Construction Materials

INTERSECTII
INTERSECTIONS
http://www.ce.tuiasi.ro/intersections

The optimization of properties of self-compacting concrete by the combination of fine filler

Ales Kratochvil[1] and Jiri Brozovsky[2]
[1]*Transport Research Centre, 636 00 Brno, Czech Republic*
[2]*Institute of Building Materials and Components, B.U.T., 602 00, Brno, Czech Republic*

Summary

Our partner Virginia Transport Research Council (VTRC) has provided the Transport Research Centre (CDV) with information about rules applied for technology of self-compacting concrete (SCC) in the USA[1, 2]. According to these sources preferably in the USA ground blast furnace slag and fly ash (only after careful composition test), as the filler into concrete mixture for SCC is used. Concrete mixtures containing different types of fillers are frequently used for the production of SCC. The applicable advantage is that the certain kind of filler modifies certain properties of concrete mixture or hardened concrete.

In the Czech Republic, for SCC stoned dust removers (fillers) ground blast furnace slag, fly ash, ground limestone and silica fume are used as concrete mixture fillers. The following experiments were carried out for verification of the possibility of affecting the concrete mixture properties and SCC, by combination of different types of fillers, following tests were carried out.

KEYWORDS: self-compacting concrete, filler, ground blast furnace slag, fly ash, ground limestone, silica fume.

1. TESTS

For verification of rheological properties of experimental concrete mixture, we carried out modified tests by slumping of the cone (Abrams), then by L-box, J-ring and Orimet tests.

1.1. Slump test

When testing, Abrams cone must be placed with the smaller base on the smooth pad 750 x 750 mm and is filled up to the top edge with concrete mixture without compacting. Then by lifting of taper the slumping of concrete mixture on the pad can be carried out. We measure time needed for concrete mixture to be slumped into a cake of diameter 500 mm (T_{50}) and final diameter of the cake (M)

ISSN 1582-3024

1.2. L – box test

Testing method simulates concrete mixture penetration through reinforcement. For the measurements we used the instrument whose diagram is on Figure 1.

During the test vertical part of the instrument is filled up with concrete mixture and by lifting of sliding gate the mixture can freely leak out over inserted ribbed steel bars (in the present case 3x profile 12 mm with axial distance 50 mm)into horizontal part of 4 L – box.

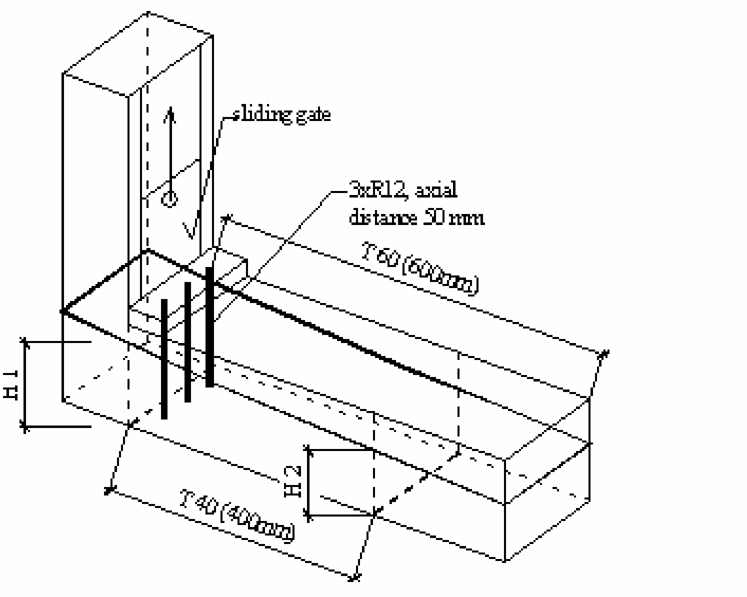


Figure 1. L - box

We measure time T_{40} ie. time when the face of concrete mixture in horizontal part of the instrument reaches the distance 400 mm from sliding door and time T_{60} ie. time when the front of concrete mixture reaches the end of L box horizontal part.

When the movement ends, we subtract further values H1 (the height of concrete mixture column in 2/3 of horizontal part of the instrument) and H2 (the height of concrete mixture column by the opening of vertical part of instrument). The ratio H1/H2 determines the movement locking of mixture through reinforcement.

1.3. Orimet test

We measure the flow through swaged opening of the plant. The test results give us the information, technically accurate enough, about mixture viscosity (Figure 2).

1.4. The combination of Orimet and J – ring tests

Testing procedure described in the preceding paragraph is in this case completed with apparatus that enables to assess locking of mixture through reinforcement – J – ring test (Figure 3). Basically it means the annulus inserted in constant distance of spiky steel bars of the same profile. The distance of bars as well as applied annulus profile depending on the maximum used aggregate granule differs. J-ring test apparatus is placed centric under the opening of Orimet during the test. We again measure the flow time of concrete mixture throw the opening of Orimet and visually assess the locking of concrete mixture movement through J-ring.

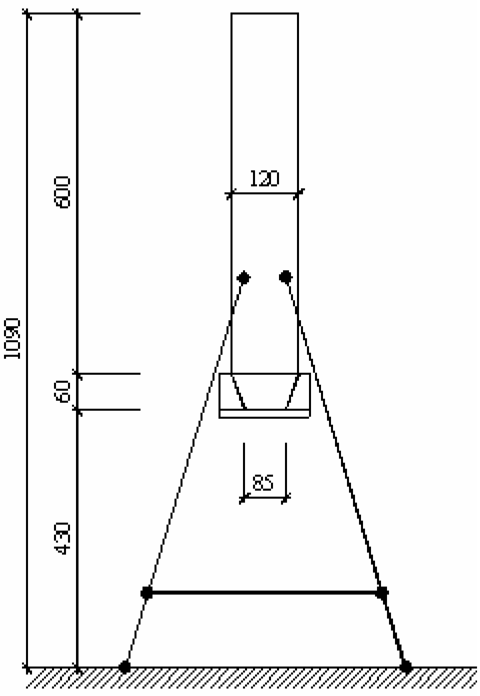


Figure 2. Orimet

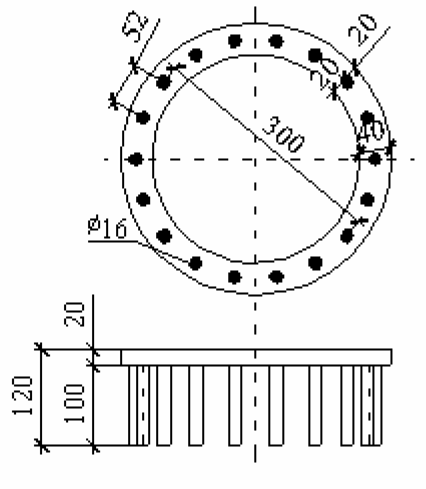


Figure 3. J - ring

These treated compound formulas were applied for sample production to test strength an frost resistance (beam: 100 x 100 x 400mm).For verification of resistance against water and defrost elements (CHRL), testing cubes with the side of 150 mm were produced.

Bending strength and tensile compression fraction tests were gradually carried out on the beam. Frost resistance of hardened concrete was observed by the decrease of sample resistance after 75 and 150 freezing cycles [4], and the measurement of concrete water resistance and CHRL in individual steps after 25 freezing cycles in some cases up to the total 250 cycles were carried out (5).

Table 1. Experimental concrete mixtures and material properties [kg/m^3]

Mix No.	I	II	III	IV	V	VI	VII	VIII	IX	X
Cement Mokra 42,5 R	404	406	391	399	406	402	402	401	402	396
Sand 0-4, Tovacov	829	710	743	817	710	703	703	762	703	693
Aggregate 4-8, Tovacov	232	233	225	229	233	231	231	230	231	228
Aggregate8-16, Tovacov	556	558	537	548	558	552	552	551	552	544
Stone powder	162	-	-	-	-	100	-	120	100	-
Ground granulated blast furnace slag	-	284	-	-	-	181	-	-	-	139
Fly ash	-	-	215	-	-	-	100	100	-	99
Silica fume	-	-	-	159	-	-	-	-	-	40
Ground limestone fines	-	-	-	-	284	-	181	-	181	-
Admixture (Sika5– 600)	4,0	4,0	3,9	-	4,0	4,0	4,0	4,0	4,0	4,0
Admixture (Sika 3 neu)	-	-	-	12	-	-	-	-	-	-
Mixing water	182	183	210	189	183	191	191	190	191	203
C-W ratio w [v/(c+m)]	0,32	0,27	0,35	0,34	0,27	0,28	0,28	0,31	0,28	0,30
Mix No.	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX
Cement Mokra 42,5 R	398	406	406	409	406	402	402	396	394	390
Sand 0-4, Tovacov	696	710	710	778	710	703	703	693	690	683
Aggregate 4-8, Tovacov	229	233	233	235	233	231	231	228	227	225
Aggregate8-16,Tovacov	547	558	558	563	558	553	553	544	542	537
Stone powder	-	41	20	-	-	-	-	-	-	-
Ground granulated blast furnace slag	179	243	264	225	274	261	251	238	217	195
Fly ash	99	-	-	-	-	-	-	-	-	-
Silica fume	-	-	-	-	10	20	30	40	59	78
Ground limestone fines	-	-	-	-	-	-	-	-	-	-
Admixtur (Sika5– 600)	4,0	4,0	4,0	4,1	4,1	4,0	4,0	4,0	3,9	3,9
Mixing water	199	183	183	174	183	191	191	203	207	215
C-W ratio w [v/(c+m)]	0,29	0,27	0,27	0,27	0,27	0,28	0,28	0,30	0,31	0,32

3. OBSERVED FINE FILLERS

To verify concrete mixture properties modified by various types and combinations following materials were used:

- silica fume (SF), Oravské ferozlitiarenské závody, a.s.,Istebné (Slovakai, specific surface 230 568 cm^2.g^{-1}
- ground blast furnace slag (GGBS),Kotouč Štramberk, S= 629 cm^2.g^{-1}
- ground limestone (L), specific surface 4 857 cm^2.g^{-1}
- fly ash (FA), power plant Chvaletice, specific surface 2 426 cm^2.g^{-1}
- stone powder (SP), from quarry Zelešice, specific surface 4 345 cm^2.g^{-1}

4. TEST RESULTS

The graphical representation of concrete compression strength test results of basic compound formulas set is shown in Figure 4. The strength of dispersion after 28 days of maturing (water placing) was cca. 40 % of maximum measured value depending on the type of applied fine filler. The highest strength was achieved at samples produced from concrete mixture using silica fume as the fine filler (81 MPa after 90 days).

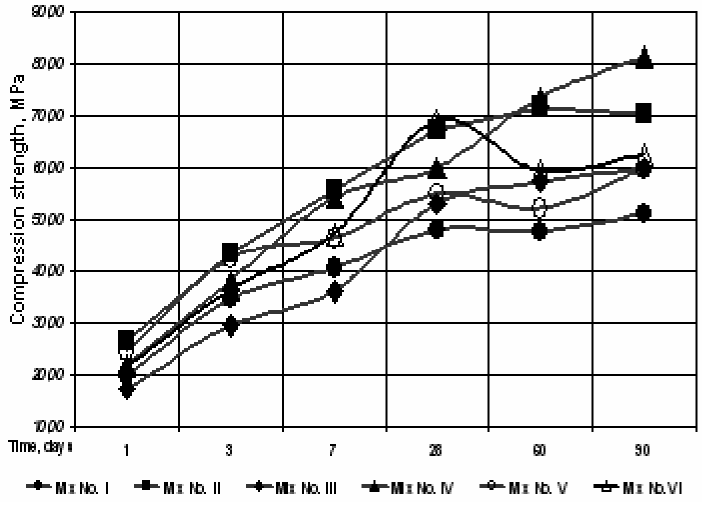


Figure 4. Compressive strength gain with time

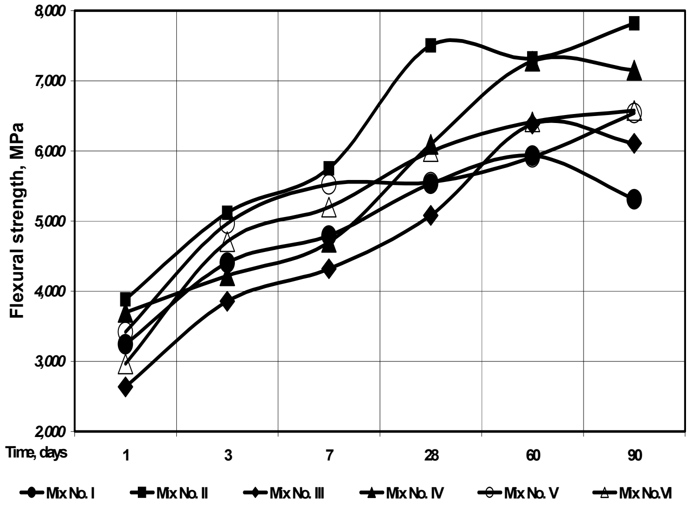


Figure 5. Tensile strength under bending gain with time

ISSN 1582-3024

For tensile strength under bending (Figure 5) the dispersion test results of basic compound formulas after 90 days were similar (cca 35 % of max. measured value) and the highest strength was achieved at samples no.II and VI.(7.82 a 7.15 MPa). In graphs representing the comparison of concrete compound formulas show that entire dose of fine filler necessary for achievement of demanded rheological mixture properties is secured by silica fume.

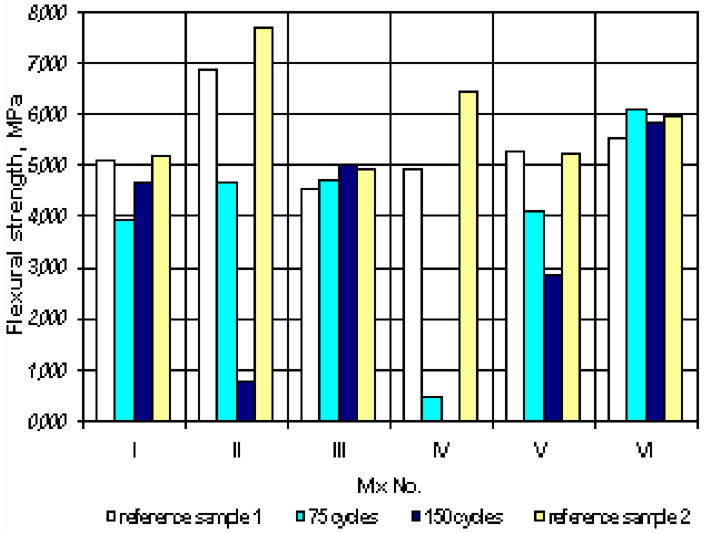
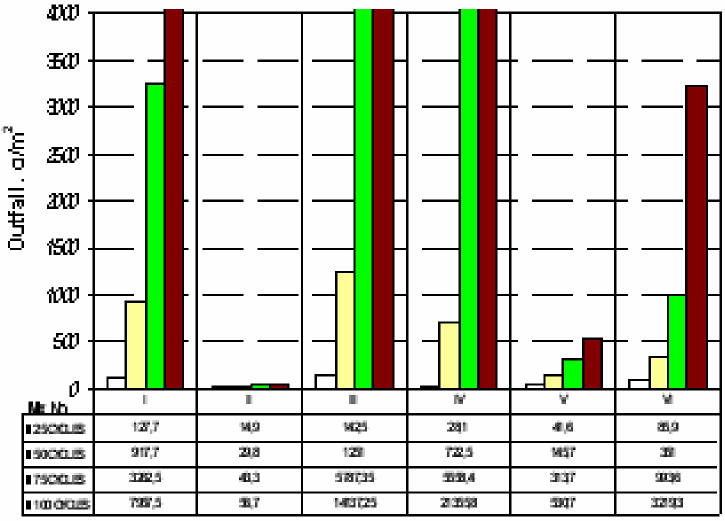


Figure 6. Frost resistance - Tensile strength



Mx No.	I	II	III	IV	V	VI
■ 25CYCLES	127,7	14,9	142,5	28,1	41,6	85,9
■ 50CYCLES	917,7	20,8	1230	722,5	145,7	331
■ 75CYCLES	3262,5	40,3	5787,35	5538,4	313,7	993,6
■ 100 CYCLES	7987,5	58,7	14837,25	21355,8	530,7	3229,3

Figure 7. Chemical resistance (3 % NaCl solution)

ISSN 1582-3024

The measurement results in this case confirm preceding experiences, that so high silica fume doses (159 kg/m^3 of fresh concrete) result in massive decrease of concrete durability (see graphs in Figures 6 and 7). On the contrary very favorable results from durability point of view showed samples produced from concrete that contained combination of stone dust removers and ground blast furnace slag as fine fillers. The concrete produced only with slag admixture showed outstanding chemical resistance (3% NaCl solution), but determination results of its frost resistance at higher number of freezing cycles were distinctively worse. Equal results were obtained from frost and chemical resistance point of view from samples where an admixture ground limestone was used.

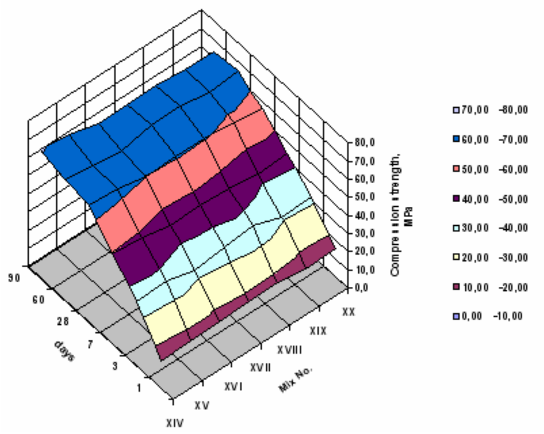


Figure 8. Compressive strength gain with time

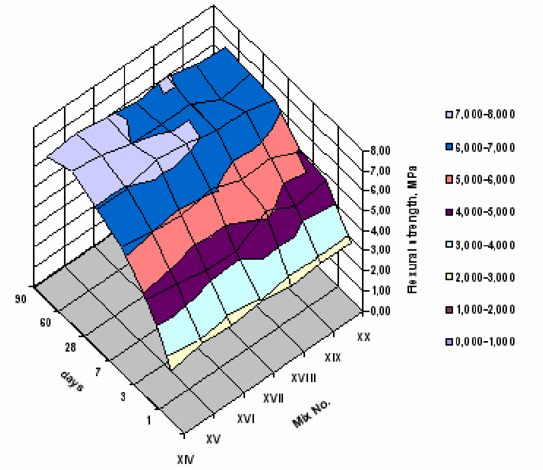


Figure 9. Tensile strength under bending gain with time

Graphs of developments of tensile strength under bending and tensile compression at these formulas are shown in figure 8 and 9. From the course of individual curves, it is evident, that expected increase of strength SCC, depending on increasing silica fume dose, did not become apparent. The reason might be on relatively high volumes of ground blast furnace slag applied in these mixtures for achievement of their rheological properties in fresh state. High doses of slag might at least partially suppress the effect of the strength increase of SCC by silica fume. From the graph in the Figure 7 on the contrary it is evident considerable effect of silica fume dose on SCC chemical resistance. Considerable increase of sample damage with 3%NaCl solution occurred when we had higher number of freezing cycles and doses over 10 % of silica fume in SCC (referring to concrete weight). On the contrary, the dose of silica fume no has effect on frost resistance of SCC (Figure 6).

5. CONCLUSIONS

The results of the performed tests show that there is a favorable effect of GGBS on strength values SCC as well as on chemical resistance of these concrete. However before concluding on unambiguous positive assessment, in that case it is necessary to wait for final durability (frost) test results.

From frost resistance point of view, the most favorable results of already finished tests, were achieved from compound formulas no.I,III a VI and then all compound formulas observed within assessment of silica fume dose effect on SCC (concrete mixtures no.XIV up to XX).Different frost resistance results at the samples produced from concrete mixtures no.II a XIV (both mixtures contained GGBS as a filler) might be caused by various volumes of blast furnace slag in both compound formulas.

This presumption will have to be verified by other tests. Comparing the compound formulas of concrete mixtures showing the highest frost resistance of produced SCC with the achieved chemical resistance is evident, that the highest durability was achieved at mixtures marked no.V, XIV, XV and XVI. The performed tests results showed that the usage of higher silica fume doses in concrete mixtures is not the best solution from the durability of self compacting point of view.

Foreign experiences and the performed tests results show that optimization of SCC proportion with consideration of demanded properties of fresh concrete mixture and resulting properties of hardened concrete require complete knowledge of individual characteristic of concrete mixture components in the course of all technological cycle of concrete production. E.g according to American experience, durability of SCC using fly ash as filler is possible to be increased by concrete mixture aeration.

In that case it is however necessary to pay high attention to their rheological properties because higher air content influences mobility of mixtures as well as its other properties. As fine filler in the Czech Republic for utilization in SCC seems to be highly perspective combination GGBS with stone powder, respectively with fly ash, when taking into consideration the current prices.

To evaluate concrete resistance to aggressive medium (chlorides in this instance - 12 months evaluation time period according to the CSN 73 1340 Standard) there is necessary to ensure that no one parameter under monitoring shall decrease during this interval.

Acknowledgements

In this article results of a research intention MD ČR 0-44994575 are presented: Sustainable transport - chance for the future and the financial support of the Ministry of Education, Youth and Sports, project No. 1M680470001, within activities of the CIDEAS research centre.

References

1. Publication NO. FHWA-RD-00-02: *Portland-Cement Concrete Rheology and Workability: Final Report*, Federal Highway Administration, November 2001.
2. Publication NO. 1574: *Materials and Construction. Advances in Concrete and Concrete Pavement Construction*. Transportation Research Board, National Research Council, Washington D.C., 1997.
3. CSN EN 12350-2 *Testing fresh concrete – Part 2: Slump test*.
4. ČSN 73 1322 *Determination of frost resistance of concrete*.
5. ČSN 73 1326 *Resistance of cement concrete surface to water and defrosting chemicals*.