# Effect of superplasticizers on concrete durability indexes

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**Abstract.** Use of durability index (DI) is one of the several approaches that have been used or advanced through various test methods for the purpose of evaluating the durability of concrete mixtures. In South Africa, use of DI's has developed through testing and research over the past years. A consortium of three tests of oxygen permeability index (OPI), water sorptivity and chloride conductivity are employed.

This paper presents an investigation conducted to determine the effect that superplasticizers may have on durability indexes of concrete. Concrete mixtures of strengths ranging from 30 to 50 MPa were cast using two types of commercially available superplasticizers, herein referred to as *GL* and *RSP*. The admixtures were of different chemical bases with *RSP* being a sulphonated naphthalene superplasticizer while *GL* was a polycarboxylate ether superplasticizer. The tests conducted were compressive strength, oxygen permeability and water sorptivity.

It was found that use of *GL* increased the compressive strength of concrete by about 10 MPa over the strengths of mixes made using *RSP*. Correspondingly, *GL* had an adverse effect on durability performance, as it decreased the OPI and increased the sorptivity indexes. The results implied the possible coarsening of the pore structure of the hardened concrete which could have resulted from the use of *GL*. Results also showed that the influence of chemical admixtures on hardened concrete properties and durability characteristics of high strength concretes may be less significant for high strength concretes.

**Keywords.** Marsh cone test, viscosity modifying agent, saturation point, superplasticizer

## Introduction

The assessment of concrete durability is principally based on methods and techniques that attempt to represent the ingress of aggressive agents into concrete. As such, the transport properties of concrete are perhaps the most important but not the only crucial factors that influence durability. Nearly all aggressive agents that lead to deterioration of concrete through non-mechanical processes, will involve external ingress of at least one of the agents that is involved in the attack process [1,2]. To illustrate this point, we may consider some chemical attack processes: chloride /carbonation attack arises from ingress of $Cl^-/CO_2$ and the presence or ingress of moisture, external /internal sulphate attack involves ingress of either sulphate ions and/or moisture. Although the reactive

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agents for alkalis-silica reaction (ASR) attack are usually part of the concrete matrix i.e alkalis in the pore solution and reactive aggregates, it takes an external ingress or supply of moisture for ASR attack to evolve and remain sustained. Similarly, freeze-thaw attack requires saturation of the concrete with water from the environment. Clearly, evaluating the permeation characteristics of concrete is probably one of the most important considerations in attempting to assess durability. Over the past years of research, different techniques have been proposed in the literature, for the purpose of evaluating durability.

In South Africa, index methods based on oxygen permeability, sorptivity and chloride conductivity have been the foremost techniques used for durability evaluation of concretes [3]. A recent study comparing some SA-index tests with international standard methods showed good agreement which adds credence to the local index tests [4].

## 1. Background

As mentioned in the prior section, durability Index testing is a South African approach that has been in development through research, in response to the need for innovation and improvements in evaluation of the durability of concretes exposed to aggressive environments. For conditions in Southern Africa, it is generally accepted that for specification of reliably good quality concrete that is capable of effectively resisting attack and ingress of deleterious ions, use of the three tests of Oxygen Permeability Index (OPI), the Water Sorptivity Test and the Chloride Conductivity Test is essential. These tests measure the transport properties of concretes and are expected to reflect the integrity and microstructural characteristics of hardened concretes. The use of these three tests is increasingly being specified in construction. They form the basis for the performance-based specifications currently being advanced for evaluation of the quality of concrete for construction in South Africa [5,6]. Substantial research on Durability Index (DI) has been generated over the past 15 years, and several aspects involving the tests have been investigated including the influence of cementitious materials, curing, temperature, relative humidity, repeatability and reproducibility of the tests [7-10]. However, hardly any investigations have been conducted on the intrinsic effects of plasticizing admixtures on DI. Such information is necessary in aiding further scientific understanding of the potential and limitations of the techniques, especially considering that chemical admixtures are used extensively in concretes.

Plasticizing admixtures may influence both concrete workability and its performance properties, in some cases adversely. There are many variables that can affect their effectiveness including its chemical base, dosage rates, timing of admixture addition into the concrete mix, incompatibility with cementitious materials, field conditions during concrete placement, interaction with other admixtures, among others. The characteristics of cementitious materials that often interact with chemical admixtures have long been identified in the literature as fineness, tricalcium aluminate ($C_3A$), alkalis ($Na_2O$), and sulphates ($SO_3$) [11]. Chemical admixtures containing triethanolamine and/or lignosulfonates are known to cause incompatibility problems. The air content of concrete is also affected, depending on the slump of concrete and chemical formulation of the superplasticizing admixture. Investigations have shown that naphthalene-based superplasticizers have the tendency to increase air content. Melamine-based superplasticizers may in some cases reduce air content in concretes

[12]. Investigations (reported in [13]) on the influence of different superplasticizers on the pore structure of hardened concretes have shown mixed results. Chemical admixtures also variably affect creep and drying shrinkage of concretes [14]. In addition, new generation plasticizing admixtures continue to enter the market. The long-term influence of these admixtures may be unknown.

This paper investigates the potential influence of superplasticizers on concrete durability indexes. As mentioned earlier, there is presently little or no work in the literature concerning the influence of chemical admixtures on durability indexes.

## 2. Experimental

This investigation consisted of eight concrete mixes of varied compressive strengths and water-cementitious ratio (w/cm). The design strengths of the concretes were 25, 30, 35, 40 MPa. Two mixes were prepared for each design strength category, as shown in table 1 of the mix parameters.

**Table 1**. Concrete mix parameters

| **Mix ID** | **1,8** | **2,7** | **3,6** | **4,5** |
|---|---|---|---|---|
| Design strength (MPa | 25 | 30 | 35 | 40 |
| w/cm* | 0.55 | 0.54 | 0.49 | 0.47 |

w/cm = water-cementitious ratio

The main variable in the investigation was the use of different types of chemical admixtures. Two types of commercially available superplasticizers were used in the mixes. *RSP* was a sulphonated naphthalene-based superplasticizer and was applied in mixes 1 to 4. *GL* was a polycarboxylate ether superplasticizer and was used in mixes 5 to 8. Cube samples of 150 mm size were prepared and cured for 28 days prior to testing. Compressive strength tests and the durability tests of oxygen permeability index and sorptivity index were measured [3].

The durability index tests comprising oxygen permeability and water sorptivity, were tested using 68 dia x 30 mm discs extracted from the concrete cube samples. The discs were subjected to oven-dry conditioning at 50$^{o}$C for seven days, prior to testing.

## 3. Results and discussion

### *3.1 Durability index results*

Altogether, sixteen (16) disc samples were prepared then tested for oxygen permeability and sorptivity. The results for the index tests have been plotted in Figures 1 and 2, respectively showing the OPI and sorptivity values for the various samples. From the charts, individual results can be related across all samples while trends can be easily identified. The individual sorptivity results for all mixes generally ranged from 6 to 9 mm/hr$^{0.5}$, which falls within the good durability class. The OPI results of mixes made with *RSP* gave values exceeding 10, meeting the criteria for excellent durability.

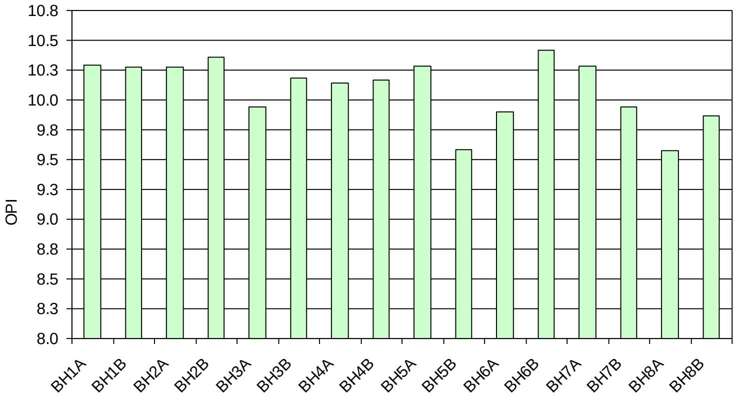


**Figure 1**. Oxygen permeability indexes

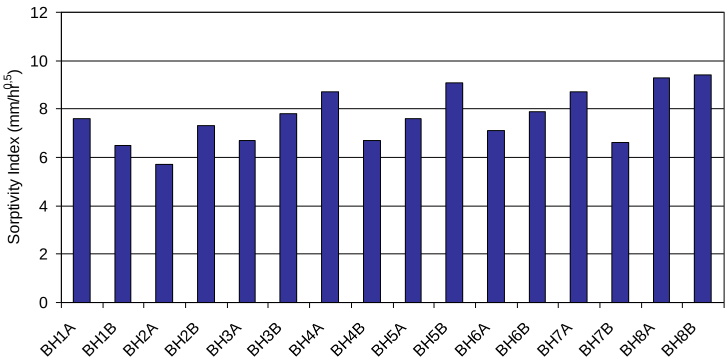


**Figure 2**. Sorptivity indexes

### *3.2 Discussion*

The durability index test results obtained for the various mixes, as influenced by the two different superplasticizers, *RSP* and *GL*, are given in Table 2. It is interesting to note that the use of *GL* consistently led to increase in the compressive strength of concrete (mixes 5-8) by about 10 MPa over the strength of mixes (1-4) made using *RSP*. However, for high strength concretes (mixes 2 and 5) of strengths greater than 50 MPa, the difference in results (due to use of the chemical admixtures), diminished and was negligible.

The corresponding effect of the superplasticisers on durability indexes is also evident. It can be seen in Table 2, that mixes made using *GL* and which gave higher compressive strengths, also exhibited higher water sorptivity indexes relative to their counterparts made using *RSP*. Mixes made with the former, gave sorptivity indexes that were 0.2 to 2.3 mm/hr$^{0.5}$ higher than the corresponding indexes of mixes made using the latter. This effect of the different superplasticizer was also clear with OPI results. It can be seen that the OPI values of mixes made using *GL* were generally 0.2 to 0.6 units lower than the corresponding values for mixes made using *RSP*.

**Table 2.** Durability index results of the various concrete mixtures

| Mix ID | Compressive strength (MPa) | OPI | Water Sorptivity (mm/hr$^{0.5}$) |
|---|---|---|---|
| Mix 1 | 35.0 | 10.3 | 7.1 |
| Mix 8 | 43.5 | 9.7 | 9.4 |
| Mix 2 | 37.0 | 10.3 | 6.5 |
| Mix 7 | 48.0 | 10.1 | 7.7 |
| Mix 3 | 43.5 | 10.1 | 7.3 |
| Mix 6 | 52.5 | 10.2 | 7.5 |
| Mix 4 | 54.5 | 10.2 | 7.7 |
| Mix 5 | 55.0 | 9.9 | 8.4 |

Clearly, the differences in strengths and durability of concrete, as a result of using the two superplasticizers, indicates an alteration in the pore characteristics of the hardened concrete. It is postulated that *GL* may cause acceleration of cement hydration which in turn results in higher rate of strength gain. Such effects could be related to temperature increase and could have implications leading to coarsening of the pore structure of the hardened concrete. This may explain the observed results of mixes containing *GL*, which gave higher compressive strengths and corresponding reduction in durability performance.

## 4. Conclusions

In the foregone investigation, the effect of superplasticizers on durability indexes was investigated. Two different types of plasticizers were used in the concrete mixes, whose strengths ranged from 30 to 50 MPa.

Results show that superplasticizers can differently affect the durability indexes of concretes. This, however, will depend on the type of the admixture. *GL* was found to have the effect of increasing the compressive strength of hardened concrete by about 10 MPa over the results obtained by using *RSP*. There was, however, a related adverse effect of correspondingly lower durability index performance of mixes containing the GL.

## References


[1] BS EN 1504-9:2009, Products and systems for the protection and repair of concrete structures. Definitions, requirements, quality control and evaluation of conformity. General principles for use of products and systems, British Standards Institution, 32p

[2] *Fulton's Concrete Technology*, 9th Edition, Cement & Concrete Institute 2009, ISBN Number: 9780958477918

[3] Alexander M.G., Ballim Y. and Mackechnie J.M., *Concrete durability index testing manual*, Research Monograph no. 4, Departments of Civil Engineering, University of Cape Town and University of the Witwatersrand, March 1999

[4] Beushausen H. and Alexander M.G, The South African durability index tests in an international comparison. *Journal of the South African Institution of Civil Engineering*, Vol 50 No 1, 2008, Pages 25–31, Paper 671

[5] Gouws, S.M., and Ballim, Y. (2003), Towards performance-based specifications for concrete durability, *Proceedings of the 2nd International Conference of the African Materials Research Society*. Johannesburg, South Africa. University of the Witwatersrand, Dec. 2003. pp.115-116.

[6] Grieve, G.R.H. (2005), Design of concretes to meet durability requirements; Development towards a performance specification in South Africa, *Proceedings of the International Conference on Concrete Repair, Rehabilitation and Retrofitting (ICCRRR)*, Cape Town, South Africa. University of Cape Town, Nov. 2005, pp.12-13.

[7] Griesel, E.J., and Alexander, M.J.(2001), Effect of controlled environmental conditions on Durability Index parameters of Portland cement concretes, *Cement, Concretes and Aggregates*, Vol. 23, No.1, pp.44-49.

[8] Gouws, S., Alexander, M.G., and Maritz, G. (2001), Use of Durability Indexes for concrete in marine conditions, *Materials and Structures*, Vol. 37, No. 267, April 2004, pp. 146-154.

[9] Du Preez, A.A., and Alexander, M.G. (2004), A site study of Durability Indexes for concrete in marine conditions, *Materials and Structures*, Vol. 37, No. 267, April 2004, pp. 146-154.

[10] Stanish, K., Alexander, M.G., and Ballim, Y. (2005), *Durability Index inter-laboratory test results-statistical analysis of variance*, Technical Report, Department of Civil Engineering, University of Cape Town, January 2005, 87p.

[11] Bruere, G.M. (1975), Actions of admixtures in plastic concrete and cement-admixture interactions, *Workshop on the Use of Chemical Admixtures in Concrete*, The University of New South Wales, Dec., 1975, pp. 29-41.

[12] Whiting, D. and Dziedzic, W. (1992), Effects of Conventional and High-Range Water Reducers on Concrete Properties, Technical Report, RD107T, Portland Cement Association, 1992.

[13] Khatib, J.M., and Mangat, P.S., (1999), Influence of superplasticizer and curing on porosity and pore structure of cement paste, *Cement and Concrete Research*, Vol. 21, pp. 431-437.

[14] Morgan, D.R., (1975), Effects of chemical admixtures on creep and shrinkage in concrete, *Workshop on the Use of Chemical Admixtures in Concrete*, The University of New South Wales, Dec., 1975, pp. 113-148.