

Evaluation of cementitious adhesive performance

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Introduction

Island Stone (NZ) Façade Features, supplied by Stone Cladding Systems, are a range of igneous, metamorphic and sedimentary natural stone slips. The slips¹ weigh between 28 kg/m² and 100 kg/m², depending on the type of stone. The slips are adhered to a weathertight substrate (such as concrete with a weathertight coating, concrete block or fibre cement) with a cementitious adhesive and, where necessary, mechanical fixings. The cementitious adhesive must have satisfactory strength and adhesive bond to withstand all foreseeable loads.

Methodology

This report evaluates the compliance of the cementitious adhesive with Clauses B1 and B2 of the Building Code based on the performance of cementitious adhesive² used with Island Stone (NZ) slips and concrete, concrete block or fibre cement substrate.

Building Code compliance

Building Code obligations with respect to Clause B1 Structure and Clause B2 Durability apply to the Island Stone (NZ) Façade Features system which includes the cementitious adhesive. This means that the adhesion of the stone slips must be able to withstand all foreseeable loads and physical conditions and be durable, for a period of 15 years.

Cementitious adhesives are not covered in any Acceptable Solution and Verification Method, so compliance with Building Code Clauses B1 and B2 must be demonstrated by way of alternative solutions. It is assumed that compliance with BS EN 12004-1:2017 establishes compliance with B1 and B2.

BS EN 1200-1:2017 is the harmonised standard that specifies performance criteria for cementitious adhesives for internal and external applications of tiles and stones.

ISO 13007-1:2014 is the international ISO standard for grouts and adhesives for ceramic tiles that adopts the basic requirements from the EN 12004 suite of standards. As the ISO 13007 adopts the requirements from the EN 12004 suite, for the purpose of this analysis, the requirements of BS EN 12004-1:2017 are used (and referred to as EN 12004-1). The test methodologies for the standards are contained in BS EN 12004-2 and ISO 13007-2.

Independent testing has also been carried out by CSIRO on the tensile strength of the Island Stone (NZ) Façade Features system when adhered to a fibre cement substrate (CSIRO, 27/09/2007). This evaluation analyses these results and then compares them with the performance requirements of EN 12004-1 to determine the adequacy of this performance with respect to compliance with Building Code Clauses B1 and B2.

Definition and use of cementitious adhesive

EN 12004 defines a cementitious adhesive as 'a mixture of hydraulic binding agents, aggregates, or organic additives, mixed with water or liquid admix just before use'.

The component of the cementitious adhesive dry mix which reacts with water to form a strong solid (the process of hydration) is the hydraulic binding agent. However, this doesn't actually have any stickability to the natural stone or concrete substrate. That is, it doesn't have any natural bonding agents for adhering to the already hardened substrate.

A primary mechanism by which the cementitious adhesive bonds to the natural stone and substrate is by the bonded materials having a rough surface so the wet adhesive is pushed into the small holes and crevices (Royal Society Te Apārangi, n.d.).

¹ Stone slips are defined as a thin layer of stone that is used aesthetically as a form of surface finish rather than structurally.

² Refer to the Island Stone (NZ) Façade Features pass™ for compliance of the stones slips.

To further increase the bond strength or 'stickability' of the cementitious adhesive to the stone or substrate, specialised bonding agents or additives are added into the cementitious adhesive mix (Dynamic Concrete Pumping, 27/02/2020).

When assessing the performance of a cementitious adhesive in relation to bonding to a natural stone tile and a substrate, the key influences on the tensile strength (adhesive bond strength) are:

- the material, density, surface finish and dimensions of the stone tile
- the type of adhesive used
- the material and surface finish of the substrate used
- the environmental conditions the assembly is subject to.

EN 12004 Characteristics

EN 12004 classifies cementitious adhesives as C1 or C2 and S1 or S2, with additional classifications for extended open time (E) and vertical slip (T). C2 adhesives are improved adhesives that often include modified polymers, resulting in increased adhesion and bond strength as well as water repellent characteristics (TileFix, 08/12/2020). S1 and S2 are related to the elasticity/deformability of the adhesion bond with S2 classification being a highly deformable adhesive.

In terms of specifics, EN 12004 requires the following for C2 and S2 adhesives:

Table 1 – Requirements for cementitious adhesives

Basic characteristics		
Characteristic	Requirement	Test method
High initial tensile adhesion strength	≥ 1 N/mm ²	
High tensile adhesion strength after water immersion	≥ 1 N/mm ²	
High tensile adhesion strength after heat ageing	≥ 1 N/mm ²	EN 12004-2:2017, 8.3
High tensile adhesion strength after freeze-thaw cycles	≥ 1 N/mm ²	
Open time: tensile adhesion strength	≥ 0.5 N/mm ² after not less than 20 minutes	EN 12004-2:2017, 8.1
Highly deformable adhesive: transverse deformation	≥ 5 mm	EN 12004-2:2017, 8.6
Slip	≥ 0.5 mm	EN 12004-2:2017, 8.2

Clause 3.5.1 gives the definition of *adhesion strength* to be 'maximum strength per unit surface area which can be measured by shear or tensile testing'. There is no test for shear strength for cementitious adhesives in EN 12004-2:2017. It should be noted that EN 12004-1 does not distinguish between the shear direction and normal (perpendicular) direction when assessing the tensile strength of cementitious adhesives and assumes them to be equal. Reaction to fire requirements is also specified, based on the class in accordance with EN 13501-1.

Island Stone (NZ) Façade Features testing

Independent testing was carried out by CSIRO (CSIRO, 27/09/2007). CSIRO is National Association of Testing Authorities (NATA) accredited. The testing was to ISO 13007-2:2005, which was the applicable ISO test methodology at the time of testing and adopted the requirements from EN 12004-2.

The testing was for tensile strength and tested the strength required to break and cause failure of a stone fixed to a substrate using a cementitious adhesive. The substrate used in the testing was Eterpan fibre cement sheet substrate.

The cementitious adhesive used in the testing, Mapei Kerabond Plus with Isolastic Neat additive, is classified as a C2TES2 cementitious adhesive in accordance with EN 12004.

The CSIRO testing differed from EN 12004-2 as follows:

- 2500 mm² EN 14411 Group BIII complying tiles substituted with schist Island Stone (NZ) Façade Features from 3304 mm² to 5483 mm². Island Stone (NZ) Façade Features are a range of igneous, metamorphic and sedimentary natural stone slips and are within the scope of tiles or stones defined by EN 12004 as those made out of ceramic or natural and agglomerated stones
- concrete slab substrate substituted with an Eterpan fibre cement sheet substrate.

The tensile testing conducted tested tensile strength after allowing the stone to bond to the substrate after simulated weathering or ageing. The environments tested were:

- water immersion—20 days immersed in water
- heat — 14 days at 70 °C
- freeze/thaw cycles—21 days immersed in water followed by 25 cycles of 2 hours in -15 °C air then in water to maintain a temp of 15 °C for 2 hours.

The testing demonstrated that the cementitious adhesive tested, adhered to Island Stone (NZ) Façade Features and the fibre cement substrate had a tensile strength of 0.36 N/mm² or 0.36 MPa after ageing.

This tensile strength (and therefore shear strength as per the EN 12004 assumption of equality) means that it can support an allowable mass³ of stone of 9000 kg/m². While there will also be a bending moment associated with the Island Stone (NZ) Façade Features, given the maximum thickness of the stone is only 40 mm, this is deemed to be negligible.

Comparing the maximum weight per m² of the Island Stone (NZ) Façade Features of 100 kg/m² with the allowable mass demonstrated by the testing of 9000 kg/m², shows the bond achieved by the tested cementitious adhesive and substrate exceeds the strength required to support the stone slips by a significant margin.

In addition, the tested fibre cement substrate is smooth and nonporous and represents the worst case in terms of the mechanism for creating an adhesive bond between the substrate and cementitious adhesive. This means that the allowable mass is a conservative figure for other substrates.

The overall fixing of the stone to the substrate will likely fail at the substrate layer, rather than the stone layer; however, this will not occur until a tensile force of 0.36 N/mm² is exceeded.

Conclusion

The testing demonstrates that cementitious adhesive classified as C2TES2, that meets the performance requirements of EN 12004, when used to adhere Island Stone (NZ) Façade Features natural stone slips to a concrete, concrete block or fibre cement substrate, will have sufficient strength and adhesive bond to withstand all foreseeable loads for the weight per m² of Island Stone (NZ) Façade Features, with a significant redundancy margin.

On this basis, the system complies with the requirements of the Building Code with respect to Clauses B1 Structure and B2 Durability.

³ Based on a 40 m/s² maximum acceleration and $F = ma$ and ensuring the force doesn't exceed the 0.36 N/mm² tensile strength.

References

CSIRO. (27/09/2007) Determination of Tensile Adhesion Strength to Fibre Cement Board. Test Report No. 4057.

Dynamic Concrete Pumping. (27/02/2020) *Guide to concrete adhesion*.

Retrieved from <https://www.dcpu1.com/blog/guide-to-concrete-adhesion/> [Accessed on 23/09/2021].

Royal Society Te Apārangi. (n.d.) *How does cement stick bricks together*.

Retrieved from <https://www.royalsociety.org.nz/150th-anniversary/ask-me-questions/how-does-cement-stick-bricks-together> [Accessed on 23/09/2021].

TileFix. (08/12/2020) *Know your ceramic and porcelain cement based adhesives*.

Retrieved from <https://www.tilefixdirect.com/blog/2020/12/know-your-ceramic-and-porcelain-cement-based-adhesives/> [Accessed on 23/09/2021].