

INTRODUCTION

This report describes the durability of Island Stone Façade Features and the basis for which the stone slips comply with Clause B2 of the Building Code.

METHODOLOGY

This report is based on research and investigation of the Island Stone Façade Features, the relevant Building Code requirements, the corrosion of stone and what this means for durability and Building Code compliance.

DURABILITY OF ISLAND STONE FAÇADE FEATURES

Island Stone Façade Features

Island Stone Façade Features are provided in a range of igneous, metamorphic and sedimentary natural stone slips. The slips are adhered to a weathertight substrate with a cementitious adhesive and, where necessary, mechanical fixings.

The weathertight substrate is either Island Stone Cladding Systems' Eterpan Support substrate installed over a cavity, or in situ concrete, masonry block (solid fill) or precast panels.¹

Building code requirement

Stone has been used as a building material in New Zealand since the colonial period. However, unlike early colonial stone buildings, contemporary stone generally either forms part of composite load-bearing walls or it is solely a decorative cladding material (New Zealand Stone Masons Association, 2020). The Stone Cladding Systems stone falls into the latter category.

As a building element, the Island Stone Façade Features are required to meet the durability requirements of the Building Code. Although a decorative element to the cladding system, Island Stone has decided that the durability requirements that apply to a cladding system will also apply to the Island Stone Façade Features.

Building Code Clause B2 sets out the durability requirements for building elements. Clause B2.3.1(b), which applies to claddings, states:

Building elements must, with only normal maintenance, continue to satisfy the performance requirements of this code for the lesser of the specified intended life of the building, if stated, or:

(b) 15 years if:

(i) those building elements (including the building envelope, exposed plumbing in the subfloor space, and in-built chimneys and flues) are moderately difficult to access or replace, or

(ii) failure of those building elements to comply with the building code would go undetected during normal use of the building but would be easily detected during normal maintenance.

Therefore, the Island Stone Façade Features must be durable for a minimum period of 15 years.

¹ Weathertightness of the concrete and masonry substrates to be achieved either through compliance with E2/AS3 or by specific weathertightness design.

Types of stone

Island Stones stone slips fall within one of the three major rock classes, which are based on how they were formed (GNS Science, n.d.):

- › Sedimentary rocks
- › Igneous rocks
- › Metamorphic rocks.

Sedimentary Rocks

Sedimentary rocks form from deposition and the joining together of particles mostly eroded from the surrounding area. Most of New Zealand's sedimentary rocks are mudstone and sandstone that were deposited beneath the sea. Some sedimentary rocks are formed from chemical precipitation, which is the formation of a solid from a solution, such as chert and certain limestones (GNS Science, n.d.). Sedimentary rocks include sandstone, limestone and dolomite.

Igneous Rocks

Igneous rocks form when molten rock from the Earth's crust moves towards or onto the surface and cools. Plutonic igneous rocks are formed at depth. Because they don't get erupted onto the surface they cool slowly and are coarse-grained. Volcanic igneous rocks are thrown out onto the land surface or beneath the sea and cool quickly to form fine-grained and sometimes glassy rocks, such as rhyolite, ignimbrite, pumice, andesite and basalt. Igneous rocks are also classified as acid, intermediate or basic, depending on the amount of silica they contain. Acid igneous rocks are usually light in colour, whereas the basic igneous rocks are darker (GNS Science, n.d.). Igneous rocks include granite, diorite and basalt.

Metamorphic Rocks

Metamorphic rocks are rocks that began as sedimentary or igneous rocks (or even previously metamorphosed rocks) and that have subsequently been recrystallized under conditions of high temperature and/or pressure. Many of the rocks found in New Zealand have been metamorphosed by being buried deep in the crust and then uplifted to the surface as the overlying rock has been eroded away (GNS Science, n.d.). Metamorphic rocks include slate, schist, gneiss and marble.

A new igneous, metamorphic or sedimentary stone can be developed from an existing stone by a repetition of melting and metamorphism or by the weathering, transportation, deposition, compaction and cementation processes (Natural Stone Institute, 2016).

Deterioration of stone

Much of the research on stone deterioration focuses on the deterioration of historic stone buildings. This is generally in terms of the classification of the types of decay and the measurement of the extent and severity for the purpose of remediating and protecting built heritage, as well as predicting the effects of climate change on historic stone buildings.

Various classification methods exist for the classification of types of weathering forms, such as the method established by Fitzner, Heinrichs & Kownatzki (1992) and the later UAS system established by Warke et al., (2003). Studies on weathering, drawing on the classification methods for types of weathering, typically focus on the examination and classification of nineteenth-century or older buildings (Best, 2011; Gil et al., 2015; Cardell et al., 2003).

Stone decay takes many different forms; it weathers away gradually leaving a sound surface behind, scales drop away in one go, the surface erupts, the stone loses integrity and crumbles

away (Price, 1996). The stones most likely to be affected by stone decay are stones quarried from sedimentary groups (limestones, sandstones) and metamorphic groups (marbles). Igneous stone does not normally show deterioration as in general, these stones have a more inert mineral composition, a lower water absorptivity and a greater hardness than stones from the other two groups (Sleater, 1973).

Soluble salts can be considered the factor that in general induces the most damage to stone and that can, in some instances, induce the fastest deterioration and be the primary cause of the loss of historic architecture (Charola, 2016; Oguchi & Yu, 2021). Salt weathering has been implicated as a cause of stone disintegration since between 500 BC and 400 BC and systematic investigations of salt weathering have been performed over at least 200 years (Oguchi & Yu, 2021).

Soluble salts accumulate in building materials over years, either because of capillarity, aerosol deposition or reactions of the stone with atmospheric pollutants (Flatt et al., 2014). Building stones with a high percentage of small or fine pores as well as some large or coarsely porous stone can be particularly susceptible to salt damage. These include many sedimentary rocks (such as some limestones and sandstones) as well as some granites (Gil et al., 2015).

Small amounts of salts can cause damage over a long period of time when the environment causes frequent cycles of crystallization and deliquescence over time (Godts, Hayen & Clercq, 2017). The consequences of crystallization pressure are feared because of their impact on monuments such as the Pharaonic constructions in Luxor, the carved city of Petra and the medieval city of Rhodes (Flatt, Caruso & Sanchez, 2014).

However, predicting the extent and rate of salt damage is challenging. The most widely used standard test, EN 12370.4, is limited as it relies on cycles of impregnation by full immersion of specimens in a sodium sulfate solution, followed by drying. This leads to damage during the re-wetting phase. This test is not considered to be representative for most situations found in real life because of the contamination procedure, the extreme salt load and drying temperature. Other laboratory salt weathering tests have been performed; but their outcomes also depend on laboratory test conditions, so the ability to obtain reliable results from accelerated ageing is unresolved (Flatt et al., 2017).

COMPLIANCE WITH B2.3.1(B)

Exposure to natural weathering causes deterioration to stone over time. The complexities of deterioration processes and the impact of specific environmental conditions mean it is difficult to predict how quickly stone will decay. It is also difficult to obtain reliable results from accelerated ageing for key environmental processes.

However, the research on stone decay focuses on the gradual deterioration of historic stone buildings, and it is clear from the literature that decay generally occurs over extremely long periods of time.

The Stone Cladding Systems' Island Stone Façade Features are decorative elements of stonework that, unlike the historic stone buildings that are the focus of the literature, are not part of the primary structure. In addition, the Island Stone Façade Features are installed to a weathertight external envelope so do not impact the building's ability to resist penetration of moisture, other than providing additional protection to the cladding from environmental elements.

Therefore, the Island Stone Façade Features will readily meet the minimum 15-year durability period required by the Building Code.

REFERENCES

- Best, J. (2011) *Condition Assessment of Building Stone in Palma*. Available from: <https://storymaps.arcgis.com/stories/f409d26a428e4f868b619c7cc9e95180> [Accessed 22/09/2021].
- Cardell, C., Delalieux, F., Roumpopoulos, K., Moropoulou, A., Auger, F., Van Grieken, R. (2003) Salt-induced decay in calcareous stone monuments and buildings in a marine environment in SW France. *Construction and Building Materials*. 17, 165-179.
- Charola, E. (2016). *Stone Deterioration Characterization for its Conservation*. Available from: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKewjgho_E86DzAhU9wzgGHfJSAyEQFnoECAYQAQ&url=https%3A%2F%2Frepository.si.edu%2Fhandle%2F10088%2F34484&usg=AOvVaw0lBnNDFV8nA3BWVZCcD0Ww [Accessed 22/09/2021].
- Fitzner, B., Heinrichs, K., Kownatzki, R. (1992) Classification and mapping of weathering forms. *Proceedings of the 7th International Congress on Deterioration and Conservation of Stone*. 15-18 June, Lisbon. 1992; Vol. 2: 957-968.
- Flatt, R., Caruso, F., Sanchez, A., Scherer, G.W. (2014) Chemo-mechanics of salt damage in stone. *Nature Communications*. 5 (4823). Available from: <https://doi.org/10.1038/ncomms5823> [Accessed 22/09/21].
- Flatt, J., Mohamed, N.A., Caruso, F., Derluyn H., Desarnaud, J., Lubelli, B., Espinosa-Marzal, R.M., Pel, L., Rodriguez-Navarro, C., Scherer, G.W., Shahidzadeh, N., Steiger, M. (2017) Predicting salt damage in practice: a theoretical insight into laboratory tests. *RILEM Technical Letters*. 2, 108-118. Available from: <http://dx.doi.org/10.21809/rilemtechlett.2017.41> [Accessed 22/09/21].
- Gil, E., Mas, A., Lerma, C., Vercher, J. (2015) Exposure Factors Influence Stone Deterioration by Crystallization of Soluble Salts. *Advances in Materials Science and Engineering*. 2015, (348195). Available from: <https://doi.org/10.1155/2015/348195> [Accessed 22/09/21].
- GNS Science. (n.d.) *Rock types*. Available from: <https://www.gns.cri.nz/Home/Learning/Science-Topics/NZ-Geology/Rock-Types> [Accessed 22/09/2021].
- Godts, S., Hayen, R., De Clercq, H. (2017) Investigating salt decay of stone materials related to the environment, a case study in the St. James church in Liège, Belgium. *Studies in Conservation*. 62 (6), 329-342. Available from: <https://doi.org/10.1080/00393630.2016.1236997> [Accessed 22/09/21].
- Natural Stone Institute. (2016) The Geology of Stone. *Dimension Stone Design Manual*. Version VIII. Available from: <https://pubs.naturalstoneinstitute.org/pub/2BBAC4C9-9976-207C-CDB9-34962DC40706> [Accessed 22/09/2021].
- New Zealand Stone Masons Association. (2020) *New Zealand Stone Masons Association Best Practice Guide*. Available from: <https://www.nzsma.co.nz/wp-content/uploads/2020/05/Code-of-Practice-2020.pdf> [Accessed 22/09/2021].
- Oguchi, C.T. & Yu, S. (2021) A review of theoretical salt weathering studies for stone heritage. (2021) *Progress in Earth and Planetary Science*. 8 (32). Available from: <https://doi.org/10.1186/s40645-021-00414-x> [Accessed 22/09/2021].
- Price, C. (1996) *Stone Conservation, An Overview of Current Research*. Available from: https://www.getty.edu/conservation/publications_resources/pdf_publications/pdf/stoneconservation_1st.pdf [Accessed 22/09/2021].
- Sleater, G. (1973) *A review of Natural Stone Preservation*. National Bureau of Standards. NBSIR

74-444. Available from: <https://www.govinfo.gov/content/pkg/GOVPUB-C13-8e26f4f472aaeb6f99c42af7f15db44a/pdf/GOVPUB-C13-8e26f4f472aaeb6f99c42af7f15db44a.pdf> [Accessed 22/09/2021].

Warke, P.A., Curran, J.M., Turkington, A., Smith, B. (2003) Condition assessment for building stone conservation: a staging system approach. *Building and Environment*. 38 (9-10), 1113–1123.