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Self-compacting concrete incorporating filler additives: Performance at high temperatures

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ABSTRACT

An experimental investigation was conducted to evaluate the performance of self-compacting concrete (SCC) subjected to elevated temperatures. For this purpose, Portland cement (PC) was replaced with limestone powder (LP), basalt powder (BP) and marble powder (MP) in various proportioning rates. Half of the total specimens for each mix type were studied by adding polypropylene (PP) fibers to improve the understanding of the effect of PP fibers on the behavior of SCCs subjected to high temperatures. SCC mixtures were prepared with water to cement ratio of 0.33 and polypropylene fibers content was 2 kg/m^3 for the mixtures containing polypropylene fibers. Specimens were heated up to elevated temperatures (200, 400, 600 and 800 °C) at the age of 56 days. Then, tests were conducted to determine loss in weight and compressive strength. Moreover, the change of ultrasonic pulse velocity (UPV) was determined and surface crack observations were made after being exposed to elevated temperatures. Experimental results indicate that a severe strength loss was observed for all of the SCC mixtures after exposure to 600 °C, particularly the concretes containing polypropylene fibers though they reduce and eliminate the risk of the explosive spalling. At higher replacement levels of LP, BP and BP further lower resudial strength was observed. In terms of percent residual properties, control mixture specimens performed better than filler additive specimens for all heating cycles.

1. Introduction

Self-compacting concrete (SCC) is a special high performance concrete type that is a highly flowable concrete that can fill formwork without any mechanical vibration. SCC's unique property gives it significant constructability, economic and engineering advantages [1,2]. Due to its specific properties, which are achieved by the excellent coordination of deformability and segregation resistance, SCC may contribute to a significant improvement in the quality of concrete structures and open up new fields for the application of concrete [3]. SCC mixes often use a large quantity of powder materials as mineral additives and/or viscosity-modifying admixtures. The powder materials or viscosity agents are required to maintain sufficient cohesion/stability of the mix. The requirement for increased powder content in SCC is usually met by the use of pozzolanic or less reactive filler materials. A number of studies [4–7] have been reported in the literature concerning the use of mineral admixtures to enhance the self-compactibility characteristics and to reduce the material cost of the SCCs. These may include silica fume and fly ash as pozzolanic materials and/or limestone powder (LP), marble powder (MP), basalt powder (BP) as filler materials. When used in SCC, filler additives can reduce the amount of superplasticizer necessary to provide a given fluidity [8]. The successful utilization of LP, BP and MP in SCC mixtures would not only provide a solution regarding the disposal and environmental problems connected with these fillers but might also reduce the cost of SCC. These fillers can significantly increase the workability of SCC. Moreover, the incorporation of filler additives also eliminates the need for viscosity-enhancing chemical admixtures. The lower water content of the concrete leads to higher durability, in addition to better mechanical integrity of the structure [9]. The characteristics of this concrete such as high content of filler additives, large paste volume linked to its placing conditions could modify its mechanical behavior, comparatively to traditional vibrated concrete. The behavior of SCC subjected to high temperature has in particular to be evaluated. The few studies on SCC subjected to high temperature show both a decrease in strength and an increase in the risk of spalling [10] or a behavior similar to that of vibrated concrete [11].

High temperature causes dramatic physical and chemical changes resulting in the deterioration of the concrete [12]. Although concrete is recognized as an excellent thermal-resistant material among various construction materials, critical deterioration of concrete is observed when it is exposed to high temperature like as in the case of fire. A number of physical and chemical

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