Geology 229
Engineering Geology

Lecture 7

Rocks and Concrete
as Engineering Material
(West, Ch. 6)

Outline of this Lecture

1. Rock mass properties
   - Weakness planes control rock mass strength;
   - Rock textures;
   - Fracture development;

2. Engineering properties of Portland cement concrete
   - Aggregates;
   - Cement paste;
   - Air voids;

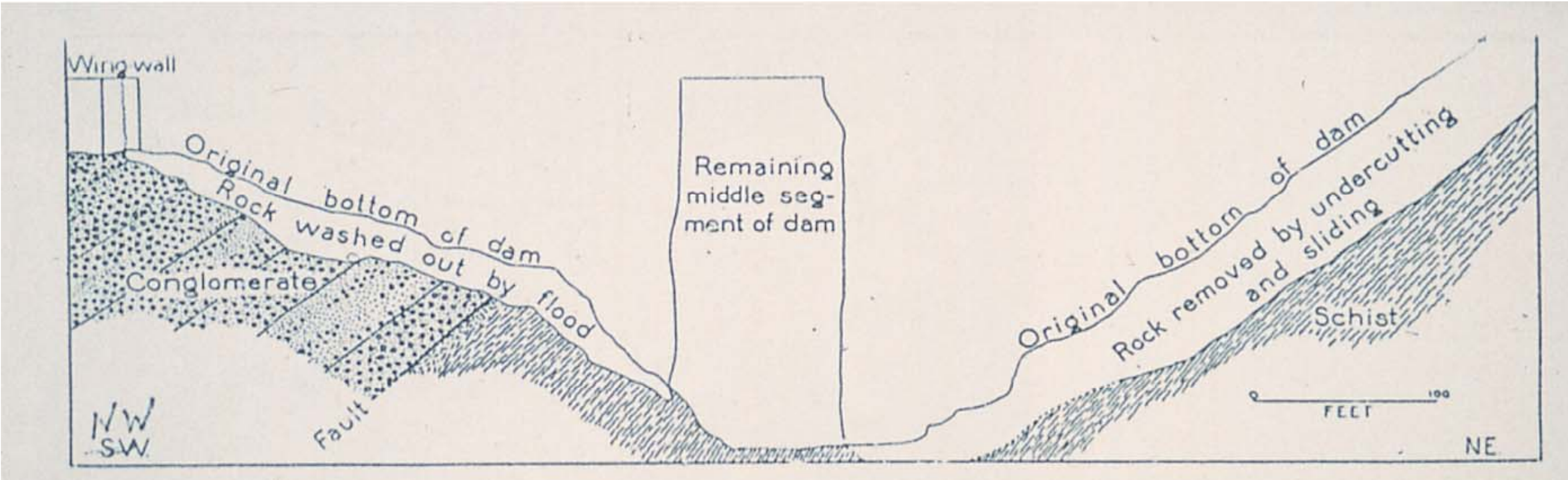


FIG. 3. Geological Section through the St. Francis dam-site.

Main reasons for dam failure:

1, Sedimentary rocks on the west lost strength when it is wet;

2, The fault separating the west and east rock formations stated to leak water;

3, Schist on the east increases pore pressure and lost shear strength after wet.

Rocks as foundation for engineering construction: Rock mass properties

Rock mass properties are related to large-scale engineering constructions.

1) abutments;
2) foundations for large dams;
3 slope stability for highway cuts;
4) tunneling, mining, and excavations.

Soil (sample) and soil mass may have very similar properties. In contrast,

<u>Rock (sample) and rock mass may appear substantially different properties.</u>

Rock mass properties (cont.)

For rocks or rock-alike materials (e.g., concrete) with the uniaxial compressive strength greater than 100 psi (700 kPa), the strength is completely controlled by the discontinuities or weakness planes.

In natural rocks, weakness planes include:

1) bedding;
2) foliation (cleavage, schistosity, gneissic structure, etc.);
3) flow banding in lave rocks;
4) joint, faults, and shear zones.

Concerns about the rock mass weakness planes

1) relative to the expose face – attitude;
2) extent (length);
3) spacing;
4) nature (irregularity, smoothness, etc.);
5) infilling materials;
6) groundwater conditions;
7) orientation.

Rock Textures:

Without considering their origin (igneous, sedimentary, metamorphic, etc.) rock textures are limited to a few basic varieties:

1) inter-locking crystals;
2) clastic pieces cemented by crystalline materials;
3) clastic pieces with infilling of matrix;
4) glassy materials.

We simplify this because in engineering geology we care most of the mechanic properties of rocks. We can afford to make this simplification.

Fracture development through rocks

1) For both clastic and inter-locking crystals textured rocks, fractures occur either through the grains and crystals or around them;

2) For clastic grains with finer non-cemented matrix, failure is through the weaker matrix, because this kind of rock is held together by overburden, so that it is easy to be broken by wetting-drying, freezing-thawing, cooling, heating --- it has poor weathering resistance.

For clastic rocks with minor amount of cementing agent, i.e., friable sandstone, fails through the cement, after only a minor agitation.

For clastic rocks with minor portion of crystallized cement, i.e., calcite, fractures are developed through either grains, or cement.

Sandstone on the surface may be extremely weathering resistant to both mechanical and chemical weathering due to water seeping, mineral deposition, and calcite. These processes increase the strength of sandstones. This phenomenon is referred as case hardening.

Best field example can be found at some of the quartz sandstone outcrops.

In general, the larger the grain size, the easier fracture develops.

Crystals oriented more random, fracture development more unlikely.

Portland Cement Concrete, or simply, Concrete

In many ways concrete is similar to rock:

- **-Physical characteristics;**
- **-Analysis methods;**

Concrete is one of the most widely uses construction materials:

bridges, highways, buildings, dams, retaining walls, sidewalks, etc.

80% of bridges were made by concrete, and 20% were steel or steel suspension bridges by early 1990s.

The compressive strength of concrete by 28-day curing is about 3000 to 4000 psi;

Prestressed, reinforced concrete can have a compressive strength as high as 4500-5000 psi.

Compared with sandstone that has the compressive strength in the range of 2780-23600 psi. Apparently, concrete can be as strong as, or even stronger than some rocks.

Concrete consists of aggregate, cement paste, and air voids. Aggregate comprises 75% of the volume of concrete. Cement paste and air voids comprise the remaining 25% of the volume of concrete.

Aggregates

The aggregates are rocks that have relatively lower expansion coefficient comparing with water-cement hydrate. Aggregates do not interact with water. A higher water-cement ratio means more calcium silicate hydrate was generated so more volume change would occur.

The purpose of the aggregate:

1) **Provide an inexpensive filler;**
2) **Provide a considerable volume of the concrete, resistant to loads, abrasion, moisture penetration, and weathering action;**
3) **Reduce the volume change effects that occur in the cement paste during hardening and from moisture change.**

The contribution of the aggregate to the properties of concrete:

1) **the aggregate particles contribute to strength, elasticity, and durability;**

2) **the nature of the surface of the articles is important (e.g., roughness decrease the workability but increase the bond after hardening;**

3) **a dense gradation of the aggregate reduces workability and increases the density of the mix;**

4) **the higher the percentage of aggregate, the lower the cost and volume change when curing.**

Cement Paste

The purpose of the cement paste:

1)**Fill the space between aggregates thereby providing lubrication in the fresh, plastic concrete during placement and tightness after concrete hardening;**
2)**Provide strength to the hardened concrete.**

The hardened cement paste includes:
1)**a minor unreacted cement particles;**
2)**a major constituent, hydrated cement (calcium silicate hydrate) – reaction between cement and water.**

The properties of the hardened concrete paste depend primarily on:
1)**The characteristics of the Portland cement itself;**
2)**Water-cement ratio by weight;**
3)**The extent of chemical interaction between the cement and water.**

Air Voids

Naturally entrapped air: 1-2%;
The desired optimal air void for concrete for freeze-thaw, and salt scaling resistances is 5-6%.

To reach is optimal air void, air-entraining agents are incorporated when proportioning the concrete. Thus, the entrained air is about 3-4%. However, higher air void implies lower strength. Typically, more cement must be used in air-entrained concrete to counteract the strength reduction.

Air void determination:
Thin section of concrete samples examined with microscope, like the lab works on rock thin sections.

Curing:
The process to accelerate cement hydration under favorable physical conditions in terms of time, temperature, and moisture. The 28-day compressive strength of standard concrete cylinders in used to determine the acceptability of concrete placement (3000, 3500, 4000, and 5000 psi are commonly required values).

TABLE 6.4 (West, p97)

Uses for Petrographic Examination of Concrete and Concrete-Making Materials

Description of the Concrete

1. Mix proportions
2. Internal structure
3. Cement-aggregate relationships
4. Deterioration

Description of the Cement

1. Composition especially presence of free CaO or MgO in undesirable amounts
2. Relative fineness
3. Identification of certain additives

Description of the Aggregate

1. Composition, grading, and quality
2. Identification of the type, kind, and source of the aggregate
3. Presence of coatings
4. Detection of contamination

TABLE 6.4 (cont.)

Identification of Certain Admixtures

1. Mineral admixtures
2. Pozzolans
3. Siliceous aids to workability

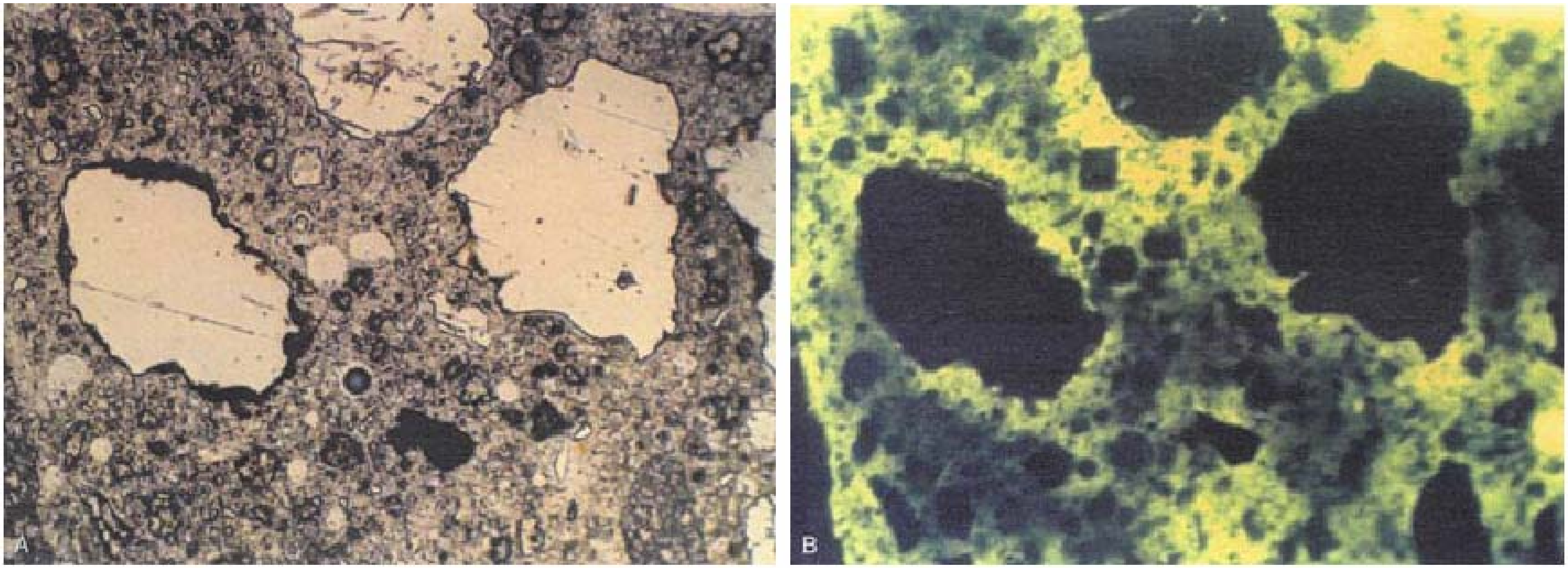
Evaluation of the Microscopic and Megascopic Void System

1. Air content of the concrete
2. Size and spacing of the voids in the cement paste

Determination of the Cause of Inferior Quality or Failure of Concrete

1. Cement-aggregate reaction
2. Attack by aggressive waters
3. Freezing and thawing
4. Unsound aggregate
5. Unsound cement, especially excessive free CaO and MgO
6. Inadequate proportioning, mixing, placing curing, or protection
7. Structural failure, abrasion, or cavitation

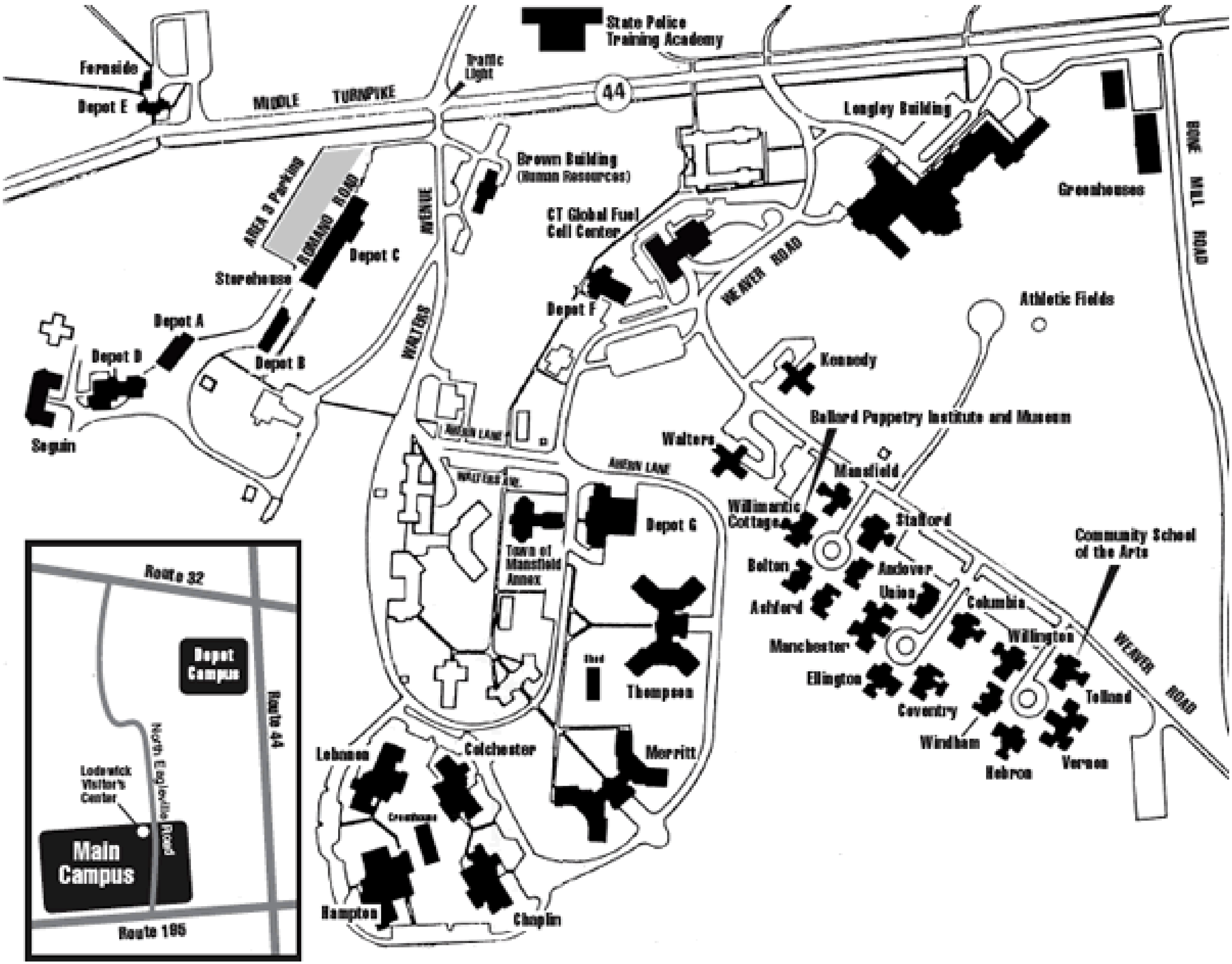
Determine the cause of Superior Quality and Performance of the Concrete



(A) (B)

THIN SECTION OF concrete FABRICATED WITH ANGULAR, DIRTY SAND. There are numerous reentrant angles. A. Viewed with plane polarized light. B. Same view as A with ultraviolet illumination causing fluorescence that delineates the pore structure. Notice the clumping of the cement grains, abundance of pores (shown by the fluorescence) at the edge of the sand, structure of the clay coatings, and general uneven texture of the paste. Such uneven texture indicates zones of weakness through the concrete.

Source: http://www.tfhrc.gov/pavement/pccp/petro/chaptr13.htm


State Police Training Academy
Fernside
Depot E
MIDDLE TURNPIKE
Traffic Light
44
Longley Building
Greenhouses
BONE MILL ROAD
Brown Building (Human Resources)
AREA 3 Parking
EDWARD ROAD
Depot C
WALTERS AVENUE
CT Global Fuel Cell Center
Storehouse
Depot F
WEAVER ROAD
Athletic Fields
Depot A
Depot B
Depot D
Kennedy
Seguin
AHERN LANE
Ballard Puppetry Institute and Museum
Walters
WALTERS LANE
Mansfield
Willimantic Cottage
Depot G
Town of Mansfield Annex
Stafford
Community School of the Arts
Bolton
Andover
Ashford
Union
Columbia
Manchester
Willington
Ellington
Shed
Thompson
Tolland
Coventry
Windham
Lebanon
Colchester
Merritt
Hebron
Vernon
Greenhouse
Hampton
Chaplin
Route 32
Depot Campus
Route 44
Lodewick Visitor's Center
North Eagleville Road
Main Campus
Route 195

http://web.uconn.edu/parking/Apartment%20Shuttle.pdf

CLAS: 9;16, 9:34

Brown Building 10:42

Readings:

Ch. 6

Homework:

Chapter 6, Problems:
Rock strength:
17, 18, 19
Concrete:
22, 24, 25

Homework problem solving example:

Problem 6.2

Confining pressure is the least principal stress σ_3 . The sample failed at 9000 psi means the uniaxial maximum principle stress loading reached 9000 psi. For case 1 we have: σ_3= 2000 psi, σ_1= 9000 psi;

For case 2 we have: σ_3= 5000 psi, σ_1= 21000 psi;

(a) See sketch; (b) ϕ = 36 degree, S_0= 400 psi; (c) τ_1= 2800 psi, τ_2= 6200 psi