EFFECT OF ADDING NATURAL FINE SAND RICH IN FINES ON THE FRESH CONCRETE PROPERTIES

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ABSTRACT

Norwegian sands are usually coarse with a low content of fines (materials less than 0,125 mm). Several authors therefore recommend to use a blend of coarse sand and a secondary finer sand rich in fines /1, 2, 3/. Crushed sand has commonly been used as the secondary sand /2/.

The aim of the work was to study the effect on fresh concrete properties by mixing coarse sand (0-8 mm) and fine sand (0-2 mm) rich in fines. The two sands were blended in such a way that the content of fines was stepwise increased from 20 to 60 l/m^3. In addition to improve the fresh concrete properties, use of natural fine sand rich in fines may be profitable with respect to resource utilisation.

For the total of 15 concrete mixes with different coarse/fine sand ratios and different sand/stone ratios, consistency, consistency loss, bleeding and compressive strength were measured. The water/cement ratio 0.60 and the volume of cement paste were held constant.

For all the sand/stone ratios tested only small variations in the consistency were observed when the content of fines varied from 20 to about 50 l/m^3. A further increase in the content of fines led to a considerable decrease of the consistency. The consistency loss in general increased with the content of fines.

An increase in the content of fines from 20 l/m^3 to 30 l/m^3 halved the total bleeding.

The compressive strength was not significantly affected by the content of fines and the changes in the sand/stone ratio.

Keywords: Aggregates, Natural fine sand, Coarse sand, Consistency, Flow measure, Bleeding and Compressive strength.

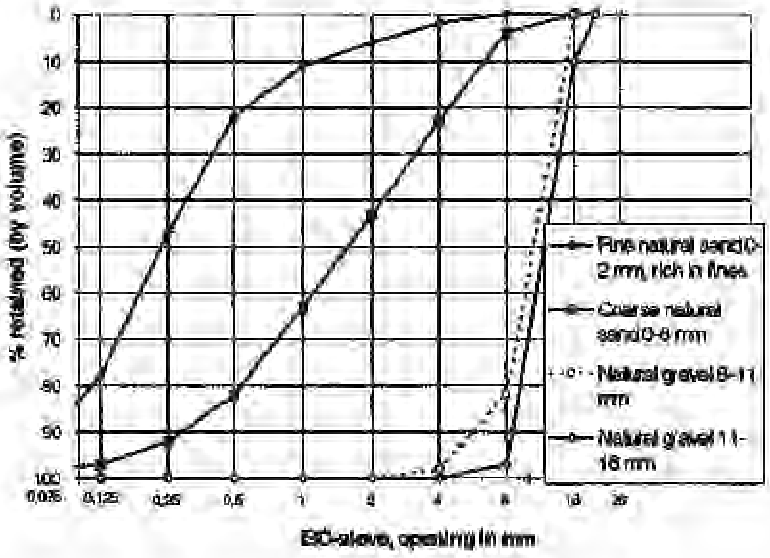
1. INTRODUCTION

Norwegian sands often have a low content of fines (materials less than 0,125 mm). Sometimes it may be profitable to add a low-priced sand rich in fines (secondary sand) to a coarse all over sand with the intention of getting the best out of different brands. When using such a secondary fine sand, the concrete workability must be focused on, and in particular the water requirement. Earlier investigations have shown that it is possible to obtain a low water requirement in concrete including a crushed secondary fine sand /2/.

A Norwegian project called "Environmental Sound Concrete Quality", working with blended cements, additives and natural and crushed sands, was initiated by NORCEM (the Norwegian cement manufacturer) in 1996 and will terminate in 1998. This paper, based on work performed in this project, focuses on workability of concrete with different blends of coarse 0-8 mm natural sand and 0-2 mm natural sand rich in fines.

2. AGGREGATE GRADING

Two natural sands, one coarse 0-8 mm washed sand and one unwashed 0-2 mm rich in fines, and washed gravel 8-11 mm and 11-16 mm were used. The grading curves are given in Figure 1.



Aggregate fractions	Volume % retained on sieve, mm								
	0,075	0,125	0,25	0,5	1	2	4	8	16
Fine natural sand 0-2 mm, rich in fines	90	79	47	22	11	6	2	0	0
Coarse natural sand 0-8 mm	98	97	92	82	63	43	23	4	0
Natural gravel 8-11 mm	100	100	100	100	100	100	98	82	0
Natural gravel 11-16 mm	100	100	100	100	100	100	100	97	10

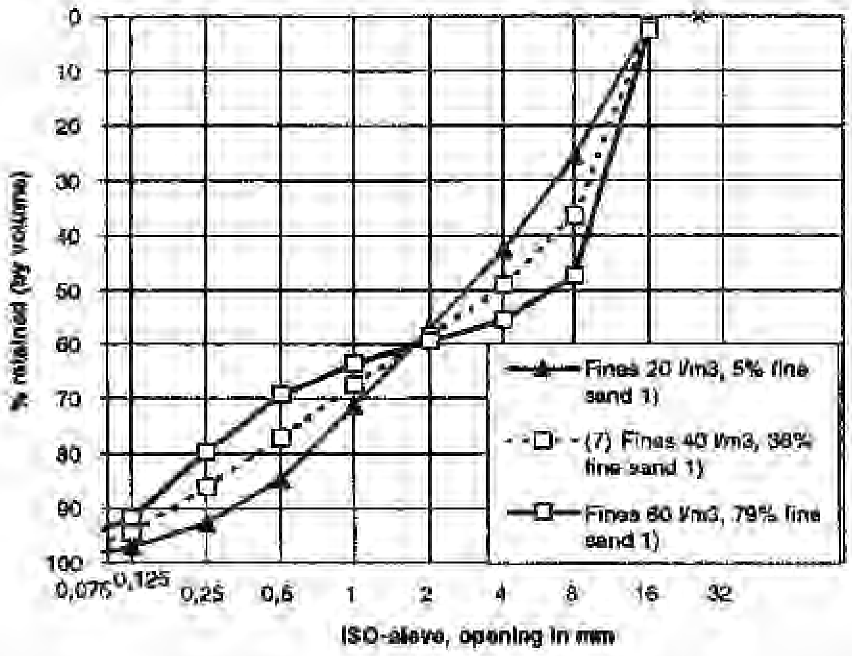
Figure 1. Grading curves for the natural aggregates from NorStone in Årdal

All the aggregates were produced at NorStone in Årdal, south-west of Norway. They all consist of about 80% granite and 20% gneiss, and the mica content in the fine fraction of the sand is low.

Different blends of natural sand were made by changing the weight proportions of the washed natural 0-8 mm sand and the secondary unwashed 0-2 mm sand. The content of fines (materials less than 0,125 mm) in the total aggregate blends varied from 20 to 60 l/m^3 of concrete (50 to 150 kg/m^3). The sand/stone-ratio also varied within a wide range (44/56 – 58/42). The following three strategies were applied for blending the aggregate, and five concrete mixes were made for each of the three groups:

1. **Constant Modulus of Fineness** (FM= 4,24)
2. **Constant volume of coarse aggregate** > 4 mm, (i.e the mortar volume is constant, but the fine sand/coarse sand ratio changes)
3. **"Balanced" sand/stone** (i.e. when increasing the fine sand content, the total sand decrease in the same proportion that the coarse aggregate increase, see Figure 4).

Figure 2 gives an example of grain size distributions for the total aggregate with a content of fines of 20, 40 and 60 l/m^3 and a constant Modulus of Fineness (4,24). The reference concrete with 40 l/m^3 of fines has a nearly straight grading curve from 0,125 mm to 4 mm.

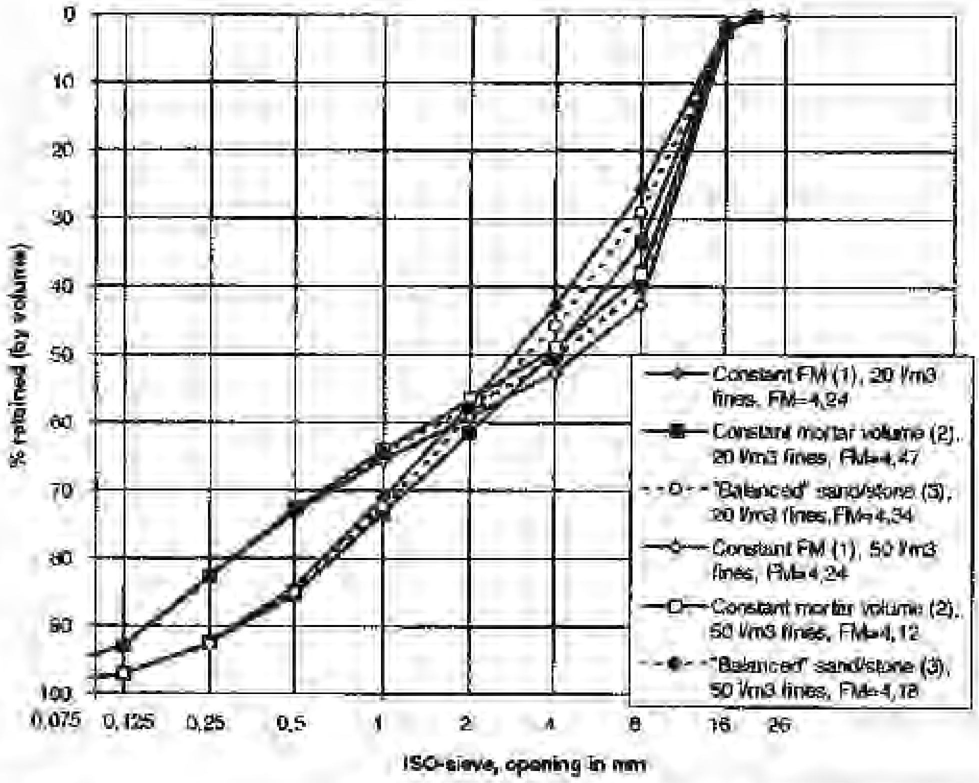


Total content of fines/ amount of fine sand	Volume % retained on sieve, mm								
	0,075	0,125	0,25	0,5	1	2	4	8	16
Fines 20 l/m^3, 5% fine sand [1)]	98,8	97,1	92,6	84,8	71	57	42,8	25,6	1,4
Fines 40 l/m^3, 36% fine sand [1)]	97,5	94,4	86,2	77,2	67	58	49,2	36,6	2
Fines 60 l/m^3, 79% fine sand [1)]	95,8	91,6	79,6	69,3	63	60	55,5	47,6	2,7

[1)]The percentage of fine sand 0-2 mm of the total sand blend

Figure 2. Grading curves for the total aggregate with 20, 40 and 60 l/m^3 of natural fines and given Fineness Modulus 4,24

Figure 3 shows the total grain size distribution for all the 3 blending strategies (numbered 1, 2 and 3) with a content of fines of 20 and 50 l/m^3, respectively. For a given content of fines, the grain size distribution < 2 mm is relatively similar for all the three blending strategies.



	Volume % retained on sieve, mm								
Aggregate composition	0,075	0,125	0,25	0,5	1	2	4	8	16
Constant FM, 20 l/m^3 fines, FM=4,24	98,2	97,1	92,6	84,4	71,2	57,1	42,8	25,5	1,4
Constant mortar, 20 l/m^3 fines, FM=4,47	98,2	97,1	92,6	85,5	73,3	61,6	49,3	33,4	1,8
"Balanced" sand/stone, 20 l/m^3 fines,FM=4,34	98,2	97,2	92,7	85,2	72,4	59,2	45,7	29,0	1,6
Constant FM, 50 l/m^3 fines, FM=4,24	95,8	93,0	82,9	73,4	65,6	59,2	52,7	42,6	2,4
Constant mortar, 50 l/m^3 fines, FM=4,12	95,8	92,9	82,8	72,8	64,0	56,6	49,0	38,2	2,1
"Balanced" sand/stone, 50 l/m^3 fines, FM=4,18	95,8	93,0	82,9	73,1	64,7	57,7	50,6	39,9	2,2

Figure 3. Total grading curves for three different sand/stone ratios and a content of fines of 20 and 50 l/m^3, respectively

3. CONCRETE COMPOSITION

With the aggregate compositions described in chapter 2, fifteen concretes with effective water/cement ratio of 0.60 were made. The following composition of the paste was kept constant:

- 285 kg/m^3 of Norcem Standard cement
- 171 kg/m^3 free water
- 0.5 % of cement weight of lignosulfonate plasticizer (40% dry material)

- 0.5 % of cement weight of naftalene superplasticizer (40% dry material)

The reference concrete with a 40 l/m³ of fines (about 100 kg/m³) has been intensively used in other parts of the programme. The composition of the reference concrete is shown in Table 1.

Table 1. Reference concrete composition, kg/m³ (with 270 l/m³ of paste and 2.5% air)

Norcem Standard cement (CEM I-42.5R)	285.0*
Deionized water	171.0*
Unwashed 0-2 mm sand	381.6
Washed 0-8 mm sand	763.3
Washed gravel 8-11 mm	381,6
Washed gravel 11-16 mm	381,6
Plasticizer Scancem P, 40%	1.42*
Superplasticizer Scancem Mighty 150, 40%	1.42*
Nominal concrete density	2365*

*These values were constant for the 15 mixes

Figure 4 shows how the content of mortar (i.e all materials less than 4 mm) varies with the amount of fines, depending on the chosen strategy for blending the aggregates. Be aware that the axes are of the same scale.

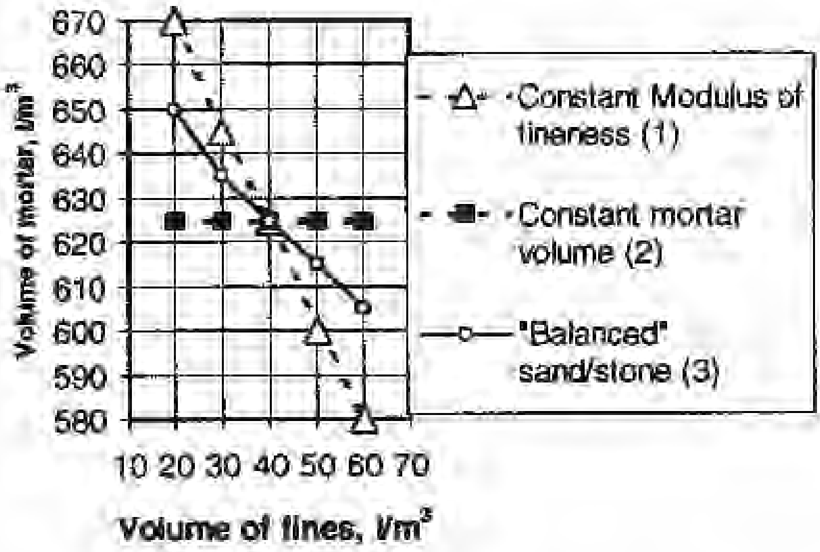


Figure 4. Mortar content depending on the volume of fines and the chosen strategy for blending the aggregates

When using a constant Modulus of Fineness (1), a given increase in the volume of fines gives twice as big reduction in the mortar volume. For example, from Figure 4 we can read that when increasing the volume of fines with 10 l/m³, the mortar volume decreases 20 l/m³ (and the volume of coarse aggregates, materials > 4 mm. increases about 20 l/m³).

When using a constant mortar volume (2), an increase in the volume of fines (constant cement content) will make the concrete more rich in fines.

The strategy with "Balanced" (3) changing of the volume of sand and stone gives an aggregate grading between (1) and (2) (see Figure 4). When increasing the volume of fines by 10 l/m ^{3}, the mortar volume decreases by the same volume (10 l/m ^{3}).

4. MEASUREMENTS, RESULTS AND DISCUSSION

4.1 Measurements

The following fresh concrete properties were measured:

- -Density and air content
- -Slump measure and "Flow Table measure" 0, 15 and 30 minutes after mixing
- -Bleeding development and total bleeding.

Concrete compressive strength was measured after 1, 7 and 28 days.

4.2 Results

Selected results are presented in the Figures 5 to 12 as functions of volume of fines and blending strategy of the aggregates. A more extensive report is presented in /4/.

The results for the mix with "balanced" sand/stone and 30 l/m ^{3} of fines are not included, because the mix was wrong (could be seen from consistency and compressive strength results).

The **density** had a slight tendency to increase and the **air content** was reduced with increasing content of fines. The air content changed slightly from one mix to another, but was nearly constant for the mixes with constant mortar content.

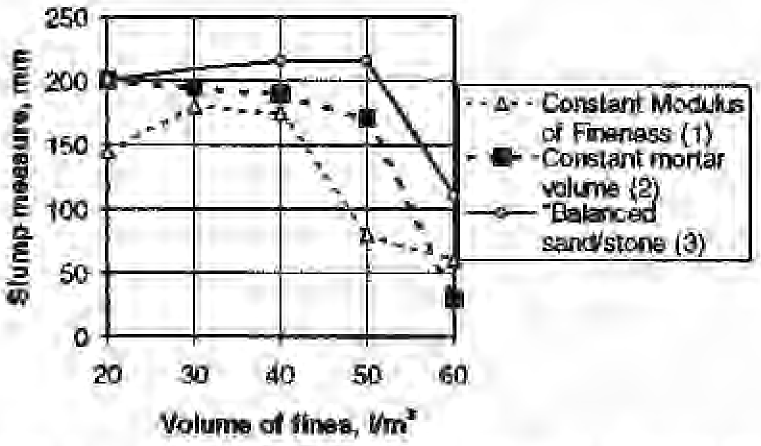


Figure 5. Slump as a function of volume of fines and the chosen strategy of blending the aggregates

Slump- and **"Flow Table"** measures as function of volume of fines and aggregate composition are presented in figure 5 and 6.

The tree sand/stone combinations showed only small variations in slump and flow measure, when increasing the content of fines from 20 to 40 l/m³. With constant FM (1) a marked reduction in consistency was observed when increasing the content of fines from 40 to 50 l/m³. Concrete mixes with constant amount of mortar (2) and "balanced" sand/stone (3) tolerated content of fines up to 50 l/m³ before the consistency started to decrease considerably. An explanation might be connected to the fact that the content of the coarse aggregate increases most for the mixes with constant Modulus of Fineness (1), see Figure 4. As shown in Figure 3, the differences of grain distribution of aggregate <2 mm is so small that it will have minor effect on the observed consistency differences.

Increased amount of fines, either as a pure filler or included in fine sand (as here), is a common method to increase the stability of lean concrete mixes. The results also confirm that the sand/stone ratio affects the fresh concrete properties.

As described above, none of the mixes lost consistency until the total content of fines was increased up to 50 to 60 l/m³ (105-130 kg/m³), despite of the fact that the total volume of fillers included cement ranged from approximately 110 to 150 l/m³. Neville /5/ recommends a total volume of fillers included cement of about 140 l/m³ (including air volume).

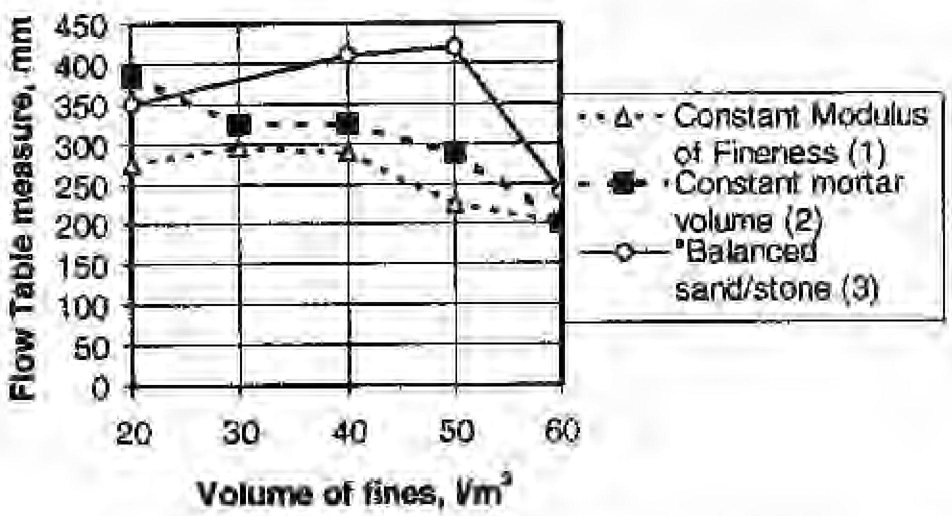


Figure 6. Flow Table values as function of fines and the chosen strategy of blending the aggregates

The last 3 mixes in the series with "balanced" sand/stone (3) with a content of fines of 40, 50 and 60 l/m³ had higher consistency values than the other series. This is probably due to more moisture on the surface of the coarse aggregates. A new bag of gravel 11-16 mm was brought into the laboratory and it was observed that the aggregate particles had a "moist colour". In contrast to the fine aggregates, the water content of the coarse aggregates is normally considered from a surface dry state.

In Figure 7 a correction for the higher moisture content in series (3) has been made by decreasing the slump measure of the reference concrete (with 40 l/m³ fines), to the slump level of the concrete in series (2) with identical composition. The other slump values in this series (3) (except the slump for the mix with 20 l/m^3 fines) are also decreased with the same percentage. However, the corrections do not influence the main conclusions drawn above.

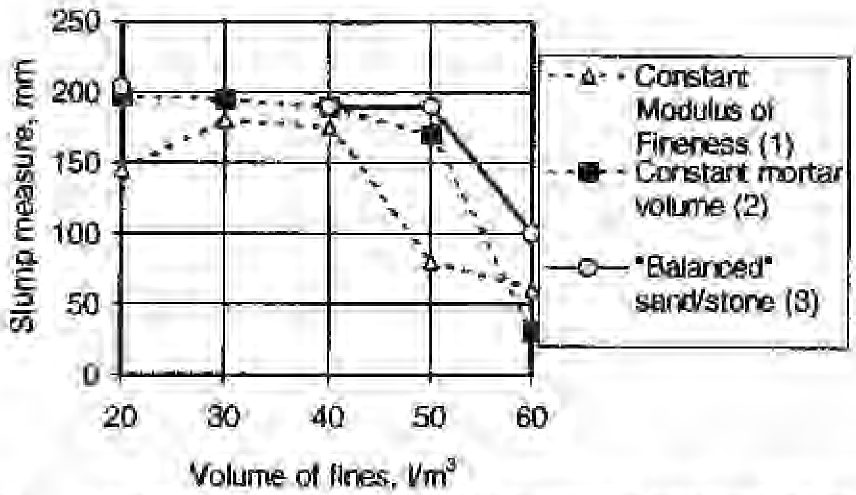


Figure 7. Corrected slump as function of volume of fines and the chosen strategy of blending the aggregates

Slump loss versus content of fines is shown in the Figures 8 and 9 as a function of aggregate composition. When using constant Modulus of Fineness (1) and constant mortar volume (2), the slump loss increased with increased content of fines.

In contrast to this, the concrete mixes with "balanced" sand/stone (3), which had the highest slump measures after mixing showed no increase in the slump loss when the content of fines increased from 20 to 50 l/m^3. Increasing the fines content up to 60 l/m^3, however, made a high slump loss also for this series. The high slump of series (3) (probably due to a slightly higher coarse aggregate moisture content) is supposed to be the reason for less slump loss, i.e. the differences in slump loss cannot be traced back to differences in the aggregate compositions.

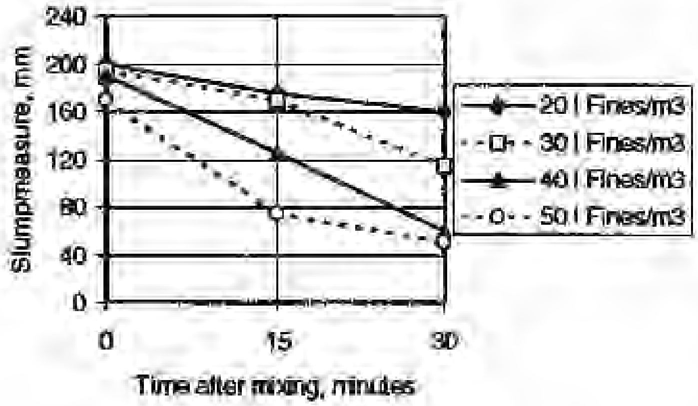


Figure 8. Slump loss as function of volume of fines. Constant mortar volume 625 l/m^3 (2)

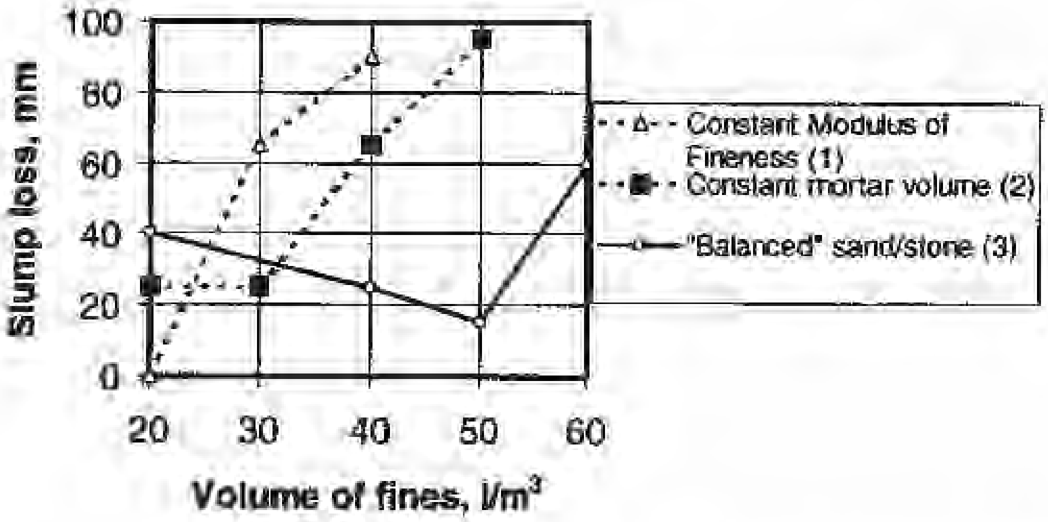


Figure 9. Slump loss from 0 to 15 minutes as function of volume of fines and the strategy of blending the aggregates

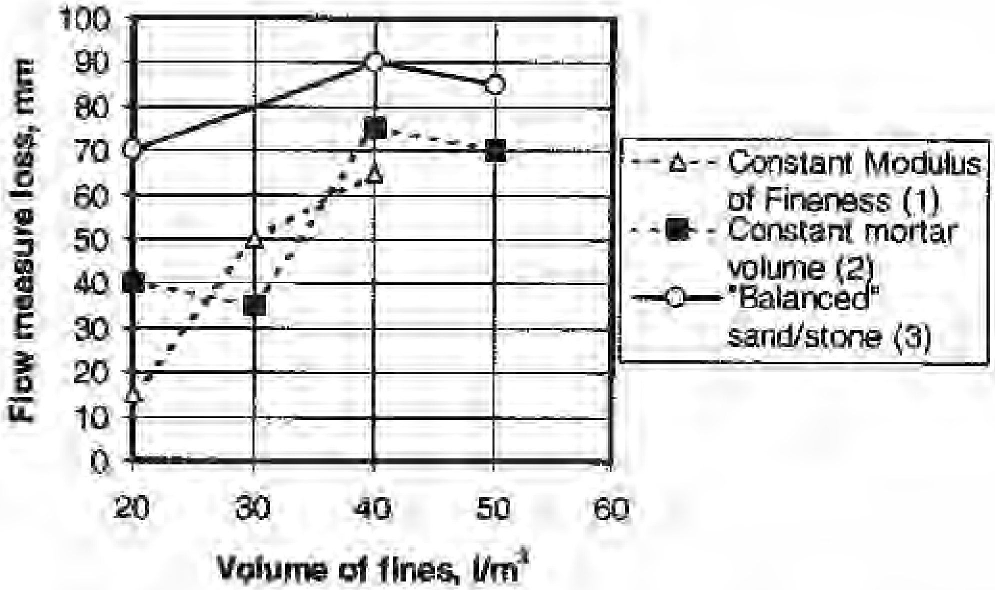


Figure 10. Flow measurement loss from 0 to 15 minutes as function of volume of fines and the strategy of blending the aggregates

The Flow measure loss, as shown in Figure 10, also had a tendency to decrease with increasing content of fines. In contradiction to the slump loss, the series with "balanced" sand/stone (3), showed the highest Flow Table values directly after mixing. The ranking of the concretes with respect to consistency loss is strongly dependent on whether one is measuring the slump or the flow. Often the loss of consistency is earlier detected using Flow Table test than using slump test.

Total bleeding as function of content of fines and aggregate composition is shown in Figure 11. The total bleeding at the lowest content of fines (20 l/m^3) were relatively high and independent of the three sand/stone-ratios, (see Figure 4). An increase in the content of fines from 20 to 30 l/m^3 gave a marked reduction in the total bleeding for concrete mixes with constant Fineness Modulus (1) or constant mortar content (2). A further increase of fines had only a minor effect on the total bleeding.

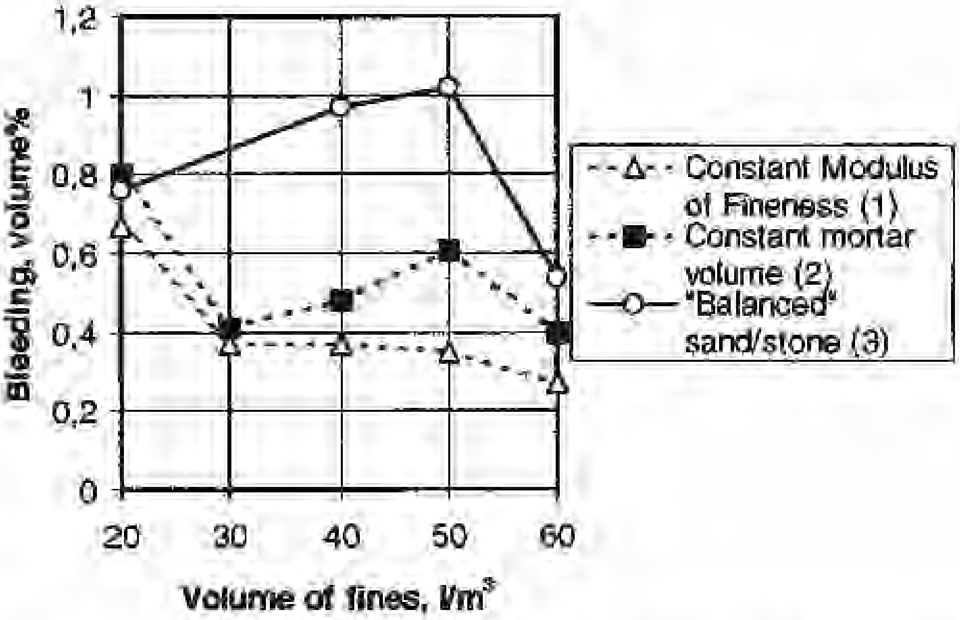


Figure 11. Total bleeding as function of volume of fines and strategy of blending the aggregates

However, for concrete mixes with "balanced" sand/stone (3) the total bleeding increased with increasing content of fines up to 50 l/m^3. The bleeding was first reduced at the highest content of fines (60 l/m^3). The reason is probably connected to the increased water content as discussed before.

All the measured **compressive strengths** were relatively similar, and laid within the range statistically expected for concrete of the same composition (see Figure 12). A slight tendency to somewhat higher compressive strength after 28 days for 30 and 40 l/m^3 is not significant. The standard deviation within the same mix with three parallel cubes was less than 1.0 MPa. Then we can conclude that the measured compressive strength was not significantly affected by the sand/stone-ratio and the content of fines for a w/c-ratio of 0.60.

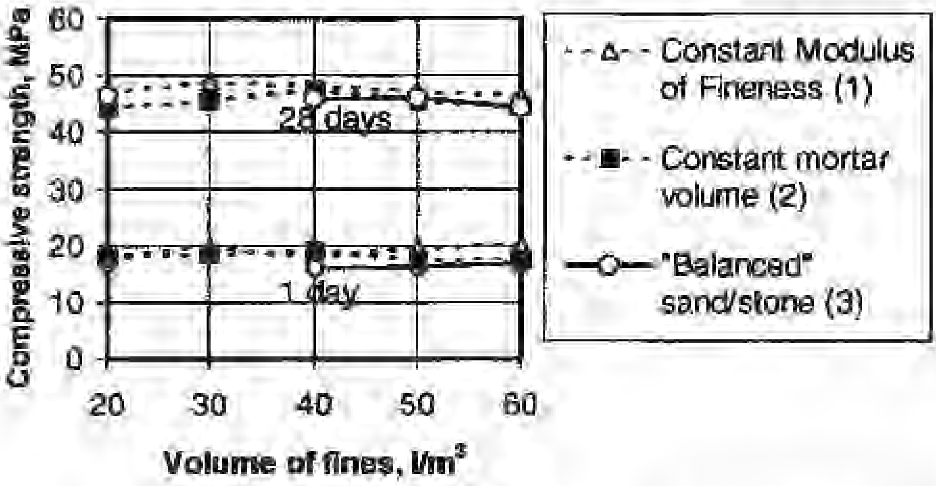


Figure 12. Compressive strength as function of fines volume and strategy of blending the aggregates, w/c=0.60

5. CONCLUSIONS FOR W/C-RATIO 0.60

A study of the effect of fines/sand/stone relations on the fresh concrete properties and compressive strength of concretes with water/cement ratio of 0.60 and 285 kg/m³ of standard cement led to the following conclusions:

- Air content decreased slightly and density increased moderately with increasing amount of fine sands (i.e. increasing content of fines).
- For different sand/stone ratios and the content of fines (< 0.125 mm) varying from 20 to 50 l/m³ of concrete, only small variations in the consistency (slump and flow measure) were observed. A further increase in the content of fines led to a considerable decrease of the consistency.
- The consistency loss increased in most cases with increasing content of sand rich in fines.
- The concrete mixes with the highest slump (200-220 mm) with moderate volume of fines (20-50 l/m³), had a low slump loss, but a high flow measure loss.
- For filler content from 30 to 50 l/m³ the total bleeding to some extent depends on the aggregate composition.
- For concrete mixes with w/c-ratio 0.60 it is possible to use considerable amounts of fine sand rich in fines and still retain acceptable fresh concrete properties, without changing the paste composition.
- The compressive strength was not significantly affected by the amount of natural fine sands and changes in sand/stone ratio.

6. REFERENCES

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