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WORKABILITY AND COMPRESSIVE STRENGTH OF SELF COMPACTING CONCRETE CONTAINING DIFFERENT LEVELS OF LIMESTONE POWDER

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Abstract: *Self compacting concrete (SCC) is an innovative construction material in construction industry. It is a highly fluid and stable concrete that flows under its own weight and fills completely the formwork. The flowability of SCC is achieved by increased paste content with employment of some mineral admixture in the form of limestone powder. The use of this type of filler increases the workability and the compressive strength for an optimal cement content replacement and also provides economic and environmental advantages by reducing Portland cement production and CO_2 emissions.*

Key words: *Self compacting concrete, limestone filler, workability, compressive strength*

1. Introduction

Self compacting concrete (SCC) was discovered in the late 1980s by a Japanese professor, H. Okamura, who aimed to improve the quality of conventional concrete. It represents an upgraded type of mixture characterized by high fluidity, which flows under its own weight without the need of mechanical compaction during the casting process. SCC flows through restricted sections with congested reinforcement without segregation or bleeding. The use of SCC as structural material intensifies the productivity due to the shortened construction time, enhances the quality of the construction site concrete, reduces noise and helps in achieving high surface quality. One of its disadvantages is its cost correlated with increased volume of cement and chemical admixture. A solution to reduce the cost is the use of mineral admixture such as limestone powder added to concrete during the mixture procedure.[1] By substituting a quantity of cement with filler the paste properties on different levels are affected: chemical – introducing new reaction or modifying the existing ones during the hydration process, physical – improved nucleation, dilution effect – adjusting distance between cement particles and filler effect – filling the

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small pores between cement particles. The use of filler is a common practice in European countries, especially in France and Sweden, where it is stored in silos alongside the concrete plants.[2] Limestone are sedimentary rocks primary of calcium carbonate. The filler represents a by-product of limestone crushers which has been accumulated in large volumes and constitutes a source of environmental pollution. The addition of this powder improves the workability, deformability and stability of fresh self compacting concrete.[3], [6]

2. Objectives

The limestone filler is often used as a mineral addition in self compacting concrete.This study represents an analysis of 20 different mixes with different filler contents to evaluate the workability and compressive strength of SCC and to set an optimum amount of cement replacement.

2.1. Material and Methods

In order to investigate the effect of limestone filler content on the workability and compressive strength of SCC were analysed 4 series including 20 mixes of SCC. [5], [8], [11].

Mix proportions for 1m³ Table 1

	cement	LP	water	w/b	F.A	C.A.	SP
SCC1	**560**	**0**	**167.5**	**0.30**	**757**	**971**	**14**
SCC2	450	110	162.5	0.29	912	760	8.3
SCC3	420	140	194	0.35	993	662	7,8
SCC4	380	180	178	0.32	925	757	7,0
SCC5	280	280	167	0.30	940	770	4,7
SCC6	**550**	**0**	**182**	**0.33**	**728**	**935**	**8.4**
SCC7	495	55	182	0.33	866	775	8,8
SCC8	440	110	182	0.33	863	771	8,8
SCC9	385	165	182	0.33	860	768	8,8
SCC10	375	175	167	0.30	940	770	4,7
SCC11	**540**	**0**	**167.5**	**0.31**	**692**	**988**	**13.5**
SCC12	450	90	163	0.30	925	750	9.2
SCC13	430	110	155	0.29	925	750	8.6
SCC14	400	140	155	0.29	918	752	8.1
SCC15	390	150	186	0.34	993	668	8.1
SCC16	**500**	**0**	**175**	**0.35**	**1131**	**621**	**10**
SCC17	370	130	160	0.32	945	713	7.0
SCC18	330	170	175	0.35	941	764	7.0
SCC19	295	205	197	0.39	914	750	5.5
SCC20	280	220	167	0.33	980	800	3.5

Each series has constant powder content and a control mix to evaluate the compressive strength, the proportions are given in Table 1

The following materials were employed: ordinary Portland cement conforming to EN 197, river sand as fine aggregate, river coarse aggregate. A polycarboxylate admixture of new generation was selected as a superplasticiser.[10]

Basic requirements for SCC in fresh state are: flowability, viscosity, passing ability and segregation resistance.

The slump flow test shows the filling ability of the mix and the T500 time is a measure of the speed of flow or viscosity. The main steps for this test are exposed in EN 12350-8.

L-box test is used to assess the passing ability of SCC in the form of a flow through restricted sections with congested reinforcement without segregation or blocking. The procedure of test is described in EN 12350-10.

Cubic specimens 100 x 100 x 100 mm were prepared for evaluation of the compressive strength. They were demoulded after a day of casting and cured in water for 28 days.[12-19].

3. Results and Discussions

Limestone is considered an inert mineral admixture, but some researches **[5-6-7],** revealed that it modifies the hydration process contributing to the transformation of monosulpho - aluminate to monocoarbonoaluminate.

The physical effect of filler consists in the acceleration of the hydration due to precipitation of crystallized hydrates which are promoted by heterogeneous nucleation of filler particles. The addition of powder is also diluting the cement particle system, affecting the ordinary distance between them and modifying the water quantity available for the hydration process.

The slump flow and T_{500} time assess the flowability and flow rate of SCC in absence of obstructions. All SCC mixtures presented satisfactory slumps flows in the field of 650-790 mm, with flow time 2-4,5 s, which is a good index of deformability. It was observed that the cement may be replaced with limestone filler up to 25 % to increase the selfcompactibility, and that at a greater amount of filler, the mix becames denser and its workability decreases.Fig. 1, Fig. 2.

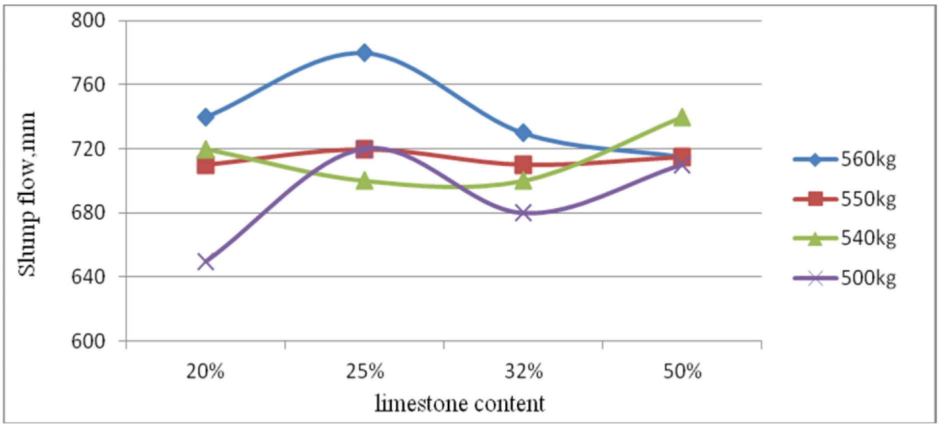

Fig. 1. *Effect of filler content on the slump flow*

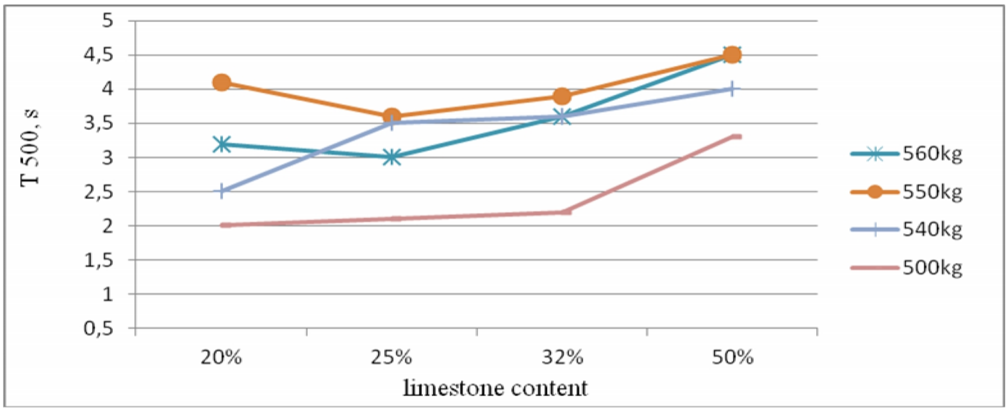

Fig. 2. *Effect of filler content on the* T_{500} *time*

The viscosity of concrete paste increased with the decrease of its fluidity. The higher values for T_{500} time were obtained for the cement replacements of more than 30%.

Limestone filler enhances hydration rate and increases the strength of cement compounds at early ages. It doesn't have pozzolanic or hydraulic properties and its reaction with alumina phase involves no significant changes on the strength of blended cement.

The finer particles of limestone act as filler material and fill the gaps between coarse aggregates, improving the microstructure of concrete. This effect increases the mechanical properties and reduces the overall porosity of cement paste. Fig.4 shows variation trends of compressive strength for SCC mixes with various levels of limestone filler contents. For the cement substitution up to 20 %, the compressive strength increased due to the intensification of packing density and started to decrease significantly with the filler substitute higher than 25 %, which corresponds to the recommendations indicated in EN-197-1: the maximum limit of cement replacement with limestone filler is around 35%, Fig. 3.

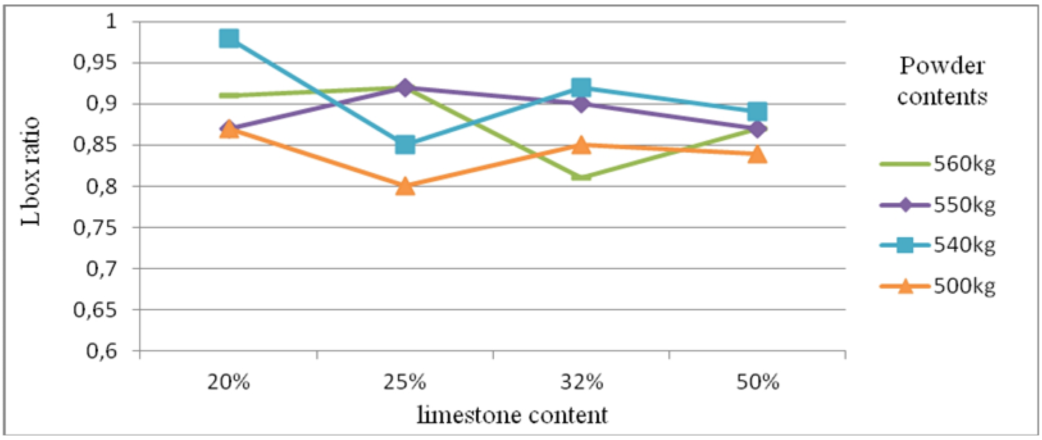

Fig. 3. *Effect of filler content on the L-box ratio*

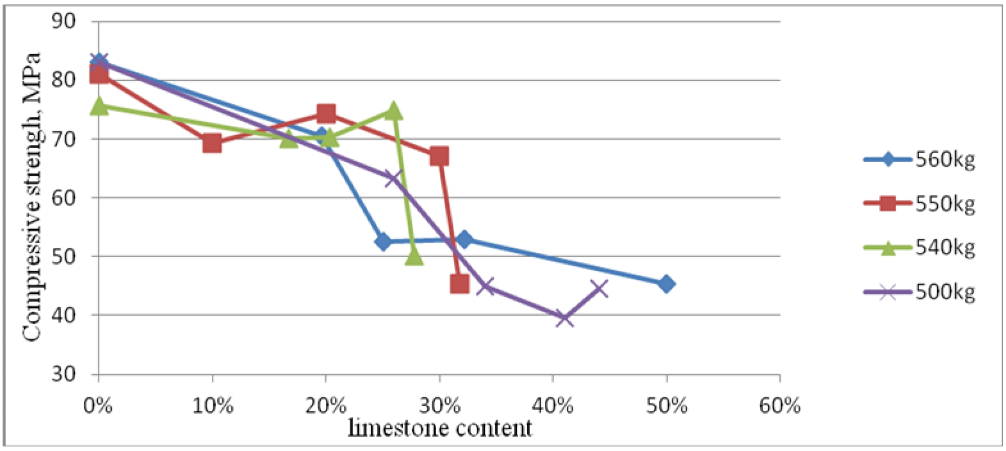

Fig. 4. *Effect of filler content on the compressive strength*

The following conclusions can be drawn from the results of this study:

- The addition of limestone filler improves the properties of SCC in fresh state.
- The filler effect on the hydration process is mainly physical, accelerates the hydrations process, dilutes the cement paste and increases the effective w/c ratio. The chemical effect is limited.
- The replacement of cement with limestone powder as a mineral admixture increases the workability.
- The compressive strength was reduced significantly when filler was used to replace more than 25% of the mixture.

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