Rocks and Soil as Construction Materials

Prof. Dr. Ziad Abu-Hamatteh
Faculty of Engineering Technology
Al-Balqa Applied University
Civil Engineering Department




Construction Materials

- Rocks, Weathered rock and Soils as Construction Materials, comprise two categories:
    - Hard rock-- requires blasting
    - Soft rock-- generally accessible by ripping.
- Quarried products fall into five classes:
    - Dimension stone - blocks with even surfaces and of regular size and shape;
    - Broken stone - blocks with irregular size and shape;
    - Crushed stone - crushed & screened material;
    - Gravel - particles >4.75 mm< 75mm; and
    - Sand - particles > 0.075mm< 4.75mm & naturally occurring. Also termed “Fine Aggregate”.
- Aggregates are mixtures of sand, gravel, crushed rock or any other mineral material.

Construction Materials

- Aggregates may be natural or synthetic.
- **DIMENSION STONE** :used little today apart from decorative facing and monumental work. Now largely replaced as construction material by concrete.
- Appearance is a major factor in facing stone choice. Reflects colour, texture and mineralogy of rock.
- Durability or resistance to weathering is a critical parameter.
- Presence of jointing controls the maximum size of quarried blocks. Too many joints destroys its use as dimensional stone.
- Most dimensional stone is igneous in origin, i.e.., granite, granodiorite, diorite or gabbro.
- Limestone, marble, calc-silicate hornfels, and sandstone may also be used. i.e., Helidon Sandstone, quartz sandstone with secondary quartz cement

Construction Materials

- **BROKEN STONE** :needs to be hard, strong, massive and durable.
  - While appearance is not a consideration, ability to interlock and shield structures is vital.
- **CONCRETE:**
  - Consists of cement paste + water + aggregate.
  - Combined in correct proportions, it is workable, strong, durable & low cost material.
  - Up to 75% aggregate, with approx. 25% cement paste +1-2% air.
  - As air % increases, concrete strength declines.
  - Aggregate reduces volume change effects during hardening, etc.
  - Aggregates mostly have compressive strengths between 70-300 M Pa, but concrete paste has a strength of 70 M Pa.

Construction Materials

- **Rock strength:**
  - Subject rock to three primary stress types:
    - **Compressive;**
    - **Shear; and**
    - **Tensile.**
  - Compressive stress decreases the volume of rock by inwardly-directed opposing forces.
  - Shear stress caused by two equal forces acting in opposite directions as a couple.
  - Tensile forces tend to pull a rock apart by outward-directed equally opposing forces.
  - Compressive strength (q_u) given by: $q_u = P/A$,
    where P = failure load and A= cross-sectional area.
  - Typical compressive strengths range from 1000 kPa for weak shales, to 280 MPa for basalt and quartzite.

Construction Materials

- **Deere and Miller (1966) classification:**
  - Proposed a five way classification of rocks based on ultimate strength.
  - A- very high strength, i.e., quartzite, dense basalt and dolerite;
  - B- high strength, i.e., most igneous rocks, stronger metamorphic rocks, limestone, dolomite, and well-cemented sandstone;
  - C- medium strength, i.e., shales, porous sandstone, mica schist;
  - D- low strength, i.e., friable sandstone, porous tuff, clay shale, rock salt;
  - E- very low strength, i.e., weathered and altered rocks.

Construction Materials

- **Abrasion Resistance:**
  - Commonly measured by Los Angeles abrasion test on aggregates;
  - 5 kg of aggregate (with specific size gradation) is loaded with a specified # of steel spheres into a steel drum containing an interior projecting shelf;
  - Drum rotated for 500 revolutions, and sample sized using a 0.141 mm sieve;
  - Ratio of fine material / original weight yields % loss;
  - maximum allowable abrasion loss for concrete aggregate and base courses is 35-50%.
- **Durability**:
  - A measure of an aggregate's ability to withstand deterioration due to wetting and drying; heating and cooling; freezing and thawing during use period.

Construction Materials

- Several tests, but most common are **Sulfate Soundness test** and **Freezing and Thawing tests** .
- Sulfate Soundness test involves soaking aggregate in saturated solution of sodium sulfate/ magnesium sulfate, followed by drying in oven.
- 5 cycles of soaking & drying performed, followed by sizing of the pieces using a specified sieve.
- Ratio of finer material /original weight yields Sulfate Soundness loss.
- Loss of 12-15% typical maximum allowable for concrete aggregates.
- Sulfate solution forms crystals on drying and these growing crystals exert a force on the internal pores of rock, tending to disrupt rock.
- Sulfate test is severe and qualifies as an accelerated test to reveal natural weathering effects in a reasonable time period.

Construction Materials

- Test is particularly destructive to clayey rocks & those with extremely coarse-grained textures. Clay-rich carbonates also.
- **Freezing and thawing test** similar with 25 freeze/ thaw cycles, and similar allowable loss % as Sulfate test.
- Water absorption of aggregates is another test used in their selection. A common maximum allowable absorption value is 5% for concrete aggregate. Higher absorption indicates non-resistant material.
- Final criterion is amount of weak constituents present in aggregate.
- **Weak materials include**:
  - Shale, Siltstone, Weathered clayey carbonates, Iron concretions, Friable sandstones, coal, low density cherts
  - All of these will loosen & fall out of concrete.
  - Hence a standard allowable % of deleterious material.

Construction Materials

- Other properties:
  - For large rock exposures relating to construction sites such as dam abutments, foundations of large dams, highway cuttings and tunnels.
  - Rock strength determined by nature of discontinuities /weakness planes
  - Important consideration is the attitude of the weakness planes relative to the exposed face, the continuity of the planes, their spacing and surface characteristics, extent of infilling by other materials and groundwater conditions.
  - Natural weakness planes include:
    - **Bedding**,
    - **Foliation**,
    - **Flow banding** in lava rocks,
    - **Joints, Faults, & Shear zones**.

Construction Materials

Road Construction:

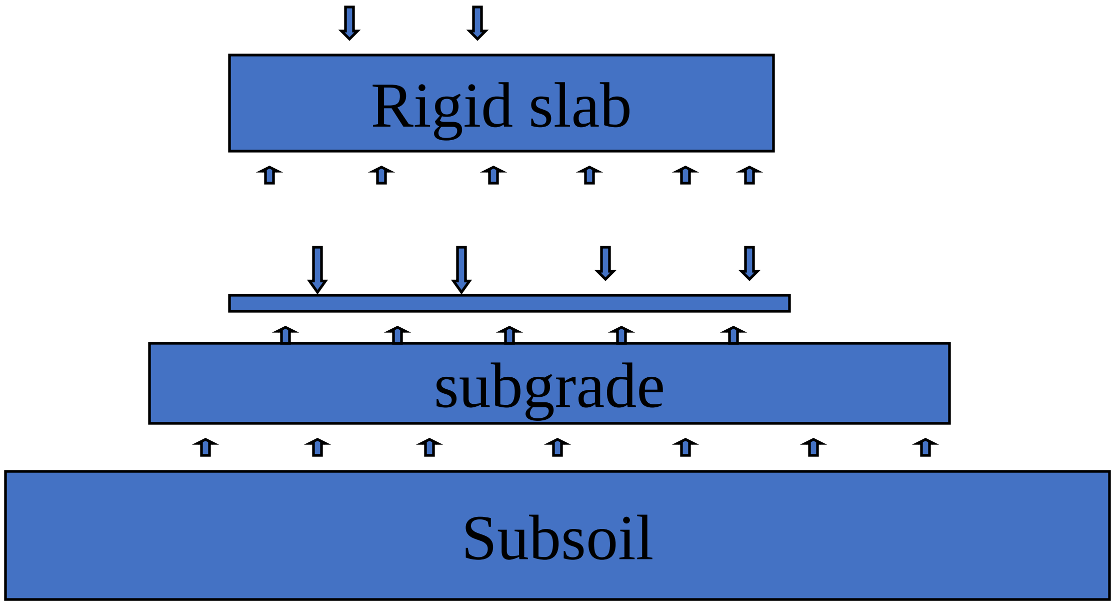
- Road surfaces range from natural “in place” materials, graded to support light traffic only, to ‘rigid pavements’ which have concrete slab sections over appropriate base materials.
- Many of Australia’s outback roads fit the first category.
- Few suburban freeways and roads fall into the latter group.
- The bulk of highways and roads in ‘settled areas’ are intermediate and consist of “flexible pavements”.

What is a pavement?

- A pavement consists of a “subgrade” or underlying material which transmits the load to the subsoil in a manner that is within it’s elastic limit. This avoids costly deformation of the wearing surface. It also enhances the vehicle ride characteristics.

Construction Materials

- Pavements can be divided into two broad categories:
  - **RIGID PAVEMENTS** - traffic loads are distributed by slab action to the subgrade;
  - **FLEXIBLE PAVEMENTS** - in which the vehicle loads are dispersed through a subgrade to the underlying soils in accordance with normal loading theory.



Construction Materials

- Flexible Pavements usually have crushed rock or natural gravels along with stabilising materials and asphalt as the wearing surface. These are the more expensive materials.
- Desirable properties for wearing surfaces are:
  - **Resistance to Abrasion and Wear** -- Must meet Los Angeles Abrasion Value and a requirement for 10% fines.
  - **Durability** -- Must be highly resistant to Physical & Chemical Weathering. Avoid any altered & weathered rocks. Use high hardness rock materials.
  - **Particle size** -- Usually restricted to single size .
  - **Particle shape** -- Select angular material that is approximately equidimensional.
  - **Porosity** --Always use low porosity material. Minimises the amount of asphalt required.
  - **Skid Resistance** -- Should present a rough appearance and texture and be resistant to polishing by traffic.