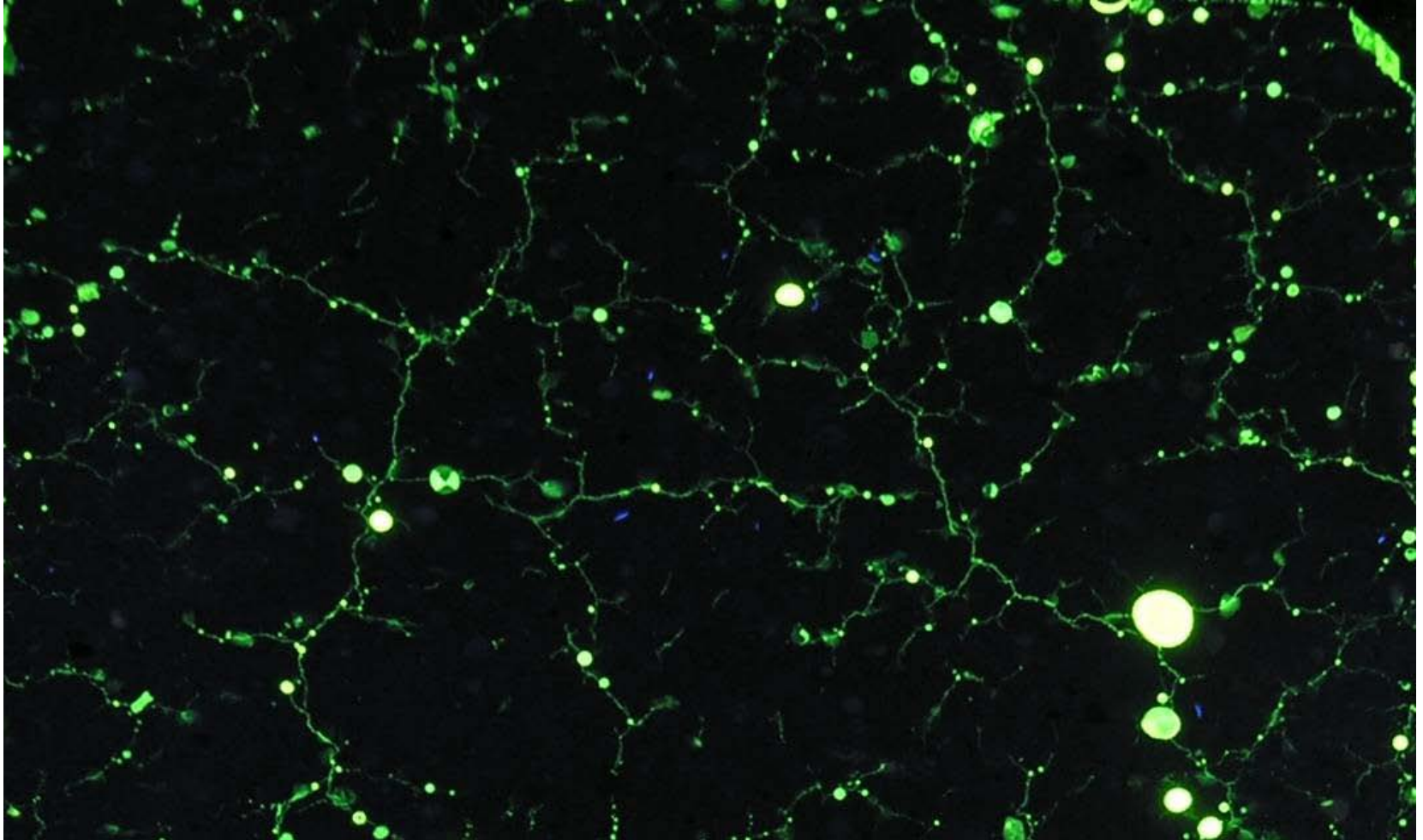
Air Content and Distribution



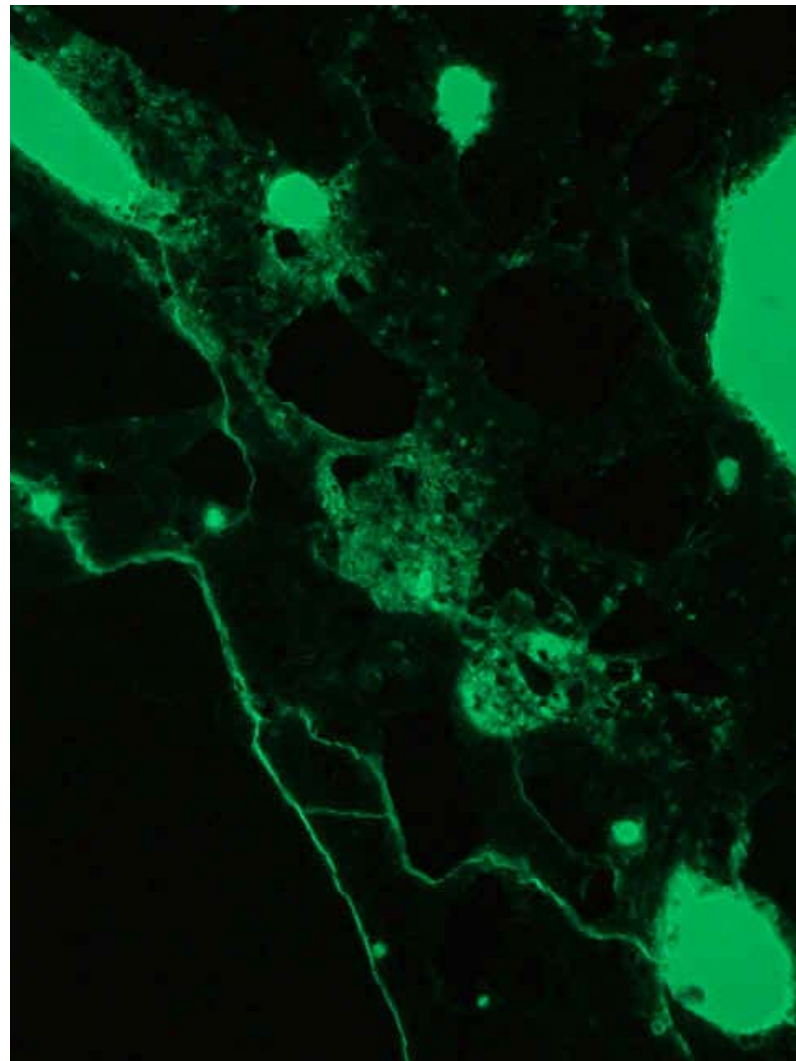
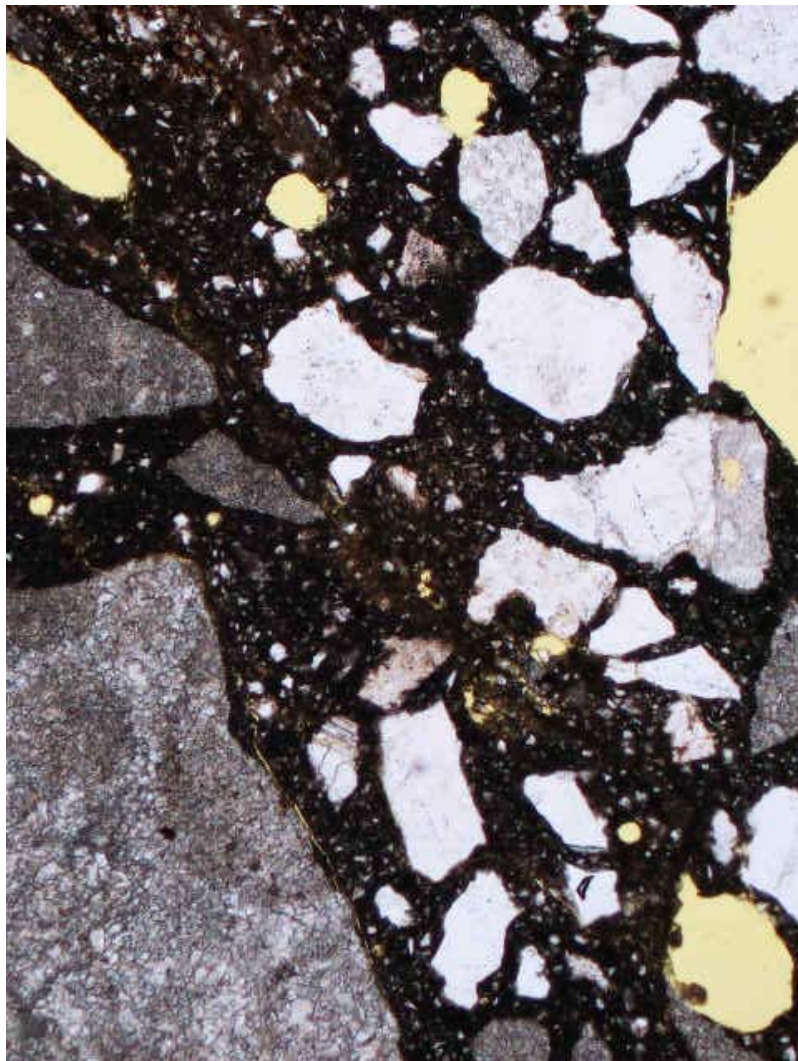
Calcium Hydroxide, Carbonation, Ettringite



Crack Length-Width-Direction



Repair Materials - Concrete Interface



Plane Section Analysis



Aggregate: shape, type, content, distribution

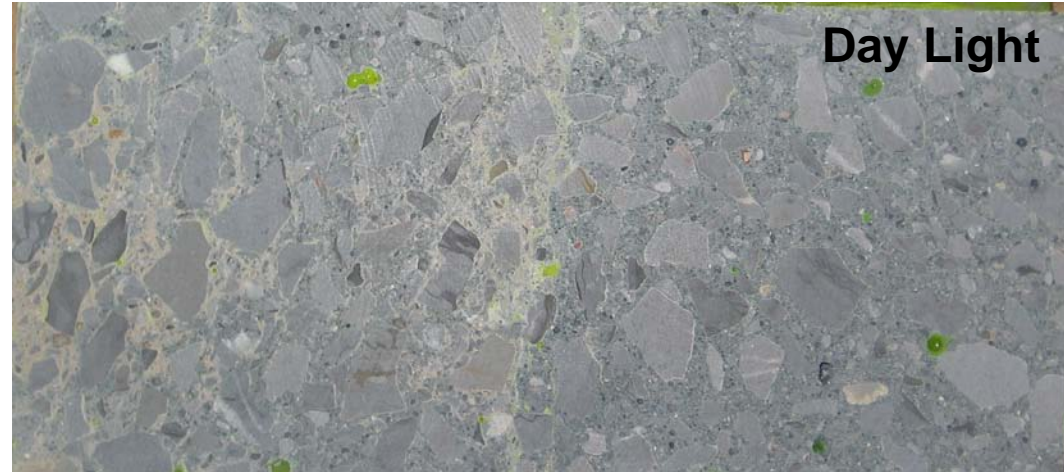
Mortar: homogeneity, segregation

Workmanship: entrapped air voids

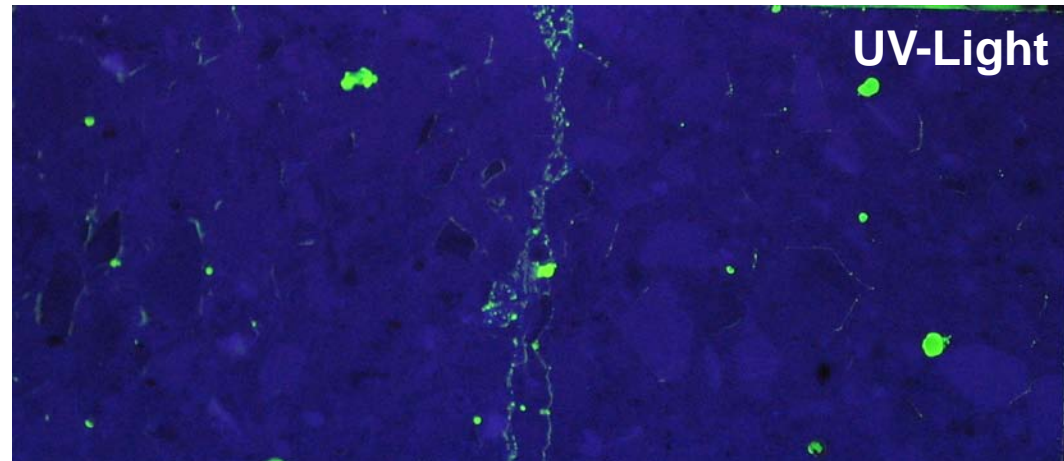
Cracks: content, direction, length, width

Surface : bleeding, damage

Rebar : size, interface, corrosion

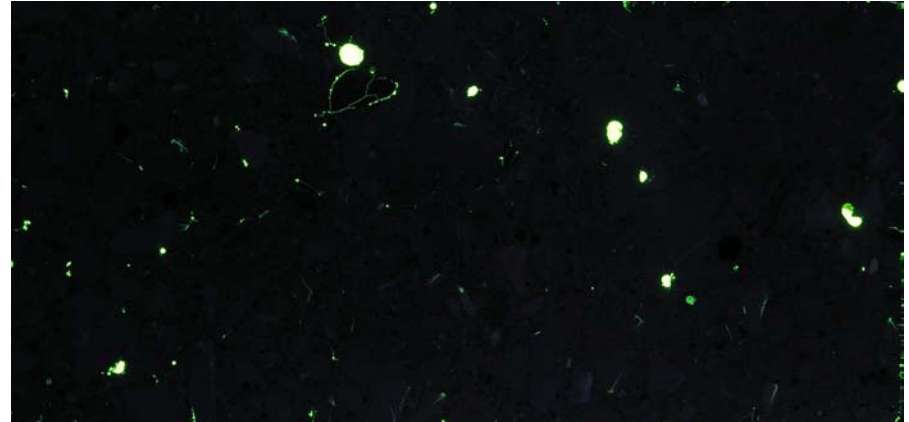
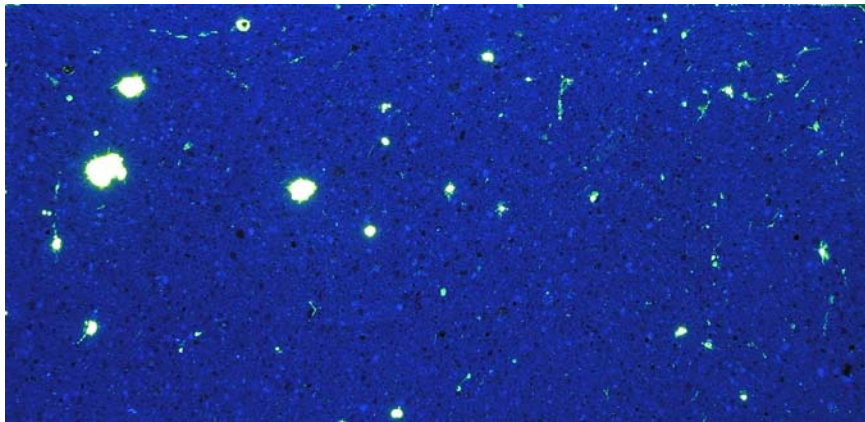
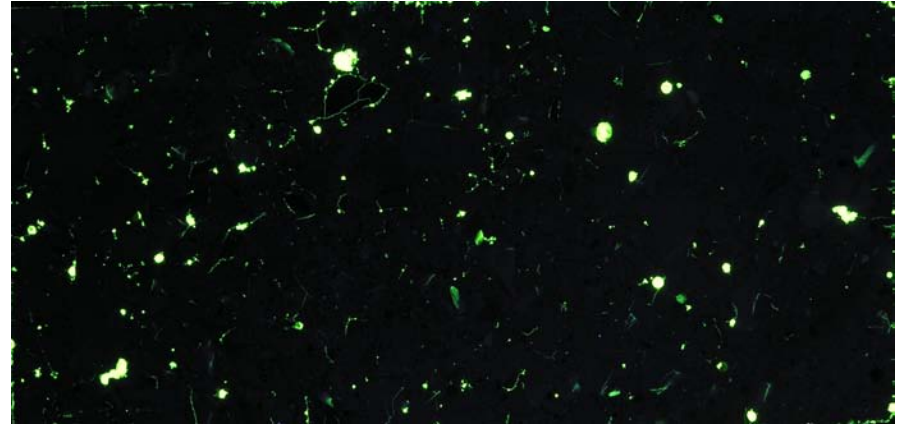
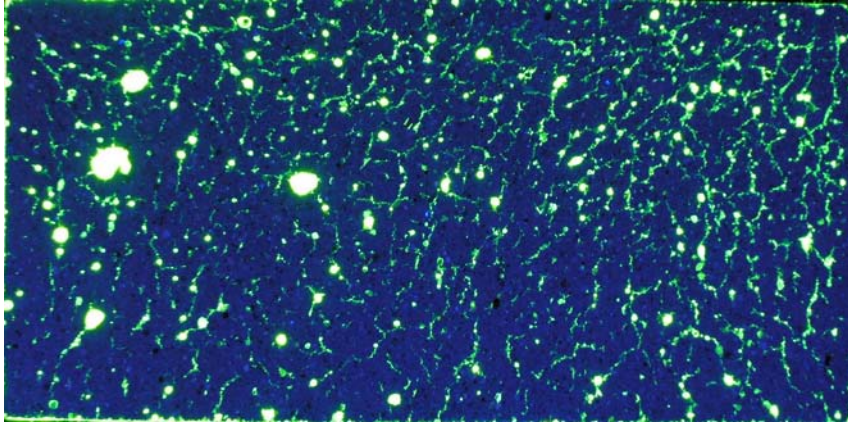


Day Light

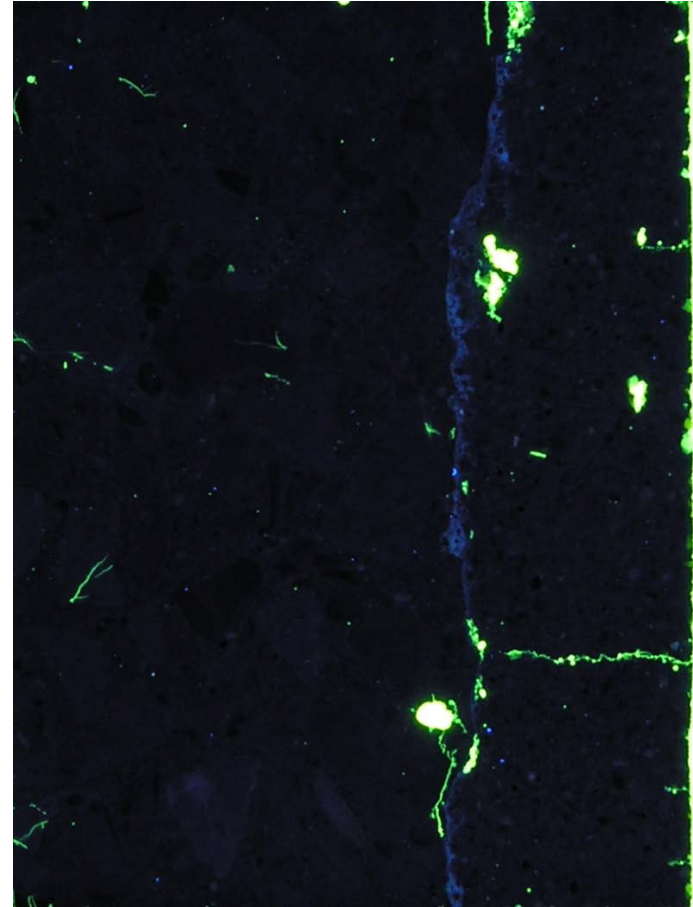


UV-Light

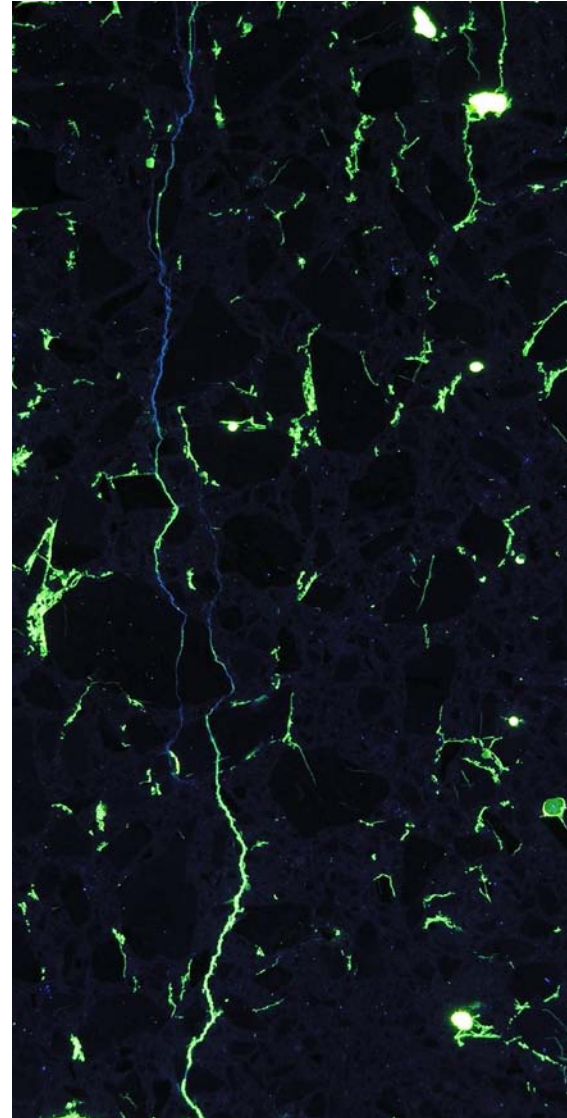
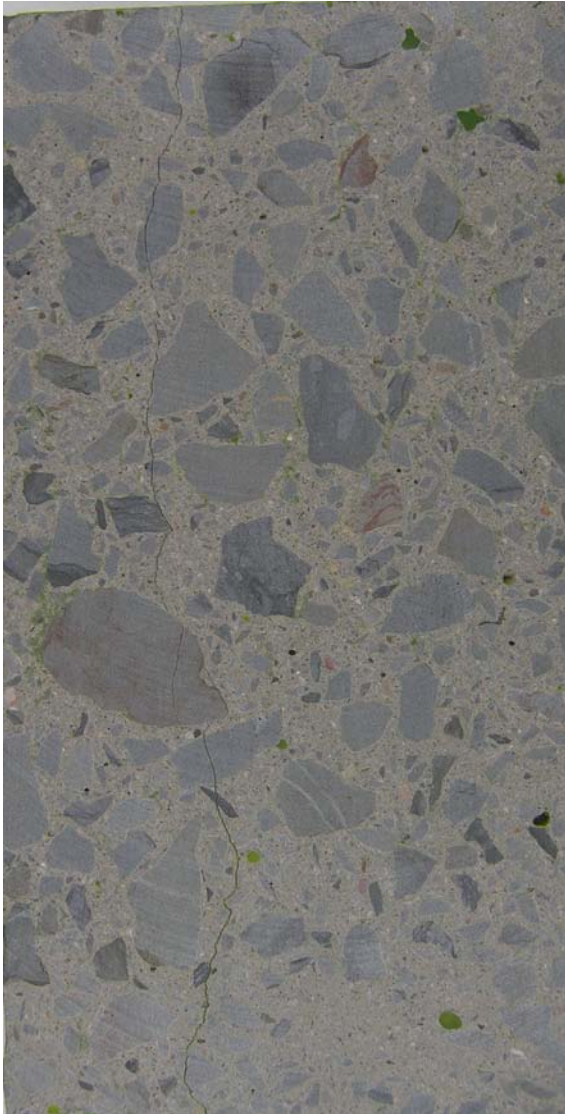
Void System



Repair Material – Concrete Interface



Epoxy Injection



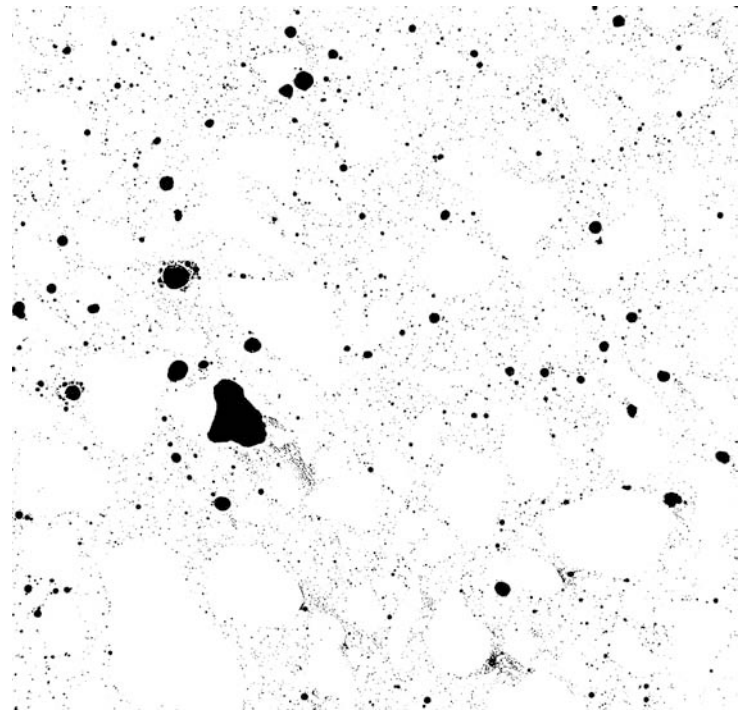
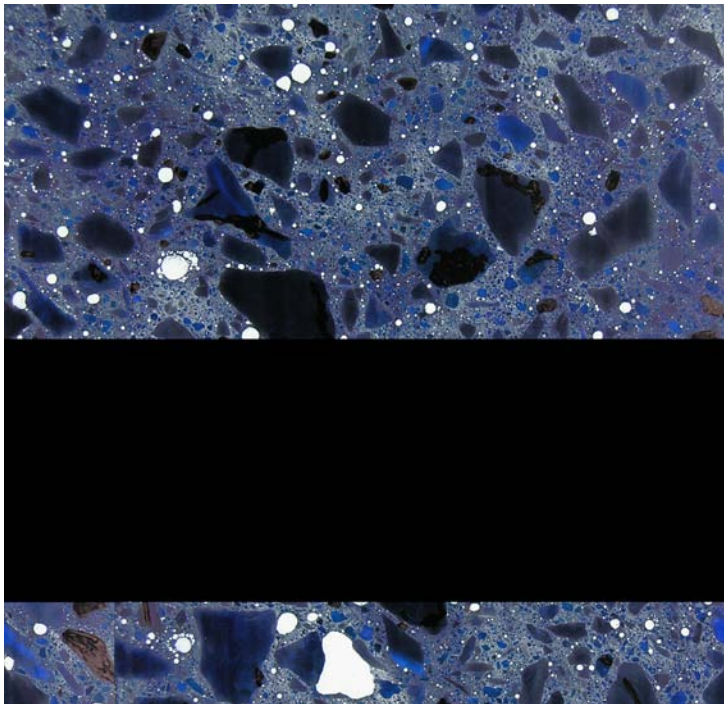
Air Void Analysis

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 !

