Cement and Concrete Research 78 (2015) 81–99

Contents lists available at ScienceDirect

Cement and Concrete Research

journal homepage: http://ees.elsevier.com/CEMCON/default.asp

Chemical admixtures — Chemistry, applications and their impact on concrete microstructure and durability

J. Plank [a,*], E. Sakai [b], C.W. Miao [c,d,e], C. Yu [d,e], J.X. Hong [d,e]

[a] Department of Chemistry, Technische Universität München, TUM Center for Advanced PCE Studies, 85747 Garching, Germany
[b] Department of Ceramics Science, Tokyo Institute of Technology, Tokyo 152-8552, Japan
[c] School of Materials Science and Engineering, Southeast University, Nanjing 211189, China
[d] State Key Laboratory of High Performance Civil Engineering Materials, Jiangsu Research Institute of Building Science, Nanjing 210008, China
[e] Jiangsu Sobute New Materials Co. Ltd., Nanjing 211103, China

ARTICLE INFO

Article history:
Received 18 March 2015
Accepted 12 May 2015
Available online 17 June 2015

Keywords:
Admixture (D)
Concrete (E)
Microcracks (B)
Polycarboxylate
Shrinkage reducing agent (C)

ABSTRACT

An overview of current PCE compositions and synthesis methods is provided, followed by novel applications for PCEs including C–S–H-PCE nano-composites and a description of still unresolved challenges for PCE technology. In addition, the functionality of chemical admixtures in specific applications for low-carbon cements and concrete systems is discussed. The action mechanisms of retarders and the recycling system of sludge water by using retarder are introduced. Furthermore, the influence of fluoride ion and the effectiveness of PCE polymers in blended cements and the effect of non-adsorbed polymer are presented. And the impact of special interface modifying materials, of a refined pore structure and of chemical admixtures, particularly shrinkage-reducing agents, is described. The article concludes that more accurate quantitative micro-analytical methods and modeling tools will be needed to obtain a holistic understanding of factors affecting the microstructure of concrete, with the final goal of achieving a more durable concrete.

Contents

* Corresponding author at: Technische Universität München, Lichtenbergstr, 4, 85747 Garching, Germany. Tel.: +49 89 289 13151; fax: +49 89 289 13152.
E-mail address: sekretariat@bauchemie.ch.tum.de (J. Plank).

http://dx.doi.org/10.1016/j.cemconres.2015.05.016

1. Introduction

Various types of chemical admixtures are used to improve the construction properties of concrete such as workability, pumpability, setting properties, the mechanical performance, the durability such as freeze thaw resistance and the shrinkage properties. Also, chemical admixtures enable the manufacture and construction of special concretes such as high fluidity concrete, high strength concrete, underwater concrete, and sprayed concrete. This three-part article reviews recent developments in admixture chemistry and applications, with a focus on polycarboxylate (PCE) superplasticizers and retarders. Furthermore, new insights into optimized concrete microstructures and the role of shrinkage-reducing agents for improved concrete durability are presented.

This contribution attempts to provide an overview of recent developments in the field of PCE technology and of its perspectives in the future in Section 2 of this paper. The invention of polycarboxylate comb polymers in 1981 as a novel class of concrete superplasticizers clearly presents a milestone in concrete technology [1]. With the help of these admixtures, it now became possible to formulate highly advanced concretes such as ultra-high strength concrete (UHPC) which can attain compressive strength values >150 MPa, or self-compacting concrete (SCC) which no longer requires compaction. Moreover, specific PCE molecules were designed which can provide long slump life (>2 h) for ready-mix concrete without sacrificing early strength [2]. These few examples illustrate the extraordinary contribution of PCE superplasticizers to modern concrete technology. In Section 2 of this paper, an overview of current PCE technology including some recent trends will be presented. This is followed by a review of new applications. In the third part of this section, the shortcomings and deficiencies of PCEs as evidenced in daily operations, and potential solutions for them will be discussed. Finally, an outlook will be given on what still can be expected from PCE technology in the future.

In Section 3 of this paper, chemical admixtures such as PCE and retarders for low carbon cement and concrete systems and their mechanisms of action are introduced and summarized. The RC Specifications of the Japan Society of Civil Engineers suggest a unit water content of 175 kg/m^3 from the point of view of ensuring the durability of concrete [3]. Both the water reduction and slump retention are required, PCE-superplasticizers are widely used. In addition to higher performance of concrete, reduction of CO_2 is becoming an important issue in the cement and concrete field. The development of superplasticizers for such low carbon cement and concrete is also important. For example, there is optimization of superplasticizer in the use of blended cement or low

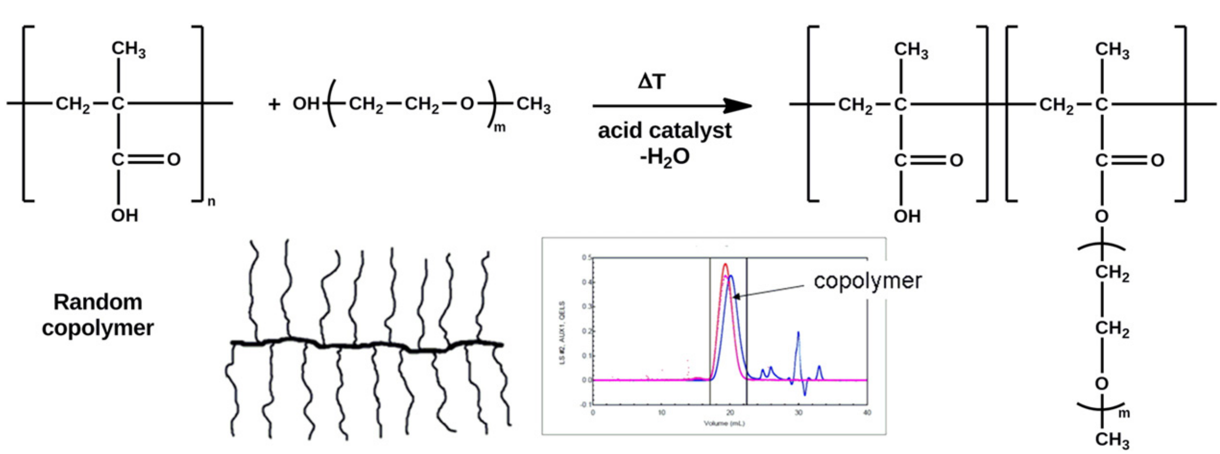

Fig. 1. Esterification (grafting) process for the synthesis of MPEG-type PCEs producing a highly uniform, random (statistical) copolymer, as evidenced by GPC.