Development and Commercialisation of Low Carbon, Low Shrinkage, Highly Durable ENVISIA® Concrete.

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Abstract: The development and commercialization of Boral's low carbon, low drying shrinkage, highly durable ENVISIA® concrete is discussed with reference to specific properties of the concrete as well as performance and perception barriers that have been met. The performance of ENVISIA® concrete is shown to be not as affected by increases in w/c ratio as conventional binder system concrete. The chloride durability of ENVISIA® has outperformed both more conventional concrete designs and the requirements of NSW Roads and Maritime Services Bridge Specification B80 leading to the potential for increased service life of reinforced concrete structures. The reduced Portland Cement content of ENVISIA® concrete makes it less susceptible to sulfuric acid attack to the point where silica fume has little impact. Despite these performance benefits the challenge remains for some specifiers to accept concrete containing old ground granulated blast furnace slag treated in a new way.

Keywords: durability, lower carbon concrete, low shrinkage, ENVISIA®

1. Introduction

ENVISIA® concrete contains a specially milled ground granulated blast furnace slag (GGBFS) which allows concretes that achieve high Portland cement replacement levels without compromising setting time or early strength. After a number of years of research and development, Boral first commercialised this concrete in July 2013 as a low carbon, high early strength concrete with low drying shrinkage aimed specifically at the high-rise post-tensioned market. Over the course of commercialization demand for other grades lead to the development of additional mix designs spanning many applications and for multiple performance benefits including low shrinkage high strength (80MPa+) and durability against chlorides and acid attack.

2. Concrete Properties

2.1 Strength and the Effect of Water

First and foremost in a majority of applications, concrete is required to achieve a specified compressive strength. The upscaling of laboratory work on ENVISIA® to field supply of concrete was relatively straight forward for the initial intended market of post tension slabs with compressive strengths of 32 and 40MPa. Good correlation between lab and field results was observed, including achievement of stressing strengths for post-tensioned concrete and verification of low drying shrinkage. Once customers started re

Despite significantly more cement and lower w/c ratio, the compressive results of the S50 concrete were only marginally higher than those of the S40 concrete. Although all supply at this stage was into applications that did not require 50MPa for structural purposes, the difficulty in achieving higher strength caused concern that there may have been an inherent limitation to concrete strength.

During the first year of supply, an anecdotal observation was made that slump and by extension water addition did not appear to be detrimental to strength or shrinkage. In August 2014 a field trial to assess finishing characteristics of ENVISIA® in industrial flat floor applications was conducted. Concrete was designed at 150mm target slump without the use of high range water reducers. Of three loads supplied, the first and third arrived at 140mm slump. The second load had extra water added at the plant and arrived at 180mm slump. It was assessed tha

ENVISIA® is supplied at higher slump than conventional concrete and high strength 80MPa ENVISIA® concrete now[1] uses 13 litres per cubic metre more water than its equivalent conventional design.

The mantra “water is bad” and “low slump makes good concrete” are well ingrained in the industry and fail to take into account developments in concrete technology. Whilst it cannot be said that uncontrolled water addition is acceptable, the data exists proving performance of ENVISIA® concrete containing extra water is not as impacted as with conventional concrete and this should be considered when assessing suitability of concrete mixes.

2.3 Chloride Durability

NSW Roads and Maritime Services (RMS) has strict prescriptive and performance requirements for concrete placed in bridges where conditions are such the exposure classification C is deemed. A summary of some of these requirements is presented in Table 4.

Table 4. Summary of Concrete Durability Requirements[2]

Minimum Cement Content	Maximum w/c ratio	Maximum Rapid Chloride Migration Coefficient NT492 ($x10^{-12}$ m/s)	Maximum Effective Chloride Diffusion Coefficient NT443 ($x10^{-12}$ m/s)
420kg	0.40	4.0	2.0

Initial research[3] by Hocking et al indicated that chloride durability would be improved in ENVISIA®. As the commercialisation of ENVISIA progressed, the need to supply concrete into highly aggressive environments led to bespoke mix designs being created to provide service life improvements to concrete structures. A summary of results is presented in Table 5.

Table 5. Summary of Concrete Durability Trial Results

Cementitious Content (kg)	w/c ratio	28 Day Strength (MPa)	56 Day Drying Shrinkage (mstrain)

Figure A.

Figure B. Acid Resistance of Concrete (10% H_2SO_4)

It is evident that at each time interval the acid resistance performance of the ENVISIA® mixes were superior to the conventional concrete control mix and that at 10 weeks the concrete which exhibited the lowest mass loss was the ENVISIA® concrete not incorporating any silica fume.

Despite these trials an alternate design was prescribed and supplied into the project. The design had a higher cement content in the hope that the extra $Ca(OH)_2$ would react with the 15% silica fume to form a more impervious barrier to the acid attack. A field sample of the concrete was exposed to the same testing regime. The average mass loss on the sample at 10 weeks was found to be 30.03%. The concrete supplied had a lower resistance to acid attack due to reliance on silica fume in isolation.

3. Conclusions

The development and commercialization of ENVISIA® concrete has led to a new generation of higher performing, low carbon concretes. As with any product introduction there have been opportunities to learn and refine mix designs to the point that ENVISIA® concrete is now available across a wide range of strength grades with performance attributes that cannot be matched by conventional concretes. The adoption of ENVISIA® has followed the typical cycle of diffusion of innovation, where early adopters who understand the performance benefits use it before wider spread adoption by the market in general. Data gained from these early adopters has proven the performance benefits of Envifum[illegible]en-USC3.

5. References

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