

Hadrian's Wall (UK)

Description: One of the most impressive archaeological analogues is Hadrian's Wall (Figure 1). The Romans occupied Britain from the middle of the 1st century AD to the beginning of the 5th century and for much of this time northern England was the edge of their empire. In AD 122, Emperor Hadrian ordered the building of a wall from the Solway Firth in the west to the River Tyne in the east in order to separate the land of the Britons from the land of the Picts to the north. Hadrian's Wall was built from stone blocks cemented together, and when it was finished it was around 100 km long and 5 m high. Along the Wall are milecastles (small forts), watchtowers and larger fortresses. The Wall was manned continuously until it was abandoned in 383 AD.



Figure 1 Section of the remains of Hadrian's Wall, showing the Romans' stone block construction bound together with cement (from Miller et al., 2000).



Figure 2 Core through a section of mortar from Hadrian's Wall (from Miller et al., 2000).

After the 1745 Jacobite uprising, sections of the Wall were destroyed in order to use the stone for a military road, which would allow the King's troops to move quickly from east to west. Today, the best remaining sections of the Wall, at Housesteads in Northumberland, are only about 1 m high. Hadrian's Wall is now officially recognised and protected as a World Heritage Site.

Hadrian's Wall is of interest as an analogue because of the longevity of the cement binding together the stone blocks. This approximately 1800 year-old cement has some similarity with Ordinary Portland Cement (OPC), because it still contains substantial amounts of calcium-silicate-hydrate (CSH) compounds which give the mortar its strength and bonding properties (see Figure 2). The formation of the CSH compounds reduced the porosity and permeability of the cement, which helped to ensure the Wall's preservation for over eighteen centuries. Pozzolana aggregate had not been used in the Hadrian's Wall cement. Instead, the CSH phases were derived mostly from the calcination of siliceous limestones during the production of the lime and, to a lesser extent, by reaction of fine-grained reactive silica aggregate (Jull and Lees, 1990).

Below in Figure 2 is a photograph of part of Hadrian's Wall and a core through a section of the mortar showing its integrity after c.1800 years (from Miller et al., 2000). The Hadrian's Wall analogue is a good illustration of how well a cementitious surface structure can survive when exposed to a temperate maritime climate for nearly two millennia.

Relevance: The Hadrian's Wall analogue is mainly of illustrative value. It allows some broad qualitative conclusions to be drawn regarding the potential stability and longevity of modern cements used in a repository (Atkinson & Hearne, 1989).

The Wall's survival also illustrates the concept of potentially durable concrete barriers in a repository.

Position(s) in the matrix tables: The Hadrian's Wall analogue belongs to the Wasteform Cement-Physical Integrity box of the near-field matrix table. It could also belong to the Waste Package Concrete-Physical Integrity box and the Buffer/Backfill Concrete-Physical Integrity box in the same matrix table.

Limitations: The Hadrian's Wall analogue is restricted to a surface environment. The chemical and mineralogical properties of the Hadrian's Wall cement are not exactly equivalent to modern Portland-type cements.

Quantitative information: No quantitative data are associated with this analogue.

Uncertainties: Information on the cement durability lacks detailed knowledge of the original formulation of the cement.

Time-scale: The time-scale of the analogue is archaeological, spanning the period from when Hadrian's Wall was built (soon after 122 AD) to the present day i.e. about 1,880 years.

PA/safety case applications: Previous uses of the analogue study in a PA or safety case include BNFL's 2002 post-closure safety case for the Drigg LLW repository.

Communication applications: An interesting response from an NGO audience has been noted by UK Nirex Limited during a dialogue process. The pictures of Hadrian's Wall were interpreted as evidence for the durability of surface stores rather than for the durability of cement and concrete barriers in a geological repository.

References:

Atkinson A, Hearne JA (1989) The hydrothermal chemistry of Portland cement and its relevance to radioactive waste disposal. Nirex Report NSS/R187.

Jull SP and Lees TP (1990) Studies of historic concrete. CEC Nuclear Science and Technology Report EUR 12972, CEC, Luxembourg.

Miller WM, Alexander WR, Chapman NA, McKinley IG and Smellie JAT (2000) Geological disposal of radioactive wastes and natural analogues. Lessons from Nature and Archaeology. Waste Management Series, Volume 2. 2000 Pergamon. Elsevier Science Ltd., Oxford.

Added value comments: Added value may be gained by a presentation of the damage history of the Wall caused by direct human actions since it was abandoned c.1,620 years ago. This may increase the perception of the Wall's durability in the public eye when presented with images of sections that are still standing.

Potential follow-up work: It may be interesting to collect and analyse a cement core sample from the foundations of Hadrian's Wall which had suffered centuries of exposure to waterlogged conditions in order to allow comparison with modern cement used for a near-surface repository in a water-saturated environment.

Keywords: cement, concrete, durability

Reviewers and dates: Paul Hooker, Enviros Consulting (August, 2003)