STUDIES OF THE FLOW BEHAVIOUR AND COMPATIBILITY OF CEMENT-SUPERPLASTICIZER SYSTEMS

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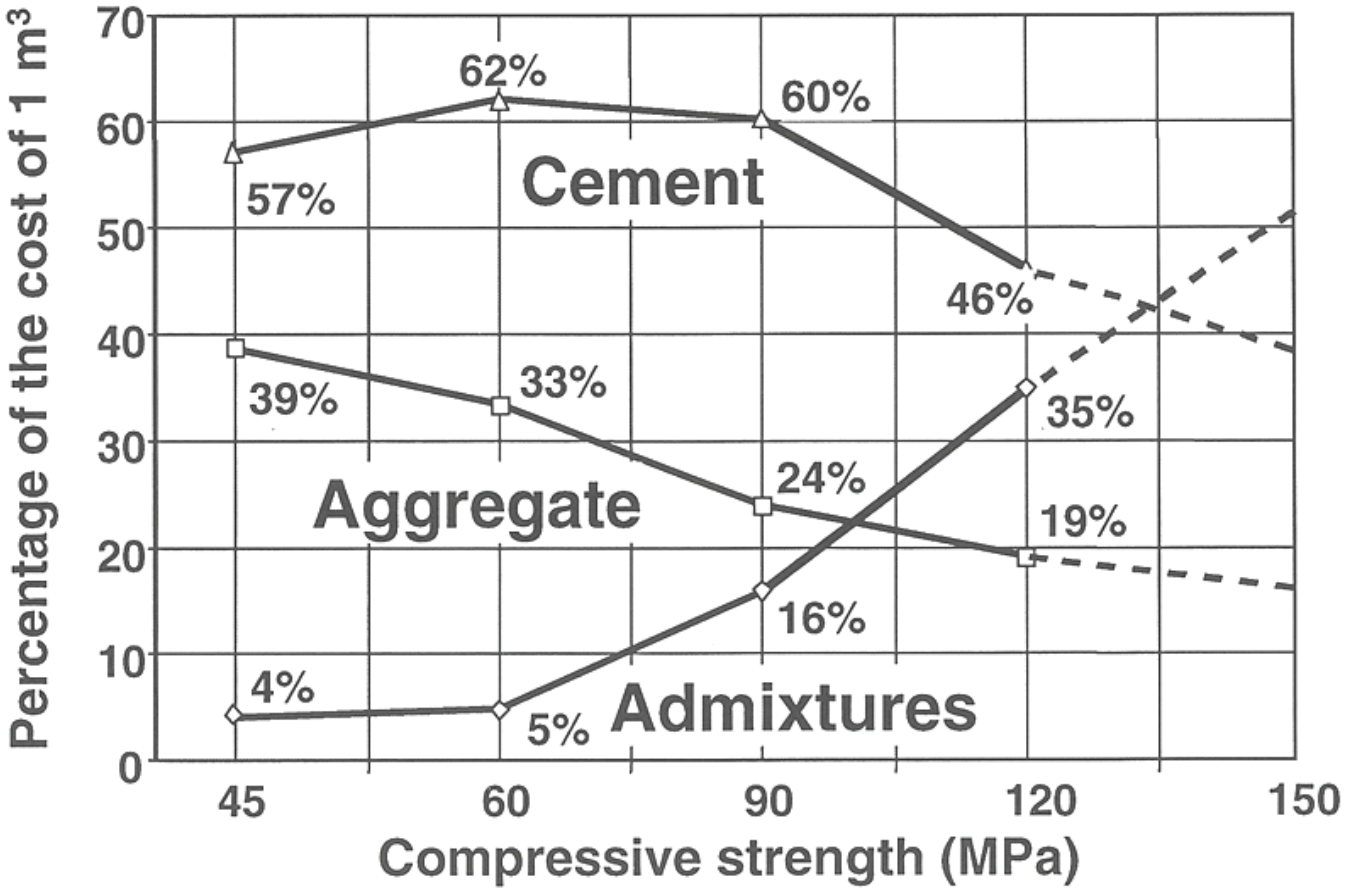
Recent Advances and Challenges in Concrete Technology

- **High quality concretes,** especially high strength and high performance concretes, incorporate **chemical admixtures** particularly superplasticizers to provide the **desired properties.**

- However, **variations** in the characteristics of **cement** and type and dosage of **admixtures, compromise the benefits** of incorporating a superplasticizer due to **incompatibility problems.**

Chemical Admixtures: Significance



Factors affecting the Performance of Admixtures

- **Type and dosage** of **admixtures**
- Nature of **cement and aggregates**
- **Water-cement ratio**
- **Environmental conditions**
- **Addition procedure** of admixtures

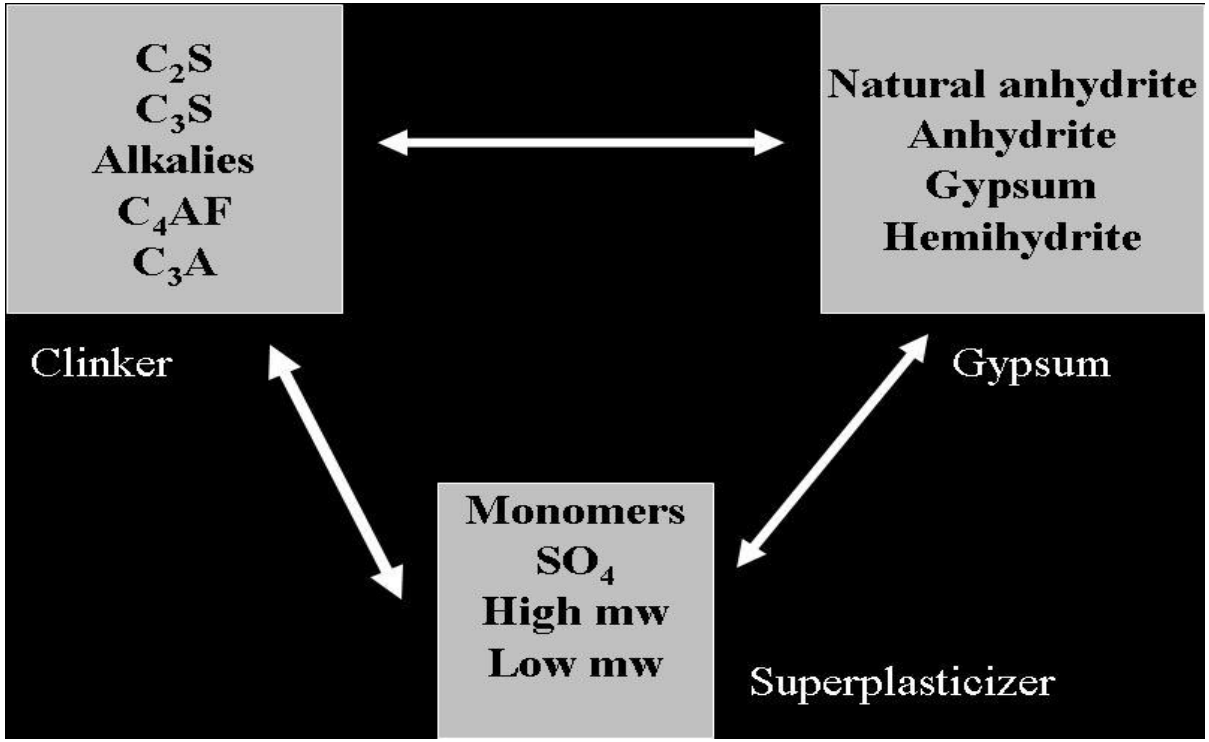
Incompatibility problems between cement and admixtures are:

- Rapid loss of workability,
- Segregation of concrete
- Acceleration/ retardation of setting,
- Low rates of strength gain,
- Entrainment of air

Cement/admixture and admixture/admixture interactions are not yet well understood.

FACTORS

Factors Affecting Cement-Superplasticizer Interactions



Direct Effects:

- Rate of hydration reactions
- Solubility of Calcium Sulphate
- Adsorption of Superplasticizer

(based on Aïtcin, 1998)

How to Handle the Interactions and their Effects ?

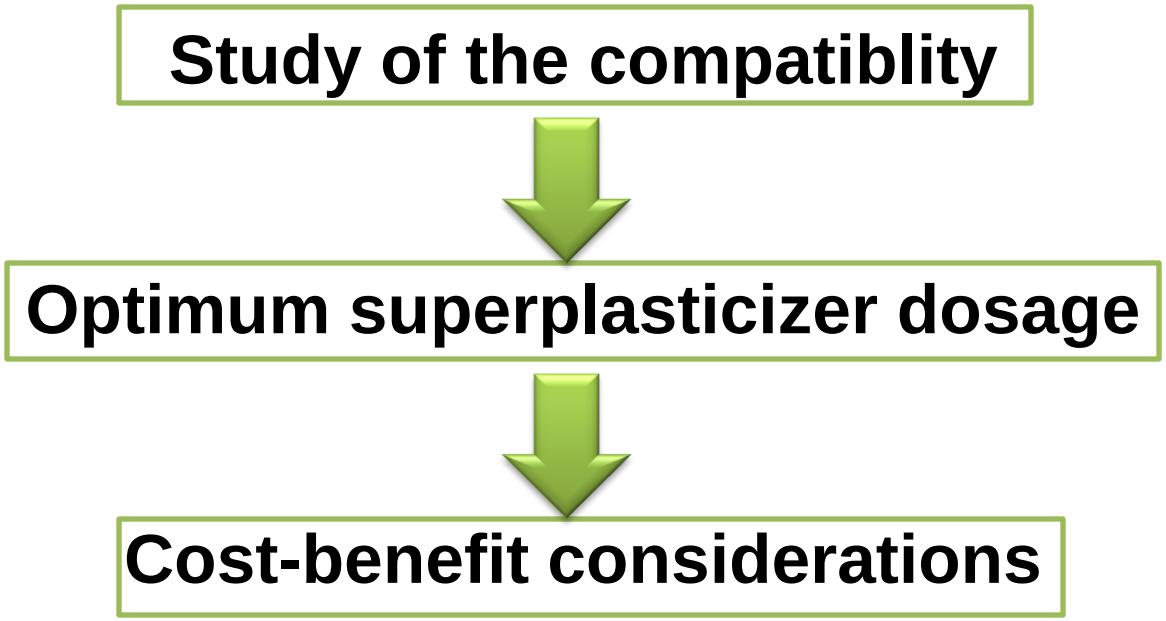
- Different **admixtures behave significantly differently** from each other even though they are all considered as superplasticizers of the **same chemical family.** Also, **different cements of the same type can behave very differently.**

- The **differences** are more **evident** in concretes with **low water/cement ratios** and **high admixture dosages.**

- The proper **selection of superplasticizer type and dosage** is necessary in terms of **compatibility with the cement.**

- **We need some simple procedures to choose compatible combinations of cement and superplasticizer (instead of performing many tests on concrete).**

Selection of the Superplasticizer



In several cases, this order is inverted, resulting in costly consequences

Cement Characteristics

Parameter	CEMENT A	CEMENT B	Requirements
1. Calcium oxide (CaO)	60.81	61.49	
2. Silica (SiO_2)	19.50	22.98	
3. Alumina (Al_2O_3)	4.12	6.07	
4. Iron oxide (Fe_2O_3)	6.06	4.56	
5. Magnesia (MgO)	1.52	0.85	max 6.0%
6. Sulphur anhydrite (SO_3)	2.48	2.23	max 2.5%
7. Insoluble residue	1.51	1.47	max 3.0%
8. Total loss on ignition	3.41	1.40	max 4.0%
9. Total chloride content (Cl)	0.01	0.01	max 0.1 %
10. Available alkali: Na_2O	0.05	-	
K_2O	0.28	-	
11. Ratio of % of lime to the % of silica, alumina and Iron oxide	0.93	0.80	0.80 to 1.02
12. Ratio of % of alumina to that of Iron oxide	0.68	1.33	min 0.66
Consistency of cement	33%	34%	
Initial setting time	99 minutes	87 minutes	
Final setting time	184 minutes	165 minutes	
Specific surface area by Blaine's test	316 m^2/kg	290 m^2/kg	

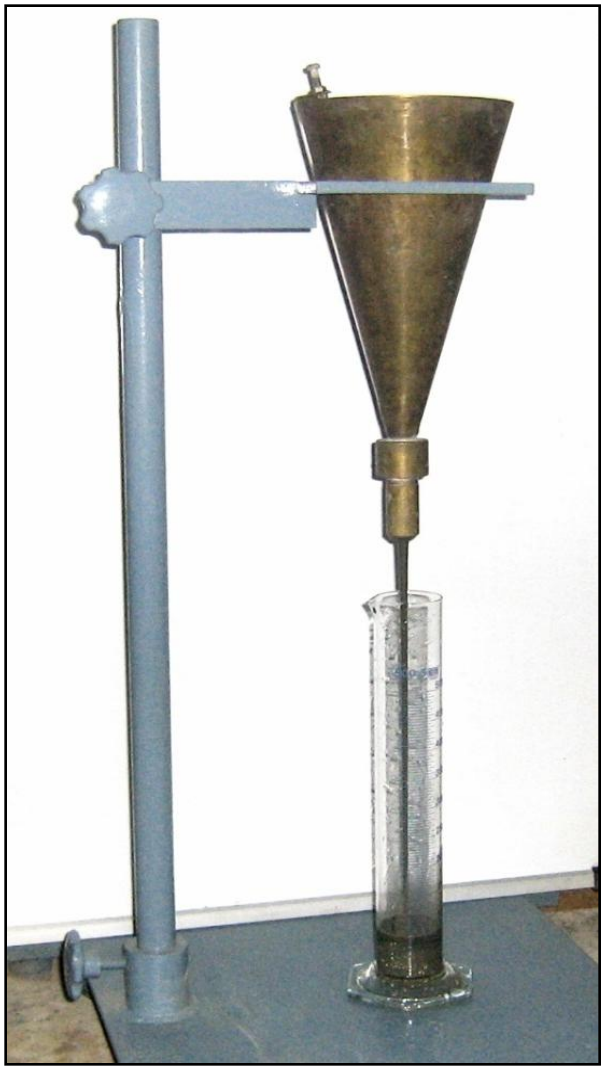
Superplasticizer characteristics

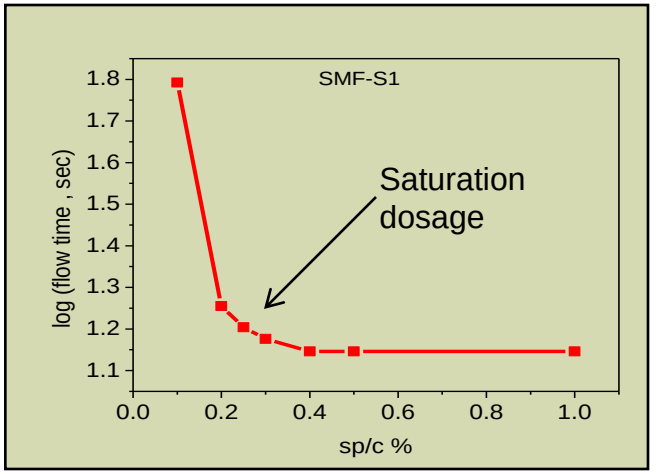
Superplasticizer (PCE)	Solids content (%)	Dosage for Cement A	Dosage for Cement B
A	33	1.0	0.75
B	30	1.0	1.0
C	38	1.0	1.0

How to Handle the Interactions and their Effects ?

- Many **factors** affect the **interaction between cement and superplasticizer.**
- Most factors cannot be modified by (or even known to) the user.
- We need some **simple procedures to choose compatible combinations of cement and superplasticizer** (instead of performing many tests on concrete).

Marsh Cone Test: Evaluation of the compatibility and dosage

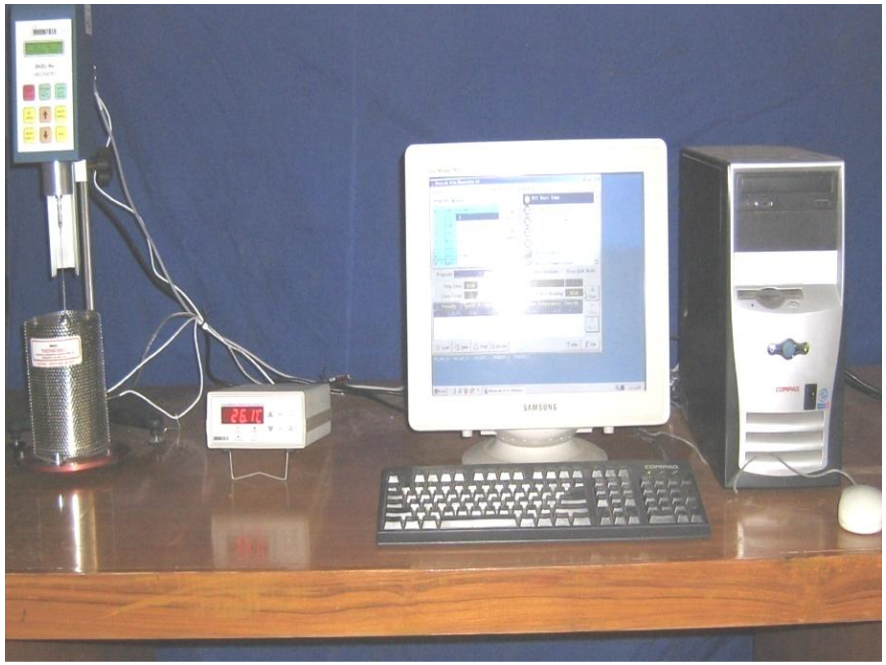




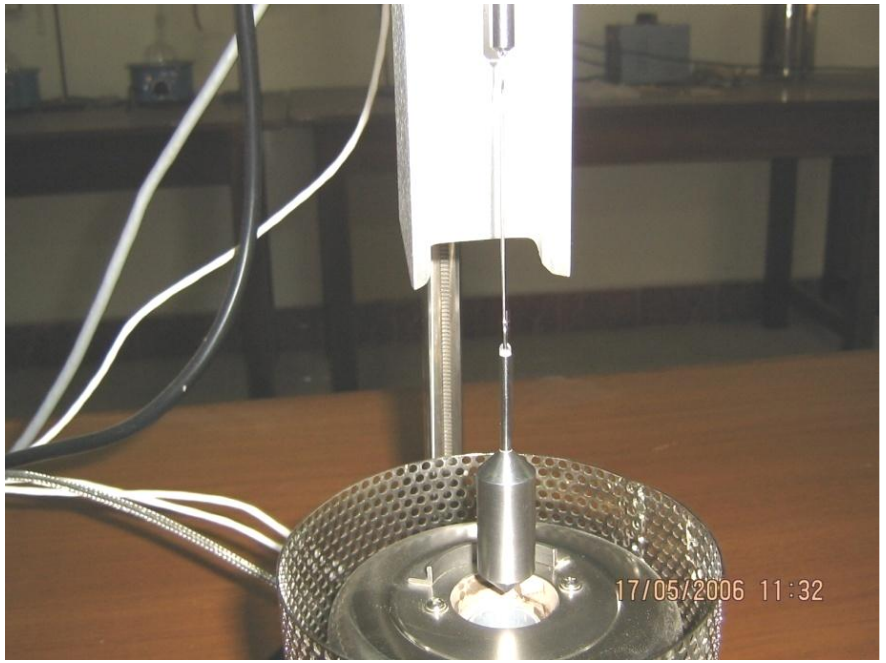
Mixing sequence:

- 70% of mixing water is added with cement initially
- Superplasticizer and remaining water added after one minute
- Mix for two minutes at same speed
- Clean the blade and sides of bowl (25-30sec)
- Mix for 2 minutes at medium speed

Viscometric Study



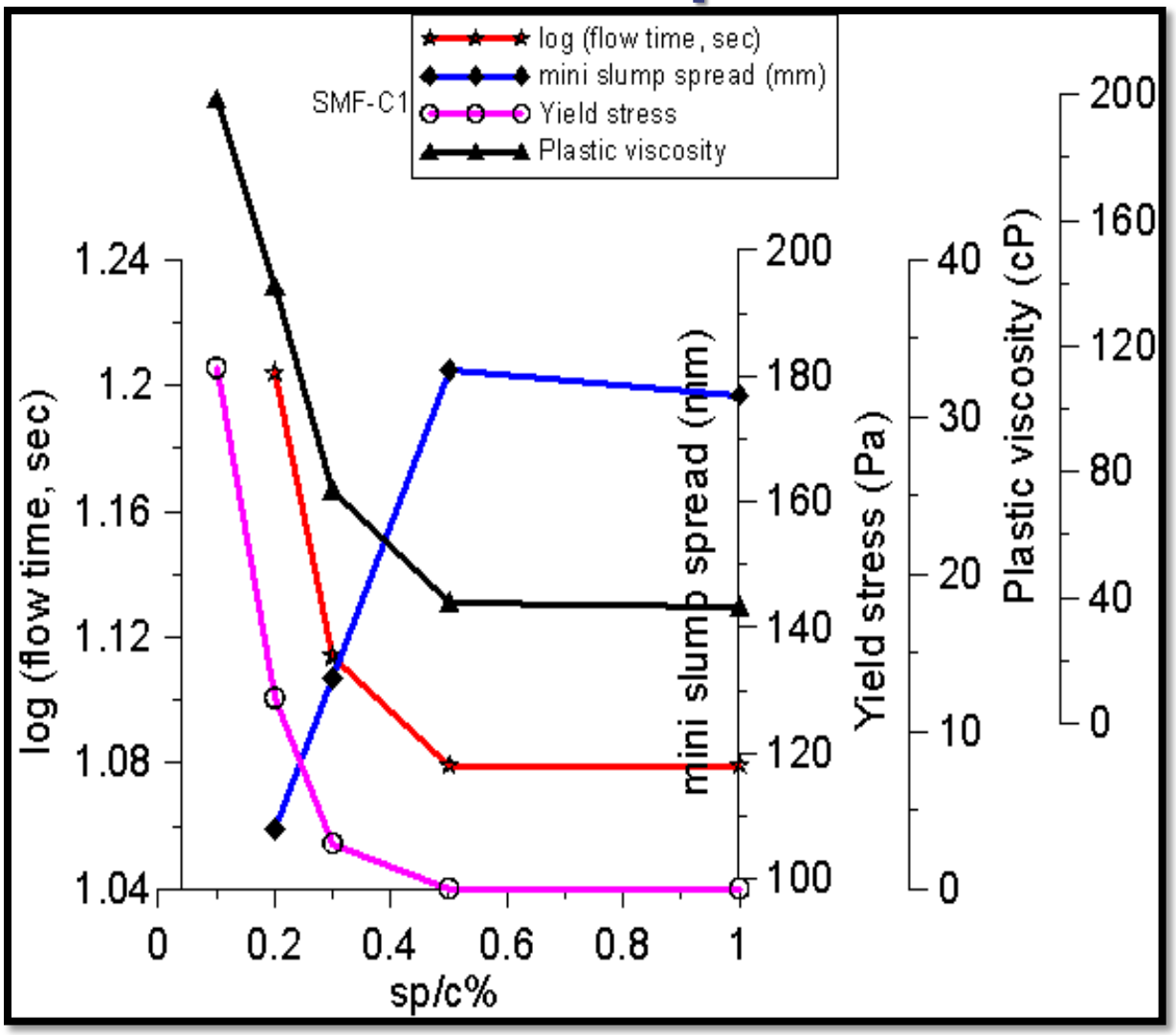
Viscometer



Co-axial cylinder setup

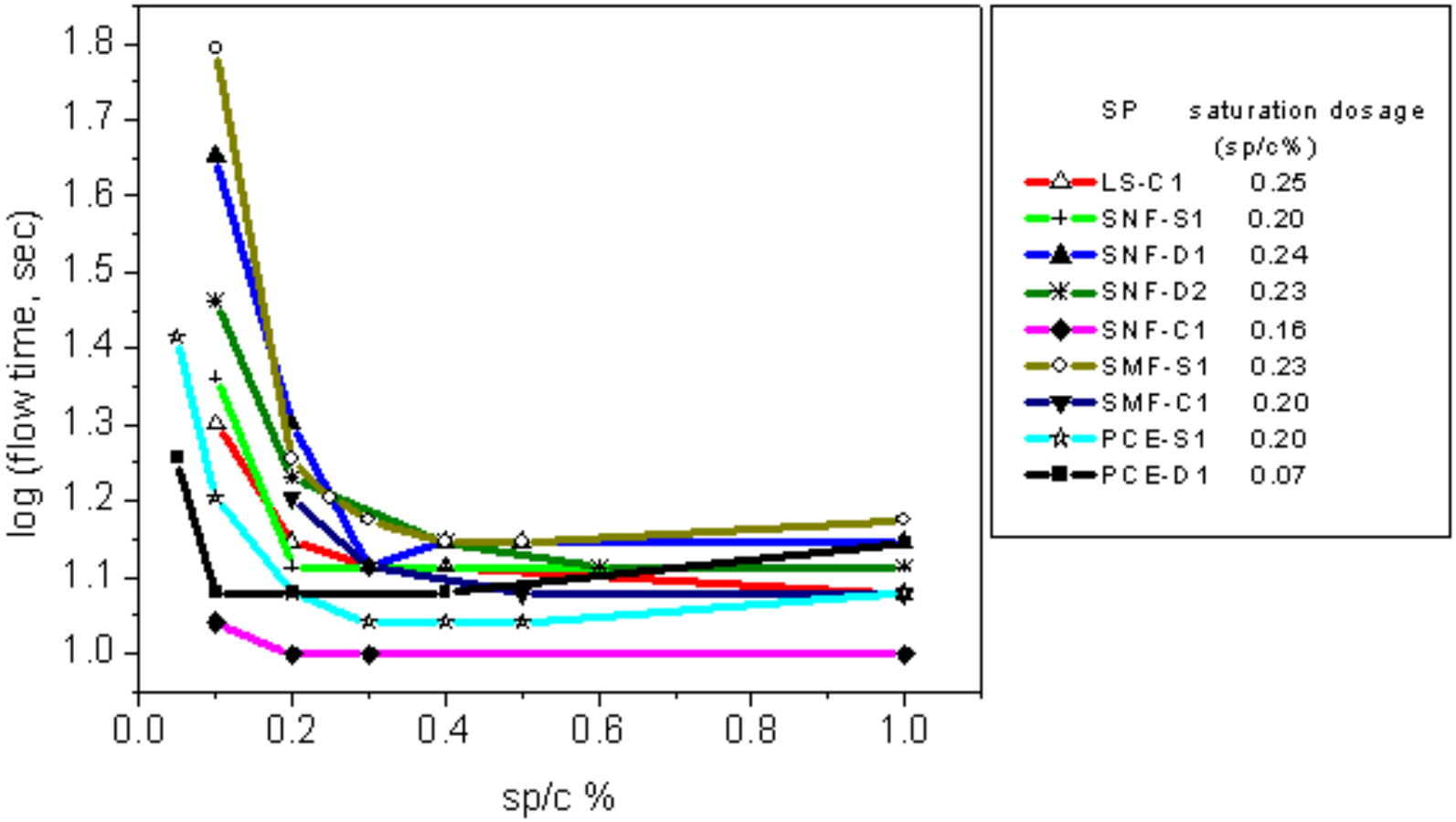
- To understand the influence of **type and dosage** of superplasticizer on **yield stress and plastic viscosity** (as defined in the Bingham model).
- The basic principle is to apply a given **shear rate** to the fluid through the spindle and measure the corresponding **shear stress produced.**

Marsh Cone Test: Comparison of flow time with mini-slump spread and rheological parameters



After the **saturation dosage**, the **flow time, spread** and the **rheological parameters** (yield shear stress and plastic viscosity) **do not change.**

Selection of Superplasticizer



1 Flow time decreases with increase in dosage of superplasticizer

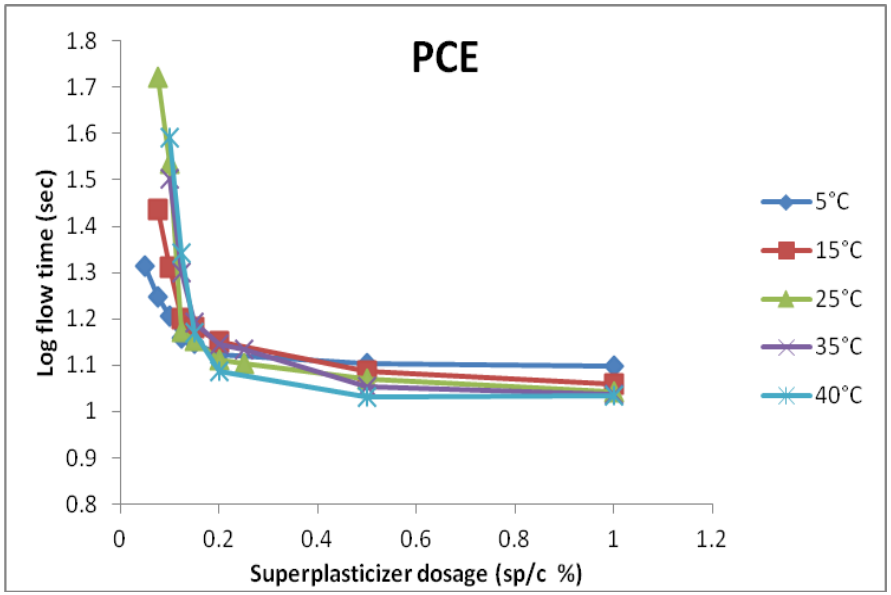
2 Saturation dosage varies with the type of the superplasticizer.

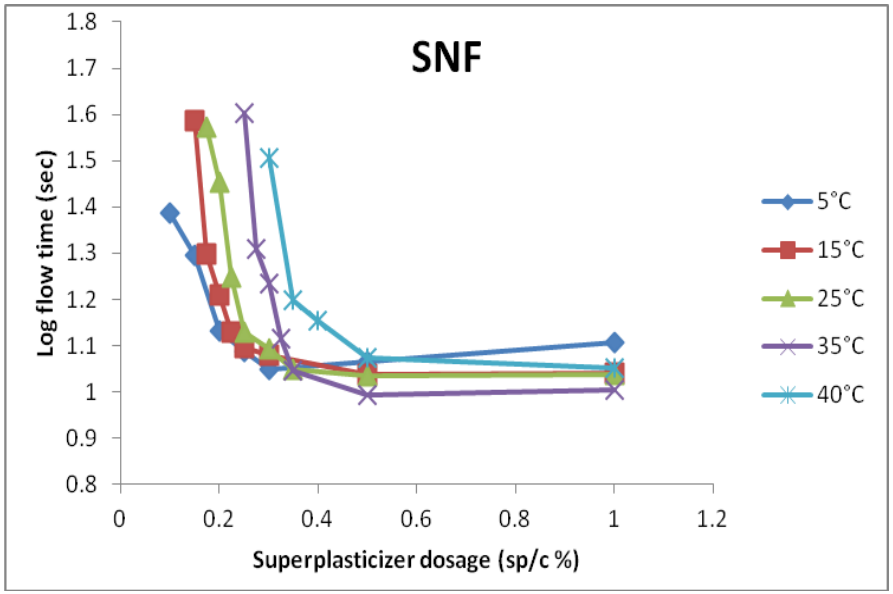
Influence of Type of Cement on Cement-Superplasticizer Interaction

Type of SP	Saturation dosages%			
	C1	C2	C3	C4
LS-C1	0.25	0.40	0.25	0.4
SNF-S1	0.20	0.25	0.20	0.25
SNF-D1	0.24	*	*	*
SNF-D2	0.23	0.3	0.2	0.2
SNF-C1	0.16	*	*	*
SNF-C2	*	*	0.2	0.4
SMF-S1	0.23	0.4	0.2	0.3
SMF-C1	0.20	*	*	*
PCE-S1	0.2	*	*	*
PCE-D1	0.07	0.2	0.08	0.15

Amounts of SO_3, C_3A and alkalis govern the flow behaviour and saturation dosage.

EFFECT OF TEMPERATURE ON THE FLUIDITY OF SUPERPLASTICIZED CEMENT PASTE





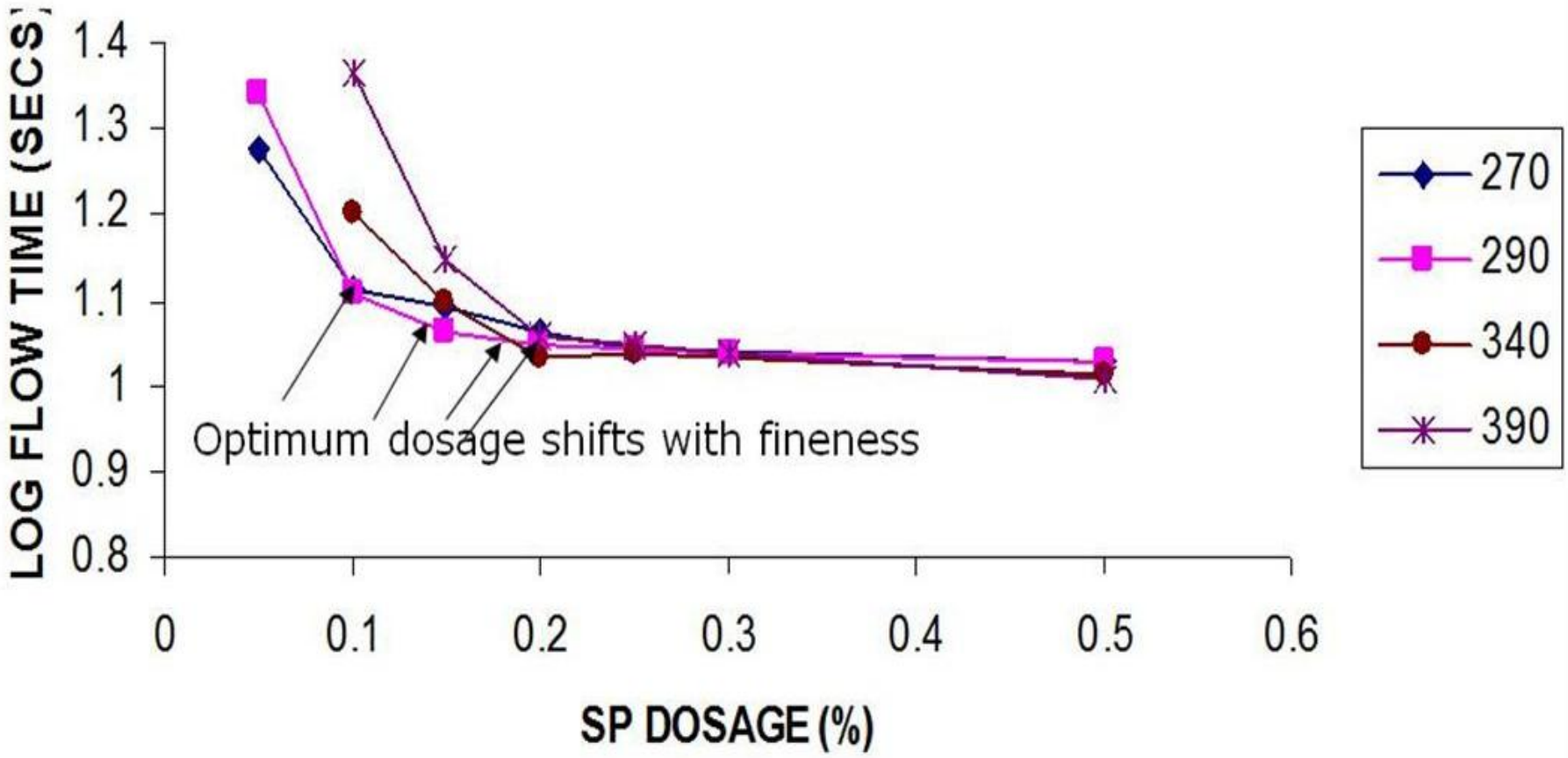
The PCE based superplasticizer is less sensitive to changes in the ambient temperature, especially when the dosage is close to the saturation dosage

Influence of Temperature on Cement-Superplasticizer Interaction

Temp. (C)	PCE	SNF	SMF	LIGNO
5	0.125	0.2	0.2	0.25
15	0.125	0.25	0.25	0.35
25	0.125	0.25	0.25	0.5
35	0.18	0.325	0.45	0.7
40	0.2	0.35	0.5	0.75

Saturation dosage of superplasticizer increases with an increase in ambient temperature

Influence of cement fineness on paste with PCE superplasticizer



Influence of fineness of cement on Cement-Superplasticizer Interaction

Cement	Optimum Dosage	
	PCE	SNF
270	0.1	0.15
290	0.1	0.15
340	0.18	0.3
370	0.20	0.35

Saturation dosage of superplasticizer increases with increase in fineness of cement

GUIDELINES FOR CHOOSING COMPATIBLE COMBINATIONS OF CEMENT & SUPERPLASTICIZER

Cement-Superplasticizer Checklist

Step 1 : Study of Paste Characteristics (1/3)

- Record the **basic properties of cement and superplasticizer** for the quality checks, as well as for comparing different batches of products.

- The Hobart mixer or a similar **intensive mixer** is essential for the preparation of the paste in order for it **to represent the paste within concrete.**

STEP 1

Cement-Superplasticizer Checklist

Step 1 : Study of Paste Characteristics (2/3)

FİRST CRİTERİON : A well-defined saturation dosage from the Marsh cone test that is within the maximum dosage of the superplasticizer recommended by the supplier.

The **dosage obtained from the paste tests** can be used as the **guideline for selecting the dosage** of superplasticizer for concrete.

STEP 1

Cement-Superplasticizer Checklist

Step 1 : Study of Paste Characteristics (3/3)

SECOND CRİTERİON : The **influence of superplasticizer on the setting behaviour** of the paste is checked.

Here, the **final setting time of paste** is limited to **16 hours** as obtained in the **Vicat penetration test.** If this criterion is satisfied, the final setting time of concrete would be not more than 12 hours.

STEP 1

Cement-Superplasticizer Checklist

Step 2 : Study of Concrete Characteristics (1/2)

- **Tests** done on **concrete** to ensure a mix with the required **slump.**

- Superplasticizer **dosage may be increased** if the saturation dosage is not sufficient; however, it is recommended that the dosage is **not more than 150% of the saturation dosage** in order to limit the retardation and possible segregation, as well as cost.

STEP 2

Cement-Superplasticizer Checklist

Step 2 : Study of Concrete Characteristics (2/2)

- From the point of view of productivity, a **minimum value of 50% of the 28-day compressive strength** is recommended at 3 days (when the early age strength is critical).

- The **final choice** of the superplasticizer can be based on the **minimum cost** considering the dosage of the superplasticizer for obtaining the desired slump **among the compatible combinations.**

STEP 2

Conclusions

The **optimum dosage of SP** is also a **factor** determining the **compatibility** between cement and SP.

A **well defined saturation dosage** obtained in the tested compositions **represents compatibility** between cement and SP.

The **optimization of cement paste** can be the **preliminary step** in the mix design of concrete in terms of selecting the **most appropriate superplasticizer and its dosage.**

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Conclusions

Single test is **not sufficient** to identify compatible combinations.

A **methodology** based on the **flow and setting behavior of pastes** can be used to identify compatible cement-superplasticizer **combinations.**

THANK YOU