INVENTORY OF NEW ZEALAND AGGREGATES PROJECT

Philippa Black, Geology, SEGGS, University of Auckland
CONTEXT OF PROJECT

- Aggregate resources are finite / demand increasing
- Current NZ consumption c. 11 tonnes/person/year
- Poor planning has sterilized many aggregate resources adjacent to areas of demand - increasing transport costs
- Risk aversion culture - over specification of aggregate for many infrastructural projects
- A wide range of different rock types are used as aggregate.
- Poor understanding of materials properties of aggregates
- Some tests used in specifications appear not to adequately predict long term performance
INVENTORY PROJECT

- Initiated by Pavements Committee of Roading New Zealand Joint University of Auckland Geology / Civil Engineering project Funded by Foundation for Research Science and Technology

- Current North Island focus – collecting data on:
  - Rock type - geological/mineralogical properties
  - How rocks present in quarry: - gravel or hard rock; volcanic flow or lahar; mass rock slide
  - Source/production properties … (CI/PI & Crushing Strength)
  - Clustering of aggregates / quarries of similar nature and properties to show their regional distribution

- Geological work will extend in 2009 into South Island (NZ coverage)

- Aims to develop matrix of properties for each aggregate type to:
  - help understanding of their performance
  - Identify which tests need further research to relate geological, source and production properties, and aggregate performance (to 2014).
TYPES OF ROCKS

1. SEDIMENTARY = fragments weathered / broken off older rocks, water transported and deposited far from source GREYWACKE
   • Sediments turn into sedimentary rocks by precipitation of mineral cements and recrystallisation of matrix clay materials
   • Weakest part of a clastic sediment is the matrix enclosing the pebbles / sand / silt grains

2. IGNEOUS = formed from melt (lava) BASALTS, ANDESITES
   • Simple mineralogy (related to rock chemistry)
   • Some minerals start crystallising at depths (and grow large during lava ascent to surface); ascent time depends on fluidity
   • Grain size of rock matrix is a function of cooling rate. Very rapid cooling results in a glassy rock.
     • Mechanically weakest component & dominant component is feldspar (strongest component is glass) ... but ...
     • Glass is the most chemically reactive / easily altered component.

3. METAMORPHIC = rocks that have been “cooked” or “reheated” and often show foliation / schistosity.
TEXTURAL and other VARIATIONS

Each aggregate/rock type has materials source properties … related to its geological/mineralogical characteristics.

Quarry may exploit a single rock type, but its geological and engineering properties may change markedly at various locations within the quarry.

Rock property variations have a variety of origins:
- primary depositional (eg grain size) or other emplacement textures (eg flow fabric)
- post depositional (eg cooling or stress relief fracturing / jointing)
- penetrative deformational (foliation / schistosity)
- large scale disruption / dislocation of packets of rock (weakening adjacent rock)
- superimposed (eg weathering/oxidation/alteration) = mineralogical changes caused by introduction of water or other fluids.

Normal North Island weathering / leaching sequence of common aggregate source rocks first produces smectite. With prolonged leaching smectite >>>> kaolin.
GREYWACKES

- Backbone of New Zealand and our most important aggregate resource for hard rock and gravel quarries.

- Geologists use greywacke to include sandstones, siltstones and argillites and other rocks (cherts and volcanics) in basement sequence.

- Quarry people reserve the term for sandstones and siltstones.

- Sand and silt grains contained in greywackes are very variable - wide range of crystal & rock fragments - indicating a range of sources.

- Map shows greywacke types based on material properties important to their use as aggregates (eg crushing resistance, plasticity /clay index etc).
GREYWACKE QUARRIES – TYPES AND SOME CHARACTERISTIC FEATURES
Capes: metamorphosed, strong deformation foliation, negligible clay and plasticity indices.

Eastern North Is and Murihiku:

.. Sedimentary texture still obvious; nature of debris variable.

.. Clay-rich matrix: zeolite and smectite clay common. High plasticity and clay indices.

.. Murihiku weaker than Eastern NI.
Torlesse – Waipapa Greywackes:

- High crushing resistance, which is in the range of 10% fines at 300-400kN
- Crush to produce chunky angular - subangular fragments
- Low porosity and water absorption
- Torlesse and Waipapa differ in their detrital debris, chemistry and hence clay mineral content
- Volcaniclastic Waipapa clay mineral assemblage dominated by chlorite; plus minor smectite (CI low/variable)
- Quartz-Feldspar rich Torlesse has clay mineral assemblage dominated by illite (negligible PI and CI)
SWELLING CLAY MINERALS: a major cause of poor performance in some greywacke types

- Clays are sheet silicates: very weakly held together. Have high plasticity and high surface areas (Clay index)
- Smectite (swelling) clays have exchangeable interlayer cations which reversibly hydrate causing volume changes.

TEM images

\[
\begin{align*}
\text{Chlorite} & \quad 1.4 \text{ nm} \\
\text{illite} & \quad 1.0 \text{ nm} \\
\text{Smectite} & \quad 1.2 \text{ nm}
\end{align*}
\]
VOLCANIC ROCKS AS AGGREGATE RESOURCES

Simple mineralogy, but variable textures and glass content.
Lava flow type, mineral composition & physical properties: related to silica %
Volcanics erupted in marine environments have significant smectite contents.
Most quarries in single lava flow. Lahars (volcanic debris flows) also quarried.

Volcanic rocks important as aggregates  Pumice products
• Simple mineralogy (feldspar, augite, olivine, magnetite, glass)
• Each flow is an individual small pulse of lava (< 0.2 cubic km in volume)
• Considerable variation between lavas
• Eruptions cluster in time / place
• All erupted onto modern landscape so flows ponded / controlled by topography
• Non plastic, clean aggregates; negligible clay index (unless weathered).
• Feldspar is the dominant component and the weakest phase in basalt
• Feldspar and glass contents control strength of aggregate
• Fine grained very glassy basalts have high crushing strength - c. 10% fines at > 300kN (less than most greywackes)
• Feldspathic basalts: 10% fines @c250kN
YOUNG TERRESTRIAL BASALTS: NORTHLAND – AUCKLAND QUARRIES

Olivine basalt

Fine-grained basalt

Feldspathic basalt

Glassy basalt

Scale bar 500μm
OLDER BASALTS ERUPTED IN MARINE ENVIRONMENT

Major Northland resource; river gravels in East Cape area.
Sea water: Basalt reactions = zeolites + smectite alteration.

MOST NEED STABILISATION

Ocean Floor crust ‘ophiolite basalt’ – emplaced in large rock debris slides very variable material in quarries

West Volcanic arc basalts individual lava flows quarried

Marine flow basalt

Ophiolite Basalts: fragmental (L) and coarse gabbroic (R)

Pillow lavas

Brown = smectite
ANDESITES & DACITES
(ARC VOLCANISM)

COROMANDEL – BAY OF PLENTY

• Quarries in individual flows, mineralogically uniform, but rock texture, vesicularity and joint spacing may vary within flow.

• Glassy, fine grained andesites are strong (< 5% fines at 130kN); feldspathic rocks (> 5% fines)

• Silica-rich andesites associated with younger rhyolite flows often altered to smectite - *stabilisation*

Augite andesite .. Marine flow
brown = smectite

2-pyroxene fresh glassy andesite

Hornblende dacite
Matrix is quartz + feldspar intergrowth
TARANAKI ANDESITES: Quarries in lahars (volcanic debris flows) & river gravels; mixed andesite types. More alkali-rich than other North Island andesites. Crushing resistance 10% fines at c. 130 kN (often lower)

GRAVEL DEPOSITS: “river farming” Mechanically very strong and fresh Greywacke gravel aggregate crushing resistance ... 10% fines at c. 300 kN
SOME COMMENTS ON TESTS USED TO SPECIFY AGGREGATE FOR ROADING

1 : PSV values - Sealing Chips

- Aggregates with high PSV values often trucked long distances

- PSV test values depend on rock texture and mineral content but also on how the aggregate has been processed

- Experiments simulating polishing and directly measuring surface friction values indicate that ultimately chips of similar rocks (eg greywackes or volcanics) with variable start PSV values polish down to similar equilibrium values - although polishing rate varies

- Coarse grained greywackes with relatively weak or slightly weathered matrices (allowing abrasive hard grains to “escape” and refresh surface) have high PSV values …. But what about their other physical properties?
2 : Transit New Zealand’s specifications ( TNZ M/4 2006 ) for aggregates used as basecourse on state highways and heavily trafficked roadways require:

- Crushing Resistance – less than 10% fines passing 2.36mm at 130kN
- Weathering Quality Index – better than CB
- Pass California Bearing Ratio and Compaction Tests
- Either a sand equivalence of > 40, or a Clay Index of < 3, or a Plasticity Index of < 5
- Two or more broken faces (gravels v hard rock quarry origin)
- Particle size distribution to be within allowable envelope limits.

Crushing resistance has a dominating effect on four of above tests and is strongly related to geological / mineralogical properties.

Weathering Quality Index - very dependant on processing methods

Clay and plasticity indices - largely related to mineral content
SUMMARY

1. Geological properties (textures, grain size, mineralogy) are very variable regionally and set the upper limits for some important physical/engineering properties – better understanding needed.

2. Some physical properties dominate other properties – i.e. tests specified are often not independent

3. Processing methodology (i.e. equipment, sequence and number of circuits) will affect aggregate source and production properties. Operators prepared to bear the “cost” can process to provide an aggregate that meets specifications.

   Questions …
   – But is it fit for purpose?
   – How will it perform in the long term?

4. Much more fundamental research is needed on relationship between geological materials, engineering properties, and performance potential of aggregates.
THANKS

SPECIALY TO THE MANY QUARRY OPERATORS WHO PROVIDED SAMPLES, DATA, AND INSIGHTFUL PERSPECTIVES ON PRODUCING AGGREGATES!