ACM

'Redefining Green'

E-Crete™

Engineering Properties and Case Studies

January 2014

Contents

1 What is E-Crete™?

E-Crete™ is a concrete that is not based on traditional Ordinary Portland Cement, instead it uses low CO_2 emission materials to replace cement resulting in an 80% reduction in emissions from the cementitious components. E-Crete™ 'Geopolymer' binder is made from a blend of fly ash and blast furnace slag, with combinations of commercially available, alkaline activating components including silicates, carbonates, hydroxides and aluminates. E-Crete™ meets all of the performance requirements of standard N-Grade concretes under AS 1379.

2 ACM and E-Crete™

Aurora Construction Materials (ACM) aims to set new standards in the manufacture and supply of sustainable construction materials. Since 2009 ACM has manufactured E-Crete™ from its high profile concrete batch and crushing facility in Epping, Victoria.

ACM combines the E-Crete™ binder with up to 100% reclaimed stone from subdivision works and up to 100% recycled water from storm water run-off and concrete agitator wash out, resulting in mix designs with exceptionally low virgin material and embodied emissions compared to traditional concretes.


3 What are the benefits?

- *Reduced carbon footprint, virgin material use and embodied energy.*

  E-Crete™ binder is 80% less emission-intensive than traditional blended cements according to independent testing commissioned by the Victorian Government and undertaken by Netbalance, Australia in 2007 and again independently verified by Start2See, Australia in 2012 (Figure 1). Production of alkali-activators is of similar emission-intensity to Portland cement, but because activators are only a small proportion of the mix, they do not contribute substantially to the overall emission intensity of the binder.

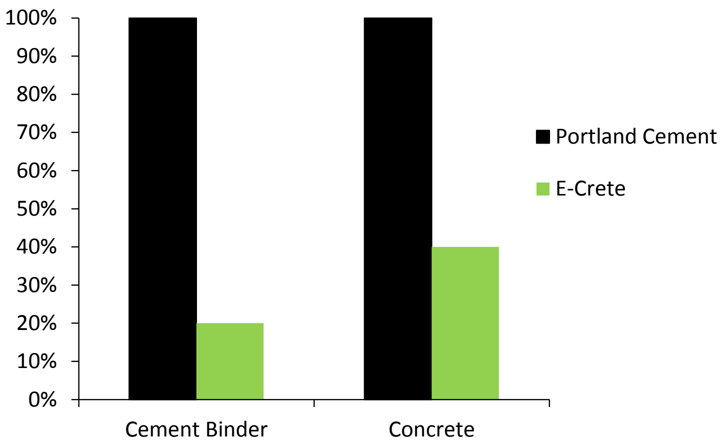


Figure 1: Percentage reduction of CO_2 emissions for E-Crete™ compared to OPC

- *Improved sustainability*

  Fly ash and slag are industrial by-products that are commonly used for low-value purposes or landfill. Fly ash is the byproduct of coal-fired electricity generation and is readily available in regions with significant coal-fired energy production. Slag is the by-product of iron production.

  E-Crete™ is capable of meeting Green Star Concrete Credit performance criteria and contributes towards earning points needed for Green Star certification.

- *Equivalent compressive and flexural strength*

  Pre-mix and pre-cast concretes made of E-Crete™ are designed to have equivalent performance outcomes to traditional concrete.

- *Superior resistance to aggressive chemicals including chlorides and sulphates*

  E-Crete™ has been shown as part of the Victorian Science Agenda (a program sponsored by the Victorian Government) to have better acid resistance than traditional OPC concrete. This makes E-Crete™ preferential for acidic environments such as water treatment processes and marine environments.

- *Enhanced fire resistance*

  E-Crete™ has been shown to have significantly better fire retardant properties than traditional concretes. Independent reports prepared by The University of Melbourne have demonstrated that E-Crete™ has over twice the fire resistance of traditional OPC concrete.

4 Use of E-Crete™ in Footings, Slabs and Paving

E-Crete™ has been used extensively in slab and pavement works. E-Crete™ has been successfully use to replace traditional concrete in applications including footpaths, driveways, general ground works, pre-cast panels, pipes, pits, kerb and channel, house slabs, retaining walls, pavers and slab on ground. See the case studies for further information.

5 VicRoads Approved

E-Crete™ is approved for general concrete paving and non-structural use in footpaths and kerb and guttering by VicRoads specification (Section 703). Projects have been completed using all grades of VicRoads concrete ranging from 20MPa to 55MPa. See the Case Studies section for further examples.

6 The need for low carbon emission cements

Portland cement based concrete is the most widely used construction material and is second only to water as the most used commodity by mankind today. Global cement production is an estimated 2.6 billion tonnes and contributes between 5-8% of global man made CO_2 emissions. Forecasts undertaken in 2006 predicted that cement production will grow to 5 billion tonnes by 2030. This projected growth is driven by rapidly increasing demand for advanced civil infrastructure in China, India, the Middle East and the developing world.

In 2005 cement production (total cementitious sales including OPC and OPC blends) had an average emission intensity of 0.89 with a range of 0.65 to 0.92 tonnes CO_2 per tonne of cement. Emissions are released primarily during clinker manufacture, in which limestone is calcined according to the reaction $CaCO_3 \Rightarrow CaO + CO_2$, releasing carbon dioxide. The reaction also requires kiln temperatures over 1,400°C, which releases CO_2 from the combustion of fossil fuels for energy. There is somewhat limited scope for improvement, with adoption of best practice (increased energy efficiency in production, improved use of blended cements and introduction of carbon capture systems etc.) estimated to be able to reduce average emissions to 0.53 tonnes CO_2 per tonne of cement by 2050.

The increasing focus on global warming, changing public and consumer preferences for "green" products, and the associated markets in carbon credits, has made a strong case for the use of alternative cements. These binding systems provide the only viable direct opportunity for near term and substantial CO_2 emissions reduction.

7 E-Crete™ performance comparison with traditional concrete

When compared with traditional concretes of the same compressive strength specification, E-Crete™ performs the same as, or better than these concretes across key performance requirements.

Table 1: Summary of performance of E-Crete™ when compared with traditional concretes

Performance measure	Summary of performance when compared with traditional concretes
Compressive Strength (28 Days)	Designed for equal performance to traditional concretes
Set time	Designed for equal performance to traditional concretes
Drying Shrinkage (up to 56 days)	Improved by 20-50%
Flexural Strength	Better than traditional concretes
Chloride Diffusion	Better than traditional concretes
Acid Resistance	Better than traditional concretes
Water Permeability	Equal performance with traditional concretes
Fire Resistance	Better than traditional concretes

7.1 Compressive Strength

E-Crete™ has been manufactured out of a number of concrete batch plants and a vast number of commercial projects have been completed. Concretes of grades 20, 25, 32, 40, 55 and 70 MPa have been successfully produced and compressive strength has been measured in accordance with Australian Standard AS 1012.9. An example of a compressive strength profile for each grade is shown in Figure 2 below.

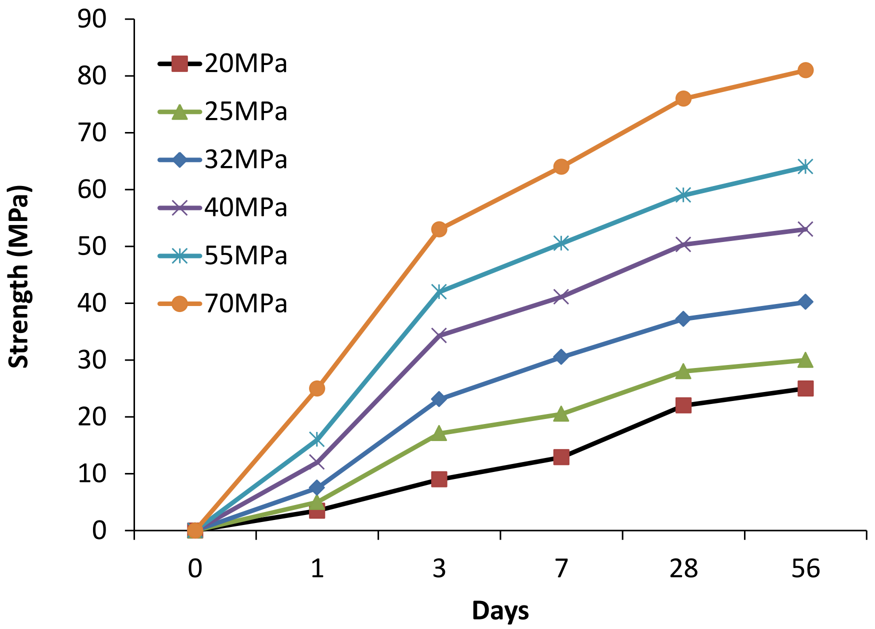


Figure 2: Compressive strength profile of different grades of E-Crete™

7.2 Set Time and Heat of Hydration

The heat of reaction of E-Crete^{TM} and cement pastes has been measured using a TAM Air calorimeter. Heat flow measurements as shown in Figure 3 clearly demonstrate that E-Crete^{TM} has a significantly reduced (approximately half) total heat of reaction of Portland cement. Set time can be adjusted according to customer requirements with formulations 1 to 3 indicating the capability to accelerate and retard set time.

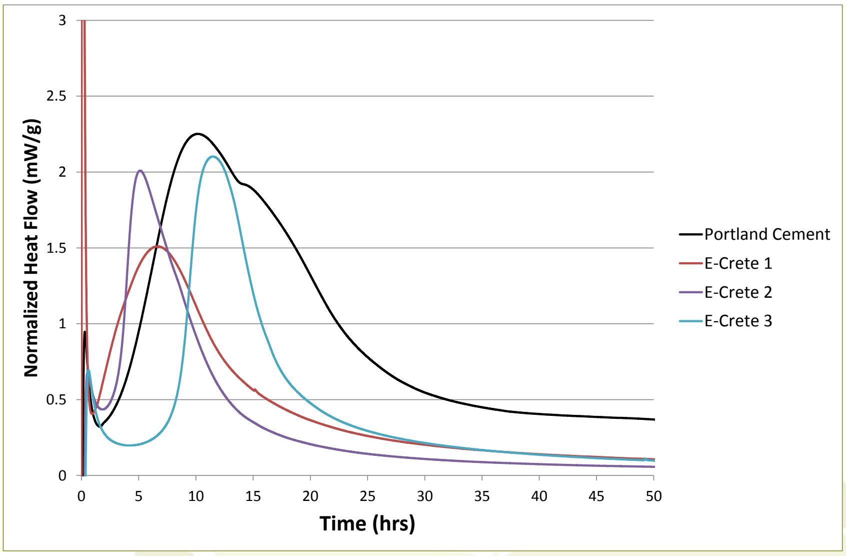


Figure 3: Calorimetry data for E-Crete binder and Cement binder at 25°C

7.3 Drying Shrinkage (up to 56 days)

The drying shrinkage of blended Portland cement based concrete and E-Crete^{TM} was measured in accordance with Australian Standard AS 1012.13; the results are shown Figure 4. The drying shrinkage of E-Crete^{TM} was significantly lower, approximately 400 (microstrain) for E-Crete^{TM} compared to 520 (microstrain). Both concretes meet the performance requirement of 600 (microstrain) at 56 days for pre-cast concrete in Australia.

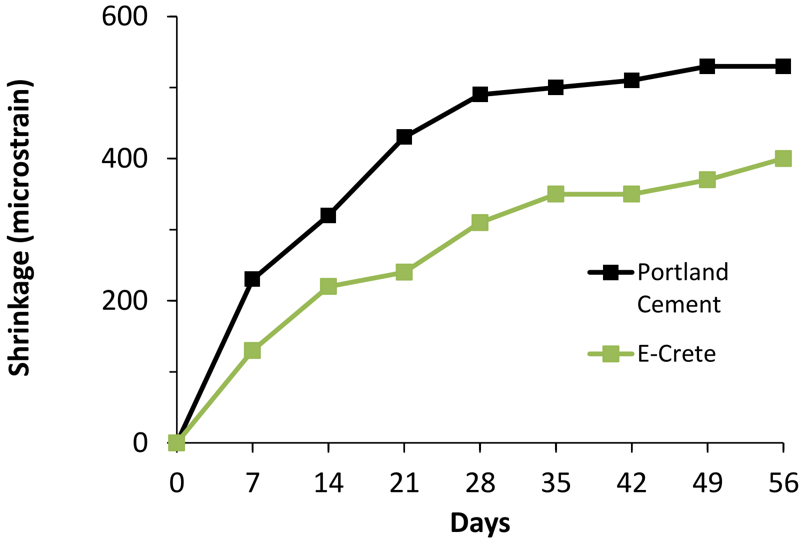


Figure 4: Drying shrinkage (microstrain) of Portland blended cement and E-Crete concretes

7.4 Flexural Strength

The flexural strength of E-Crete^{TM} has been measured, for a number of applications, in accordance with the Australian Standard AS 1012.8.2-2000. In general E-Crete^{TM} significantly outperforms Portland cement based concrete for flexural strength measurements. For this application with both materials containing synthetic fibres, E-Crete^{TM} was shown to exceed the minimum flexural requirements and be vastly improved over its Portland cement counterpart (Figure 5).

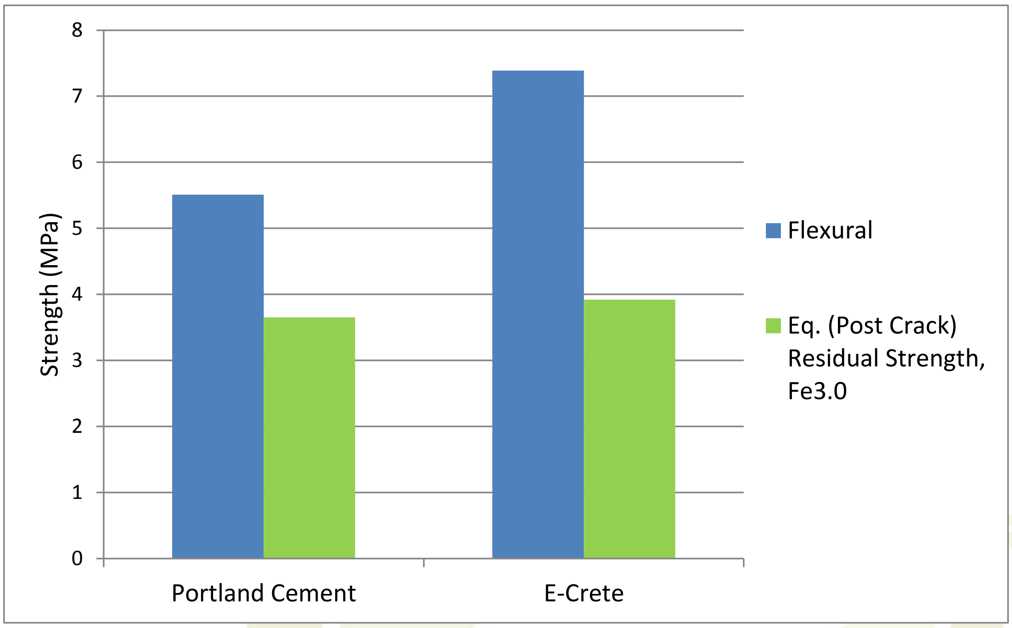


Figure 5: Flexural strength and equivalent residual flexural of fibre reinforced blended cement and E-Crete concretes. The blue indicates the flexural strength limit and orange indicates the residual strength Fe3.0 limit

7.5 Chloride Diffusion

E-Crete^{TM} and a standard Portland cement concrete were prepared using the same sand and aggregates with a specified 40MPa compressive strength. The chloride diffusion coefficient was measured by the NT Build 492 method at an independent laboratory, Pelcon Materials and Testing Aps in Denmark. As shown in Table 2, the chloride migration coefficient of E-Crete^{TM} was orders of magnitude lower than that of the Portland cement sample.

Table 2: Chloride diffusion coefficient (m^2/s) as per NT build 492 – 40MPa Concrete

	E-Crete^{TM} 1	**E-Crete^{TM} 2**	**Portland cement concrete**
Diffusion Coefficient ($\times 10^{-12}$ m^2/s)	1	1.3	26.6

7.6 Acid Resistance

Cylindrical samples of 150mm diameter × 100mm thickness of concrete were cast for exposure to sodium chloride and sulphuric acid.

7.6.1 Sodium Chloride Exposure

Samples were fully immersed in a 5wt% NaCl aqueous solution. After 1 year of exposure a cylindrical sample was removed and the chloride depth measured by an independent laboratory. A concrete sample was obtained by profile grinding to incremental depths. The mass percentage of chloride within the concrete was determined by dissolving a sample in hot nitric acid and performing a titration for chloride ions. A graphical representation of the ion profile can be seen in Figure 6 and demonstrates that E-Crete^{TM} significantly outperforms the Portland cement concrete for chloride penetration.

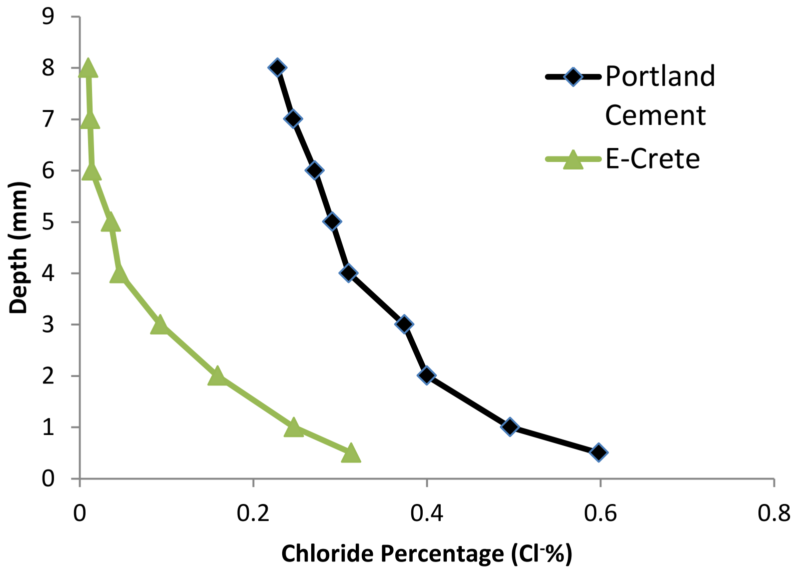


Figure 6: Profile of Chloride percentage for Blended cement and E-Crete in 5 wt% Sodium Chloride

7.6.2 Sulphuric Acid Exposure and Abrasion Resistance

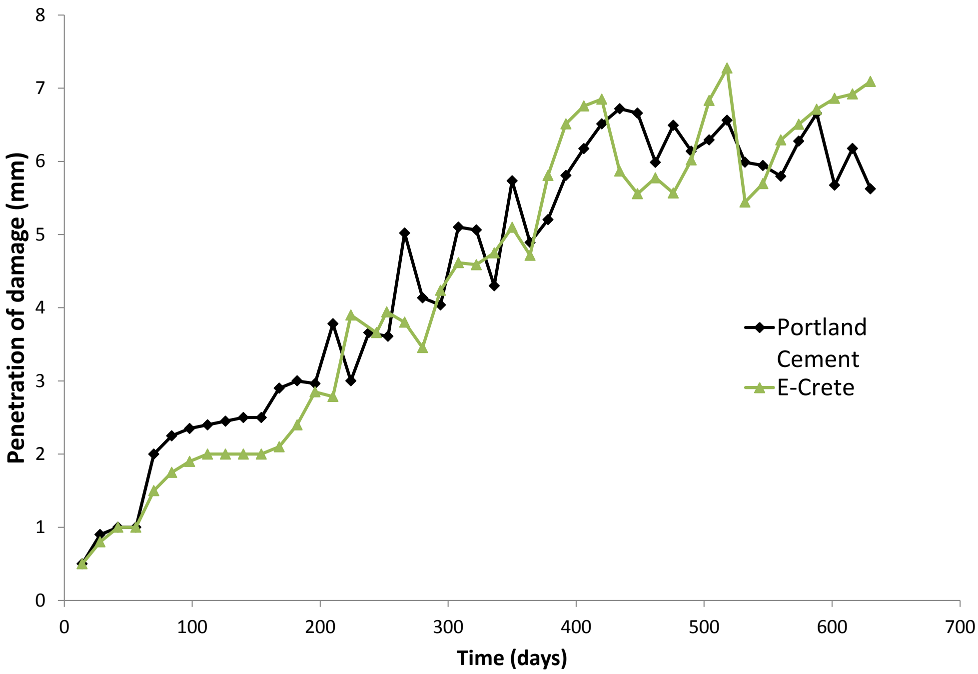


Figure 7: Depth of abrasion damage for Blended cement and E-Crete in sulphuric acid

Samples were fully immersed in a pH 2 sulphuric acid solution. The pH of this solution was maintained at 2, throughout the experiment, by the further addition of sulphuric acid. Every two weeks the samples were removed and a controlled abrasion was applied to the exposed surfaces. The resulting depth of damage was measured and is shown in Figure 7, indicating equivalent performance of E-Crete^{TM} to Portland cement concrete.

7.7 Fire Resistance

Six (five pilot-scale, 1200×1200×150mm and one full-size, 3300×3300×150mm) E-Crete^{TM} panels have been fire tested and were subjected to the Standard Time-Temperature Curve (STTC) heating profile as specified in ISO834 Standard. The furnace facilities were operated by Victoria University.

The exterior face temperature of the full size panel at the conclusion of the 4 hour Standard Time-Temperature Curve (STTC) heating profile was 81°C above ambient. This is significantly under the ASTM E119 requirement for a fire rating, which requires that the temperature rise above ambient does not exceed 140°C. No evidence of spalling /surface damage was seen throughout the testing and there was no indication that the E-Crete^{TM} binder was affected by the exposure to the high temperatures within the furnace.

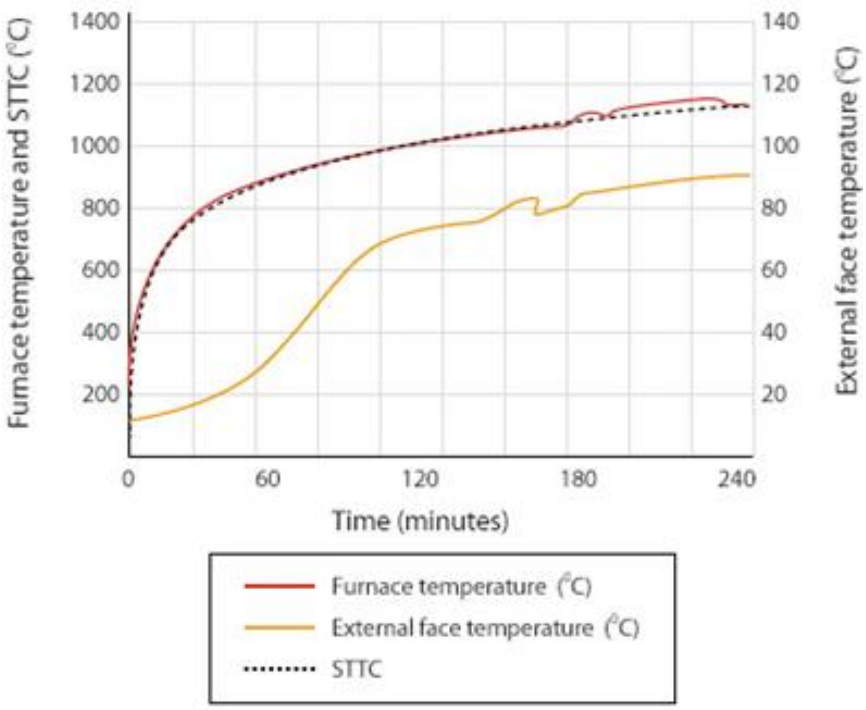


Figure 8: Temperature of exposed face and external surfaces during fire-testing of a precast E-Crete panel

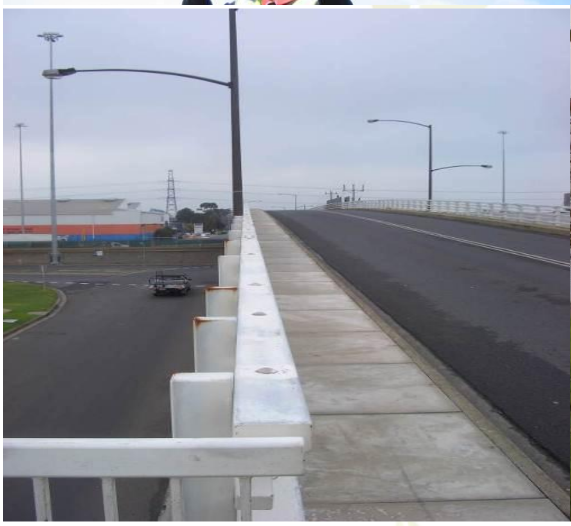
Figure 9: E-Crete Precast Panel (3.3x3.3m) during Fire Testing on 15th June 2010

8 Case Studies

8.1 Precast panels across bridge

Scope: Pre-cast concrete footpath segments
Location: Salmon St. bridge, Port Melbourne

Comment:
E-Crete™ pre-cast footpath panel segments across the Salmon Street bridge in Port Melbourne were specified by VicRoads to the highest quality concrete under their specification for 55MPa structural grade concrete (Section 620), such as that used for bridge structures. The product required high early strength for lifting, low shrinkage and long term durability. This project was completed in 2009 and is being used for long term monitoring and as a demonstration trial prior to use in structural applications.


8.2 *Swan Street Bridge Retaining Walls*

Scope: Retaining walls reinstatement
Location: Swan St. Bridge, Melbourne

Comment:
This project involved the reinstatement of the retaining walls at the Swan Street bridge in Melbourne and was completed in 2009. E-Crete™ was selected by VicRoads for this project due to the high profile location and demanding requirements. 40MPa grade structural concrete (VicRoads Section 620) was specified for this application with requirements of extended slump retention and the ability to be pumped. Equipment was installed into the wall for long term monitoring of the steel reinforcement.

8.3 M80 Ring Road Retaining Walls

Scope: 40MPa in situ cast, Retaining wall installation
Location: M80 / Furlong Rd, Sunshine

Comment:
40MPa grade structural concrete (VicRoads Section 610) was specified for in situ cast retaining walls. The installation consisted of an extended section of a major freeway upgrade in Melbourne's west at multiple heights and angles.





8.4 *Westgate Freeway Upgrade*

Scope: Pavement works and footpath reinstatement
Location: Brady St. Port Melbourne

Comment:
This was the first of many pavement projects that led to Vicroads' approval of E-Crete grades 20, 25 and 32 MPa in the specification for general concrete paving and non-structural use in footpaths and kerb and guttering in 2010. This project involved the engagement and collaboration of many parties, including VicRoads, Melbourne City Council, Port Melbourne City Council and the Alliance partners.

8.5 Melton Library

Scope: Precast Panels, Footpath and In-Situ Works
Location: Melton

Comment:
Environmentally focused building and structures made from 25/32/40MPa grade E-Crete™ with high quality appearance and accurate specification required. More than 30 precast decorative panels with exposed natural river pebble make up the exterior of the building. In situ works include footpaths, retaining walls, pits and blinding.




8.6 Highlands Residential Subdivision

Scope: Footpaths and driveways in new Highlands Estate
Location: Waterview Bvd. And surrounding streets, Highlands

Comment:
This project required 20 and 25MPa grade E-Crete™ for a typical subdivision in Highlands, in the northern growth boundary of Melbourne. As the City of Hume takes responsibility for this asset, all parties involved were required to be involved in the project, including nominal approval from VicRoads due to the proximity to roads.

8.7 *Templestowe Residential Shopping Precinct*

Scope: Footpaths for retail centre
Location: James St. Templestowe

Comment:
Manningham City Council used 25MPa grade E-Crete™ to evaluate it for everyday use when available in larger quantities. This case-study was presented by Manningham City Council to Eco-Buy as part of a Green Footpath and Roads forum.



8.8 *Thomastown Recreation and Aquatic Centre*

Scope: Pavement works surrounding the Thomastown Recreation and Aquatic Centre (TRAC)
Location: Main St Thomastown

Comment:
The Thomastown Recreation and Aquatic Centre works were completed in 2010 and show the culmination of a long term relationship with the City Council, architects, engineers and builders. It represents the first example of E-Crete being specified from the initial stages of design right through to construction. Extensive footpaths and driveways were completed in 25MPa grade E-Crete^{TM} in a range of colours and decorative finishes.

8.9 CERES Environment Park

Scope: Pavement works surrounding new pavilions
Location: Cnr Roberts & Stewart Streets, East Brunswick

Comment:
As a community environment park, CERES specified 25MPa grade E-Crete™ for coloured and decorative pavement works at an early stage of development for the extension of their pavilion facilities. E-Crete™ was pumped over the main buildings to lower ground levels.

8.10 Calder Freeway Interchange

Scope: Footpath and Bicycle Paths
Location: Calder Freeway

Comment:
Several km's of VicRoads specified 32MPa grade E-Crete™ footpath for general use and bicycle paths. This project involved daily delivery of multiple truckloads of E-Crete™ over a 3 month period in 2011.




8.11 Local Council Works

Scope: Footpath, Park Upgrades
Location: Northern suburbs, Melbourne

Comment:
Multiple projects specified by local councils using 25MPa grade E-Crete™ for footpath replacement, park upgrades and general reinstatement works.




8.12 Pre-cast Panels for Fire Resistance and Dangerous Goods Storage

Scope: Building to house dangerous goods stored on premises. E-Crete™ panels specified due to superior fire rating compared with traditional concrete.
Location: Southbank, Melbourne

Comment:
This project requires a high fire resistance as dangerous goods re to be stored inside this building. Upon receiving information showing E-Crete™ has approximately double the fire resistance of traditional concrete the construction company decided to use 40MPa grade E-Crete™ pre-cast panels.




8.13 Kerb and Channel

Scope: Kerb and Channel
Location: Mernda Village

Comment:
E-Crete™ used in place of standard concrete guttering for sub-divisions in Melbourne's northern suburbs.

8.14 Heavy Duty Workshop Floor

Scope: Workshop floor for truck servicing area
Location: Epping, Victoria

Comment:
This project used 25MPa grade E-Crete^{TM} for a large, flat area workshop floor. Trucks and heavy machinery are currently stored on the slab which has shown excellent surface hardness and wear resistance.




8.15 House Slab – Decorative Finish

Scope: House Slab for Residential Property
Location: Riddles Creek, Victoria

Comment:
Environmentally Friendly residence with 20 MPa grade E-Crete™ decorative, exposed aggregate flooring. E-Crete™ pumped and finished using standard practices. The surface was ground at 1 week of age to expose aggregate.

8.16 House Slab – Helicopter Finish

Scope: House Slab for Residential Property
Location: Epping North, Victoria

Comment:
40m^3 20 MPa grade E-Crete™ with helicopter finish. E-Crete™ pumped and finished using standard practices.






8.17 Pre-Cast Structural Grade Panels

Scope: Precast Structural Panels
Location: Thomastown, Victoria

Comment:
Standard production of high strength, low shrinkage structural grade 40/50MPa E-Crete™ panels with decorative features.