High resolution monitoring of surface morphological change of building limestones in response to simulated salt weathering

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Catastrophic retreat of granular limestones

- The initiation of decay and measures of change

Weathering simulations and the assessment of decay?

Weight loss is a crude measure of deterioration that gives few insights into the nature of decay and generally precludes consideration of spatial variability

Spatial variability in the early stages of decay

- Weight loss alone provides little incentive to investigate structural controls; for example, initial porosity variations and bedding that are nonetheless clearly important in controlling patterns of decay.
- Indeed, this is generally precluded by test blocks that are smaller than the structures under consideration

Alternative measures of surface change?

Earlier attempts to quantify surface change of salt-weathered sandstones through repeated measurement with an engineer’s dial gauge has provided tantalizing glimpses of early change that look beyond total material loss.

Smith et al. 2002

Surface area change through experimental salt weathering of three sandstone blocks (43 cycles 10% MgSO₄)

- Problems with mechanical means of measuring surface elevation:
- Time consuming.
- Could damage surface.
- Requires interpolation between limited points.
Surface morphological change through experimental salt weathering of a large sandstone block (six cycles, Sat. Na₂SO₄)

The use of high definition laser survey to investigate early-stage weathering of granular limestones

- Previously used to monitor change on buildings
- Now being trialed to quantify spatial change during salt weathering simulations

3d object scanner – Worcester College, Oxford

Blocks of 5 limestones commonly used in Oxford artificially weathered in a salt spray cabinet

- Vertical: 20x15x10cm blocks,
- Laser scanned every 5 cycles,
- Plus weight loss
- 4 datum points

Weight loss by fall from unbrushed surfaces

Stoke Ground Base Bed after 110 cycles

Micro-scale heterogeneity

Scourform pattern of quartzite followed by rapid weight loss, then further stability.
Material loss starts with the 4 most uniform granular. Heterogenous Orange Hill shows delayed response, but greatest surface distortion.
Grange Hill after 110 cycles

- Meso-scale heterogeneity

Change in surface area of Grange Hill block

- 10-30% Exponential increase in surface area, swelling prior to structural failure.
- 30-70% Stability associated with limited disaggregation.
- >70% Significant, erratic, surface breakdown, flaking and scaling.

Change in free space below an artificially set datum for Grange Hill

- 0-10% decrease in free space as surface pores filled with salt. Seen in all 5 blocks.
- Followed by swelling and desorption of surface, periodic flaking and resultant pores.

Results from successive laser scans: Grange Hill

- 10 cycles
- 25 cycles
- 45 cycles
- 50 cycles

Laser scanning of test blocks in salt weathering simulations

- Surface topography of Cotswold limestone (Grange Hill) block after 80 cycles obtained by laser scanning.
- Note linear distortion across bottom of block and central ridge associated with bands of clay lenses.

Original surface porosity of Grange Hill measured by gas permeametry

- Note irregular band of high initial porosity across base of sample and centre right.
Detail of clay lenses in Grange Hill

- Structurally weak or high microporosity?
- Note high peripheral porosity associated with shrinkage.
- Facilitates salt solution penetration to depth?
- Delayed surface disaggregation but enhanced deeper sealed failure?

Laser scanning of test blocks in salt weathering simulations: Contoured

- Digital terrain model of block after 110 cycles, dark tones indicate higher relief.
- Distortion in bottom right indicates a gravitational element factored out in experiments that weather horizontal surfaces.

The reality of gravitationally influenced stone decay: spatial non-conformity is the norm

- Cotswold limestone, Oxford

Significance and opportunities for laser scanning

- Very sensitive to surface change, especially in the early stages of weathering.
- Can detect positive as well as negative change.
- Provides a range of indicative measurements.
- Allows a spatial dimension to analysis and correlation with controlling factors that is not possible with weight loss.
- Has demonstrated, for Grange Hill at least, the significance of meso-scale heterogeneities in dictating the initiation of decay – inclusions, intra-clasts, clay lenses, fossils, textural variability – that accords well with field observations.

Real world initiation of the decay

- Detailed lithological and structural controls on the initiation of decay, Oxford
- Punctual: internal heterogeneities

Next stage: blistering, Budapest
Where to now? Somewhere between expectation and frustration