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High Early Strength Concrete without Steam Curing

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Abstract -- This paper presents the laboratory investigations of the research work carried out for the precast concrete pipe production plant to identify optimum mix proportions for the production of high early strength concrete without steam curing. Compressive strength, workability and water demand results are presented.

Keywords- **Cement, Compressive Strength, Materials, Super Plasticizer, Workability.**

I. INTRODUCTION

The purpose of this project was to develop mix proportioning information for production of high early strength concrete for precast concrete pipe production. The precast concrete pipe of 2.40m internal diameter, 250mm wall thick and a length of 4m are to be used as a casing for the gas pipe line which is crossing the river and to be placed at a depth of 35m below the bed level of the river.

At the site around 650 pipes are to be casted in a period of 3months and those are to be laid at place by pipe jacking before the monsoon hits using tunnel boring method from both the ends of the river. So the requirement for the production of the pipe is 20Mpa at the age of 16hrs without steam curing. The production schedule has foreseen to produce 6 pipes per day, which requires to strip the formwork after 6hrs and curing compound is applied immediately then pipe is shifted to the stockyard after 16-18hrs. For lifting the pipes the concrete must have reached a compressive strength of at least 20N/mm²at 16hrs. The compressive strength of the concrete shall be at least 50N/mm² when pipe jacking operations start.

II. EXPERIMENTAL PROGRAMME

The experimental programme was divided into the following three phases.

- Tests on cement and other ingredients
- Tests on fresh concrete
- Tests on hardened concrete

Cement: In a first approach Grade 53 cements of different brands (namely C-1, C-11, C-111, C-IV and C-V) were tested as per IS: 4031-1968. The strength development was slightly lower as even required by IS: 12269-1987. Beside compressive strength the hardening behavior and speed were investigated by measuring the heat development of a cement paste in a thermos container, which enabled semi-adiabatic conditions.

For the test a cement paste consisting of 200gms cement and 70 ml water was mixed in a plastic beaker. Immediately after mixing, the beaker was placed in a thermos container and equipped with a thermo-wire. The temperature gain was recorded over about 22 hrs. The setup is shown in figure 1. The heat generation of different cements relates to the strength gain for those cements are depicted in figure 2.

Figure 1: Heat Generation of Cement – Test Setup

The only alternative to a grade 53 was special cement, which is used for the production of prestressed concrete elements (Railway sleepers) because of its high and consistent quality. The special cement of different brands were represented as SC-I and SC-II.

The one day compressive strength of special cement was 20-25Mpa which is considerably higher than tested for the common grade 53 cements and matched at 7days. The BIS requirements are greater than 27Mpa with 28-30 Mpa.

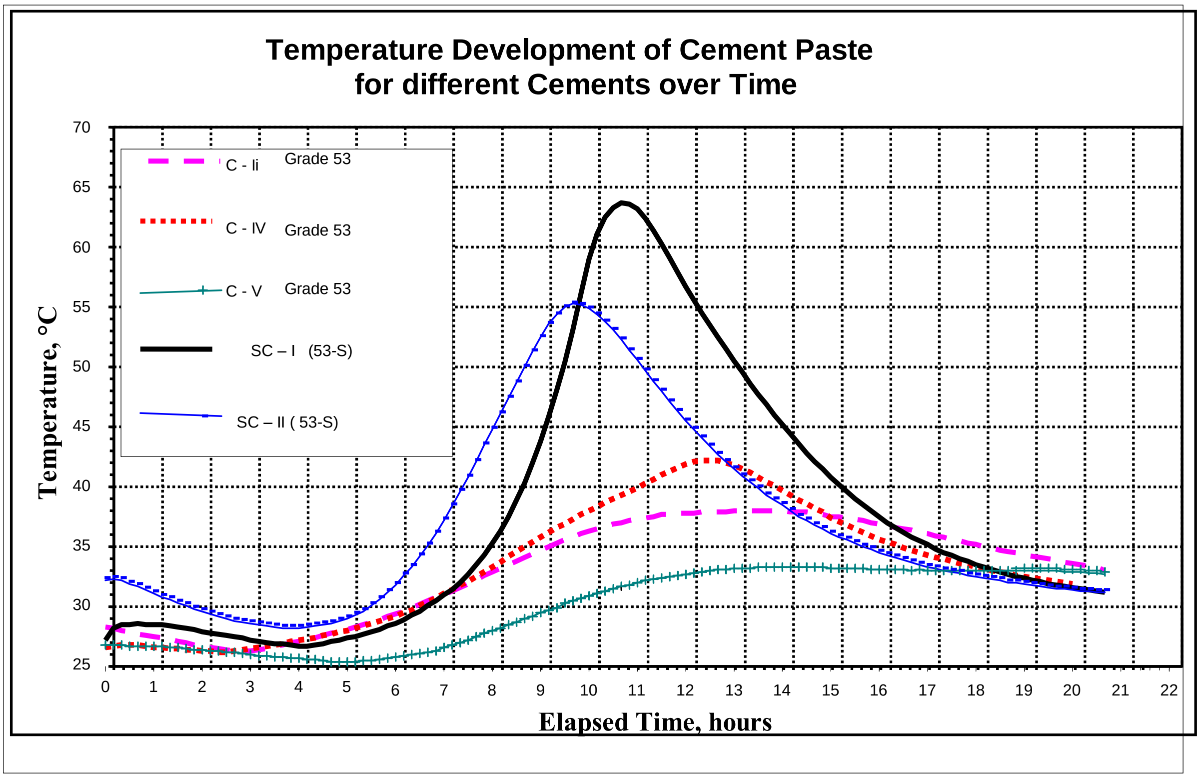

Fig.2. Heat Generation of Cement

Physical Properties of Sleeper Cement

(Tests are carried out as per IS: 4031-1968)

1. Normal Consistency – 29.5%
2. Specific Gravity – 3.15
3. Setting time (a) initial – 130 min
   (b) Final – 220 min
4. Fineness - 3700 gm/mm^2 Blains

Note: Finally the best one even from the special cements is selected from the temperature curves for the investigated cements.

A. Aggregates

Locally available river sand of specific gravity 2.53 with fineness modulus of 2.91 conforming to zone II. The fines content in river sand affects the performance of SPs [Papayianni, G. Papayianni, N. Tsohos, Oikonomon, and P. Marira 2005] and crushed quarried granite stones of specific gravity 3.01 for 20mm aggregate and 2.96 of 10mm aggregate were used as fine and coarse aggregates respectively in all concrete mixes throughout the investigation.

B. Admixtures

The following admixtures were tested in respect to their efficiency with the investigated cements and the retarding effect. The chemical basis and the types of superplasticisers used are given in table 1.

Table 1: Investigated Concrete Admixtures

Superplasticiser Product Name	Chemical Basis
SP-I	Multicarboxylatether (MCE)
SP-II	Naphthalene Formaldehyde
SP-III	Melamine Formaldehyde
SP-IV	Sulphonated Naphthalene
SP-V	Sulphonated Naphthalene
SP-VI	Sulphonated Naphthalene
SP-VII	Sulphonated Naphthalene
SP-VIII	Sulphonated Naphthalene
SP-IX	Multi carboxylat ether (MCE)
SP-X	Sulphonated Naphthalene
SP-XI	Sulphonated Naphthalene

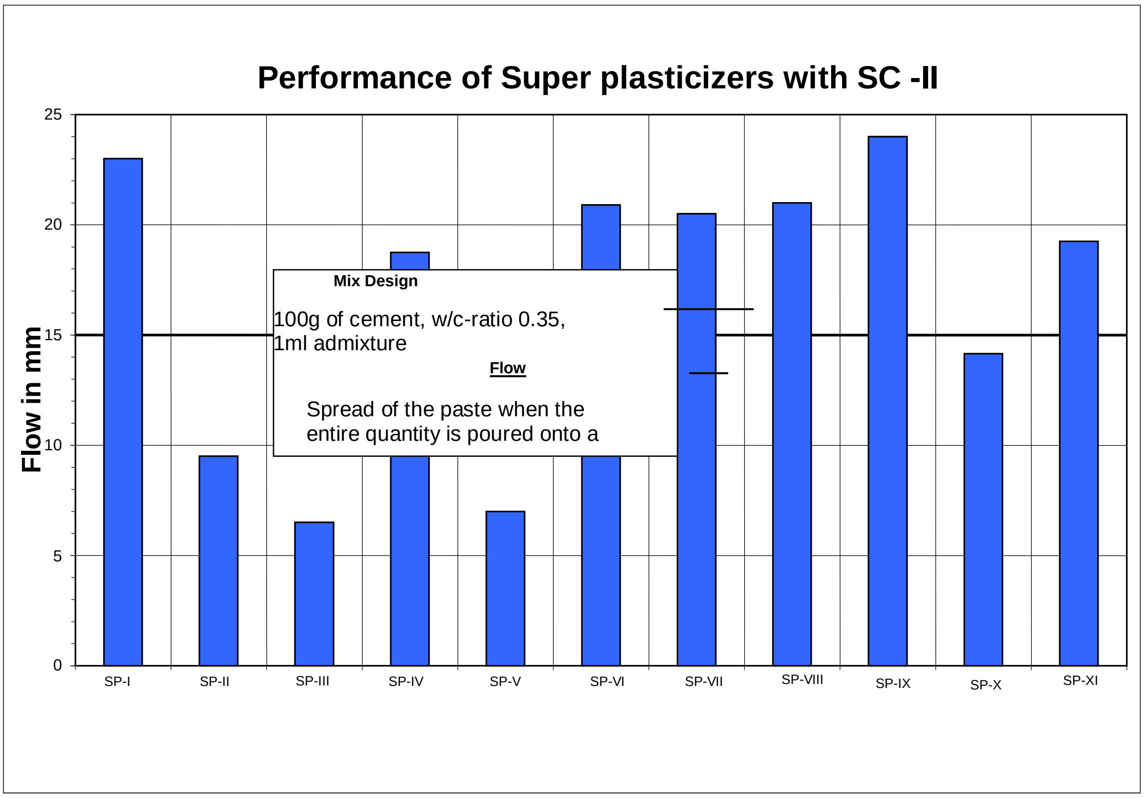

Fig 3: Comparison of Super plasticizers-flow test

The efficiency of super plasticizer were tested by a flow test. For the test 100gms of cement is mixed with 35ml of water. After mixing, 1% by wt of cement super plasticizer is added and the well mixed paste is poured onto a glass plate. The diameter of the spread paste was used to compare the efficiency of the admixtures. The figure 4 shows the performance of different super plasticizers with SC – II (53-S) which is selected for further research. It is known that plasticizing admixtures have the tendency to retard the cement hydration to a certain extend. The retarding potential of the investigated admixtures were tested by measuring the temperature gain of a cement paste with and without admixture over time.

The cement paste was prepared as mentioned for the measurement of the hydration heat. For the paste with admixture 1% of the respective super plasticizer was added. The temperature development was than measured in thermos containers as mentioned.

The temperature development for different super plasticizers is shown in figure 5. All super plasticizers shown in fig 5. are retarding, which can be seen by the delay in temperature increase compared to the reference mix without admixture. While SP-I and SP-IX retard the cement by about 3 – 4 hours whereas SP-VIII retarding by 7-8 hours. In fig.6, the cement paste with SP-XI is not gaining any temperature within 21 hours and subsequently no strength could be developed. The conclusion of the temperature graph could be confirmed by the still liquid cement paste extracted from the thermos container after 21hours.

Also in figure 6, an increase in the admixture dosage leads to a increased retardation (1% SP-II and 2% SP-II) is shown.

Based on the above test results the following super plasticizers were selected for concrete trails.

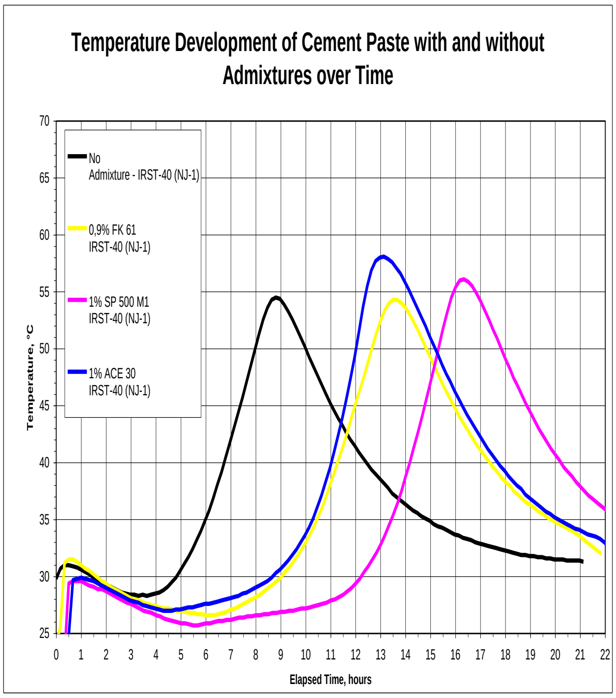

Fig4: Retarding Effect of Super plasticizers

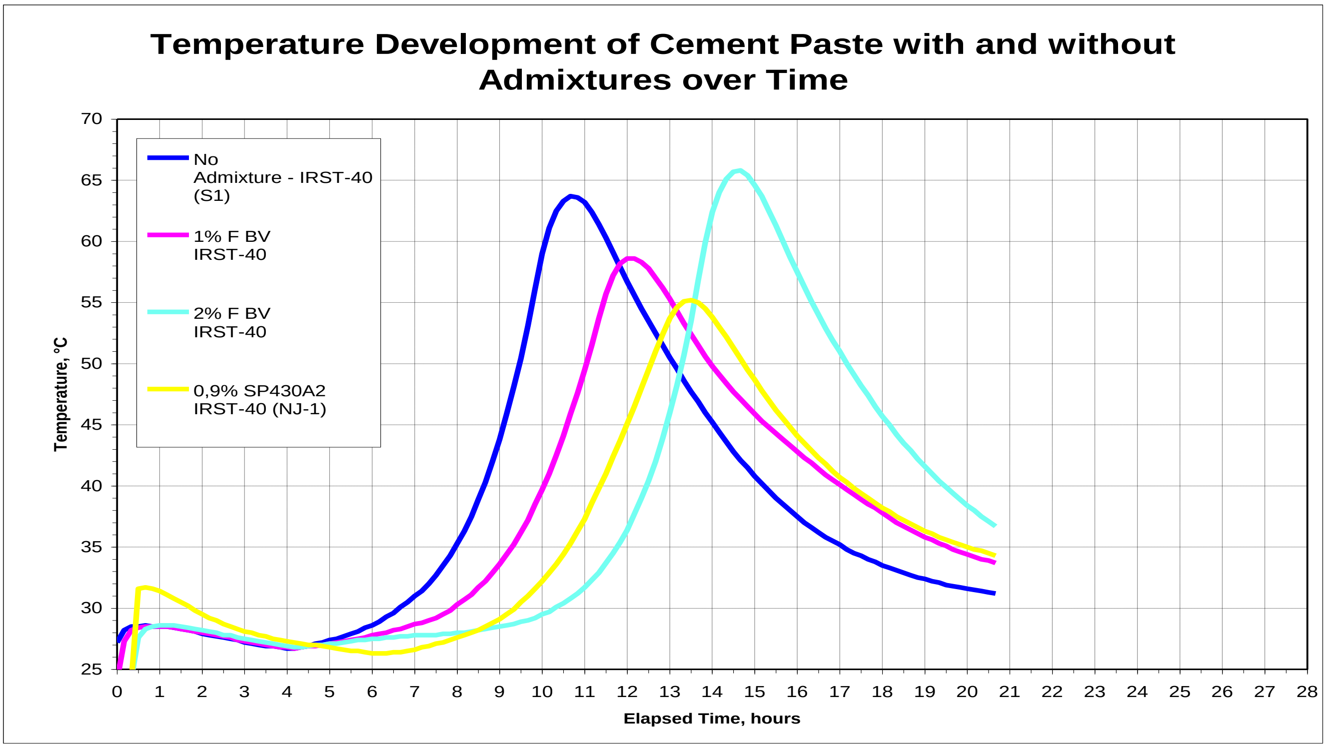

Fig 5: Retarding Effect of Super plasticizers

Table 2: Super Plasticizers Selected For Concrete Trails

Type	Product Name	Chemical Basis
Super plasticizer	SP-I	Multi carboxylatether (MCE)
Super plasticizer	SP-VIII	Sulphonated Naphthalene
Super plasticizer	SP-IX	Multi carboxylatether (MCE)

III. CONCRETE TRIALS FOR CONCRETE M50 WITH GRADE 53 CEMENT AND SLEEPER CEMENT

In a first step the findings of the cement tests were evaluated by using common Grade 53 cement in concrete trials. The basic concrete mix design used for the trials is summarised in table 3. The mix proportions are given in table 4.

Table 3: Basic Mix Design for Concrete Trials

Material	**Content**
Cement	400 kg/m³
Sand 0/2mm	800 kg/m³
Aggregates 5/10mm	400 kg/m³
Aggregates 10/20mm	800 kg/m³
Super plasticizer	0.7 to 1.8 % by wt. of c.
Water	152 kg/m³
w/c-Ratio	0.38

Table 4.Concrete Trials with Common Grade 53 Cements and Sleeper Cements

Trial Code		**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
Cement Content	Kg/m³	400	400	450	420	420	400
	Type	C-I	C-II	C-IV	SC-I	SC-I	SC-II
Water Content Kg/m³		172	163	170	160	155	150
W/C Ratio		0.43	0.38	0.38	0.38	0.37	0.38
Admixture Content	% ^by Wt	0.75	1.37	1.00	2.0	1.0	0.7
	Type	SP-I	SP-III	SP-IV	SP-II	SP-I	SP-I
Slump mm		80	60	0	0	100	10
Unit Weight Kg/m³		2.433	2.584	2.621	2.598	2.45	2.533
Compressive Strength at …Days (N/mm²)	**1 day**	8.0	10.8	12.1	35.4	30.0	31.7
	2 days	10.5	22.8	17.9	45.7	39.0	31.7
	7 days	19.0	34.1	33.3	50.4	44.1	51.3
	28 days	31.1	42.3	49.3	53.7	47.4	56.7

The concrete trials confirmed the perception that common Grade 53 cement is not suitable for the high early strength concrete needed for the pipe production. Even with a low w/c-ratio of 0.38, the concrete attained the 1day compressive strength only about 8 -10 N/mm² (figure 7 and table 4, T1 and T2). With a cement content increased to 450kg/m³ (T3) the strength improved slightly to about 12 N/mm² at 24hrs. The w/c of concrete seems to affect the performance of SPs. SNF admixtures are more prone to slump loss problems at low w/c, as compared to the PCEs. [Collepard, 1998]. Higher alkali contents promote the solubility of sulphate ions and decreases the loss of fluidity with SNF [Chandra and Bjornstrom, 2002].

Noticeable is the low unit weight of mix T1 which suggested that SP-I may entrain air in the concrete causing an additional strength loss.The early strength development with sleeper cement is shown in figure 8 and the test results are summarized in table 4. The lower early strength of T4 with SC - I is most possible caused by a quality loss due to a longer storage time at the sleeper plant. However, even with a lower quality, SC will the required lifting strength be reached after about 18 hours. Only the concrete mix design with 400 kg/m³ of cement was considered for further trials T7, T8, T9 & T10. In mixes T7 and T8 the low slump of the tested mix designs were observed.This decrease in workability at low temperature cannot be compensated with SP [Gettu, A. Aguado, L. Agullo, Carbonari, and J. Roncero, 1997].

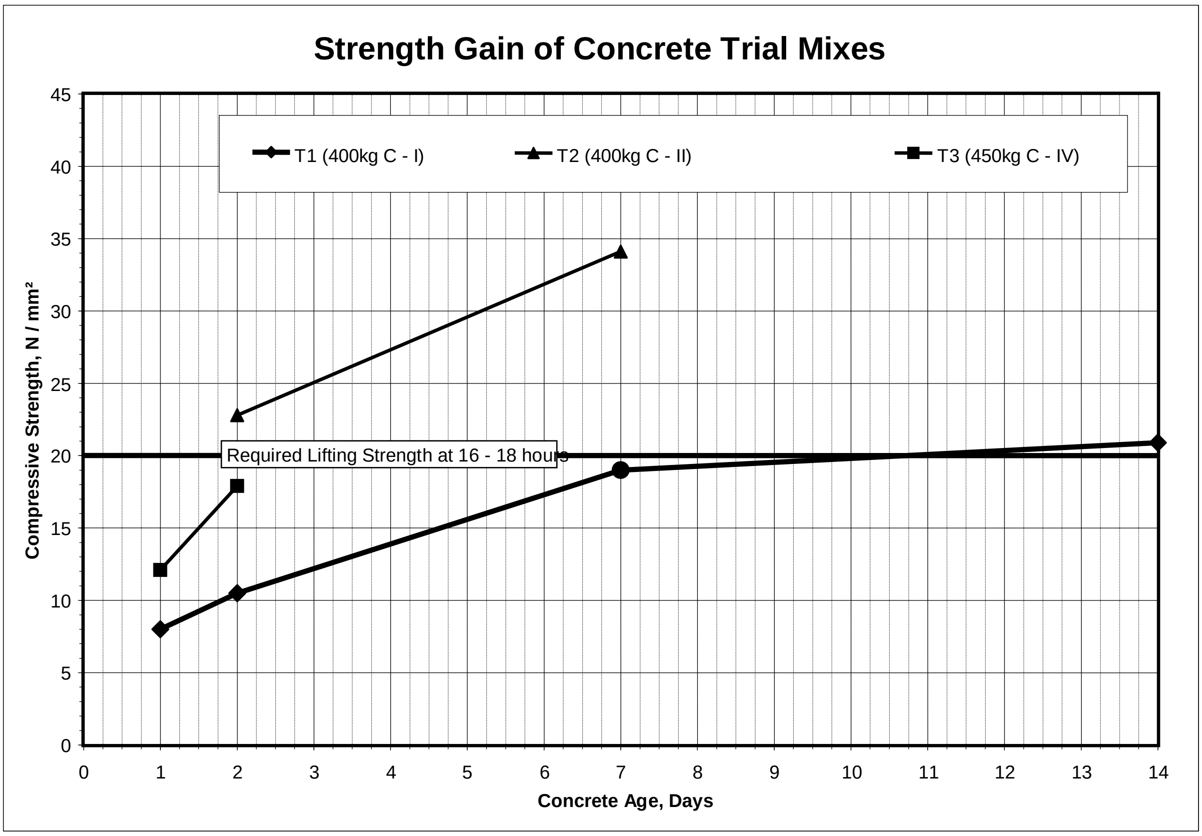

Fig 6: Strength Gain of Concrete with common Grade 53 Cements

Table 5: Early Strength and High Slump – Concrete with Sleeper Cement

Trial Code		**T7**	**T8**	**T9**	**T10**
Cement Content	Kg/m³	400	400	400	400
	Type	SC-I	SC-II	SC-II	SC-II
Water Content Kg/m³		155	150	152	152
W/C Ratio		0.39	0.38	038	0.38
Admixture Content	% ^by Wt	0.84	0.70	1.50	0.90
	Type	SP-IV	SP-I	SP-VIII	SP-IX
Slump mm		0	0	170	180
Unit Weight Kg/m³		2.530	2.533	2.526	2.572
Compressive Strength at ….hours (N/mm²)	**16 hrs**	16.3	22.4	16.7	21.3
	18 hrs	18.7	24.9	20.7	22.9
	20 hrs	22.4	27.8	22.1	24.3
	24 hrs	27.1	31.7	28.4	25.2

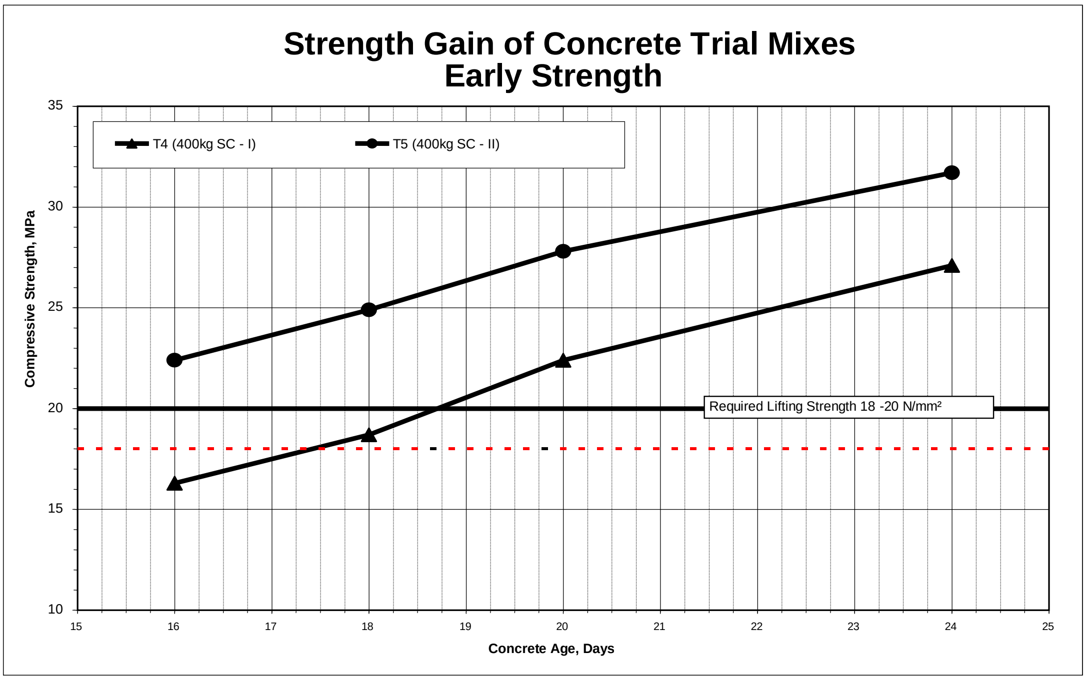

Fig 7: Early Strength Development – Concrete with Sleeper Cement

Even so the concrete consistency was with 170mm for T9 and 180mm for T10 respectively higher than aimed for, further adjustments of the admixture dosage were abandoned since a dosage established with the available laboratory mixer would anyway not match the actual dosage required at the batching plant. An adjustment of the admixture for a lower slump will not adversely affect concrete strength development. Hence to achieve 20 N/mm^2 at 16hrs without steam curing the following mix proportions were recommended for the design of concrete pipes.

IV. CONCLUSION

Design of concrete for precast concrete pipes with the following requirements.

High early strength 18–20 N/mm^2 @ 16hrs
Final strength is 50 N/mm^2 at 28 days
Cement content 400 Kg/m^3
Fine aggregate 0/2 mm 810 Kg/m^3
Coarse aggregate 5/10 mm 405 Kg/m^3
10/20 mm 810 Kg/m^3
Super plasticizer 0.7% by weight of cement of SP IX or 1.5% by weight of cement of SP VIII
Water 152 Kg/m^3
W/C ratio 0.38

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