Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 13 (1988)

Artikel: High strength concrete

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DOI: https://doi.org/10.5169/seals-12967

High Strength Concrete

Béton à haute résistance

Hochfester Beton

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SUMMARY
This paper describes the work carried out to obtain high strength concretes. The work is divided into two parts; firstly, the parameters which influence the strength of these concretes are studied, and secondly using these parameters as an approximate guide along with special aggregates, superplasticers and silica fume, high strength concrete is obtained.

RÉSUMÉ
Cette contribution décrit les travaux réalisés pour obtenir des bétons de haute résistance. Le travail est divisé en deux parties: dans la première partie on étudie les paramètres qui ont une influence sur la résistance de ces bétons, et la deuxième partie a pour but d' obtenir des bétons de haute résistance en s'appuyant sur ces paramètres et en utilisant des agrégats spéciaux, des superplastifiants et de la fumée de silice.

ZUSAMMENFASSUNG
In diesem Bericht werden die Untersuchungen zur Herstellung von Beton mit hohen Festigkeitswerten beschrieben. Der Bericht besteht aus zwei Teilen: im ersten werden die Einflußfaktoren auf die Festigkeitswerte analysiert; im zweiten Teil wird beschrieben, wie diese hohen Festigkeitswerte auf Grund der genannten Einflußfaktoren und der Zugabe von Zuschlagstoffen mit besonderen Eigenschaften, Superverflüssigern und Silikastaub erreicht werden.

1. INTRODUCTION

Not long ago the maximum compression strength of concrete could be considered to be about 50 N/mm^2 and structural concretes of 25 N/mm^2 were frequently used.

The needs imposed by construction of higher buildings, prestressed bridges of long spans, concretes with good performances against shell penetration,etc., have led to more attention being given to higher compression strength concretes and nowadays we can obtain concretes of 60 N/mm^2, which have at the same time a good workability due to the use of superplasticers. These concretes have been applied in high buildings especially in the USA and in some prestressed bridges in Japan. The simultaneous use of superplasticers and silica fume permits considerably higher strengths to be reached.

The study carried out in the Escuela de Ingenieros de Caminos, Canales y Puertos at the Polythecnic University of Madrid, which we summarize in this paper, have had the aim of analyzing which are the most convenient parameters in order to obtain concretes of high strength.

2. METHODOLOGY

This work can be divided into two phases:

2.1 First phase

In this phase we have used a high initial strength Portland cement.

We have used rounded gravel and crushed gravel aggregates in order to observe the influence of the surface texture of aggregates on the compressive strength of the concrete. Also, differents maximum sizes of aggregates have been used to observe the influence of this parameter on the concrete strength.

The compression tests have been carried out at after periods of 28 and 60 days. It is necessary to take into consideration that these types of concrete generally reach the service load in structural elements after a period of 28 days and also that it is important to carry out the tests after long periods in order to observe the evolution of the pozzolanic activity of the silica fume.

2.2 Second phase

The second phase of our work is based on the results of the first one, but in this phase we have used new aggregates, superplasticer admixture and silica fume.

The coarse aggregates used in this second phase consisted of good limestones from different areas of Spain and ophites from Navarra (Spain).

The superplasticer admixture used was a sulphonated napthalene formaldehyde condensate (SNF) and the pozzolanic addition to the concrete was silica fume in water suspension at 50 %.

The workability of the concretes was measured by means of the Abrams cone.The slump was between 5 and 8 cm.

The ages for compression tests of concretes were 28 and 60 days.

3. INVESTIGATIONS

3.1. First phase

3.1.1. Design

The cement used in all the concretes was P-550 ARI which corresponds to a high initial strength Portland cement with 55 N/mm^2 minimum compression strength at 28 days on the RILEM-ISO-CEMBUREAU.

The cement contents were: 350, 400, 450, 500 and 550 kg/m^3.

The fine aggregate was silica river sand having a fineness modulus of 2.98.

The coarse aggregates were natural rounded river gravel and crushed river gravel.

Aggregates with 40, 20 and 10 mm. of maximum size were used.

In these concretes we have used neither admixtures nor silica fume.

Two fine aggregate/coarse aggregate ratios have been used: 2.00 and 1.50.

The water contents were that necessary for reaching a good workability with a slump between 5 and 8 cm.

The compression tests were carried out after 28 and 60 days.

The specimens used were 7.5∅ x 15 cm. cylinders cast in steel moulds.

3.1.2. Test results

The results of compression tests are represented on figures 1 and 2; every one is the average of six tests.

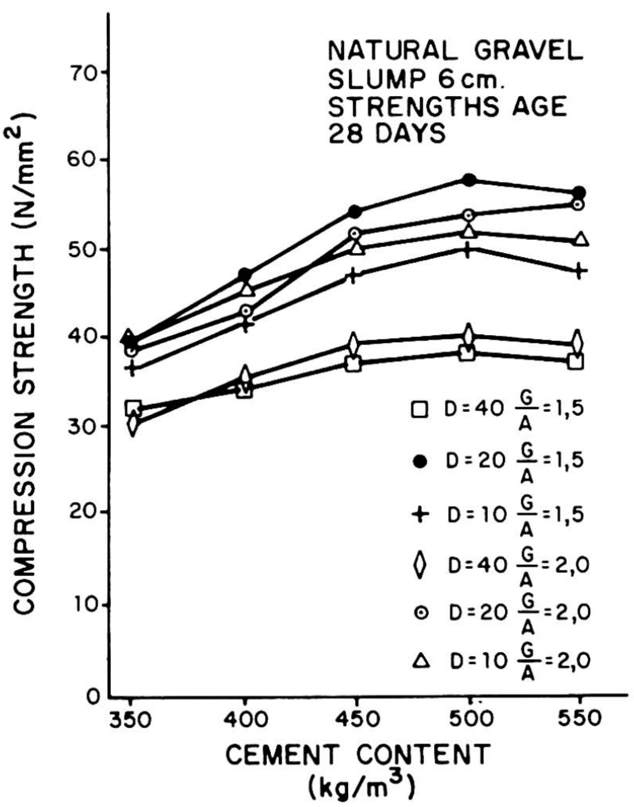

Fig.1

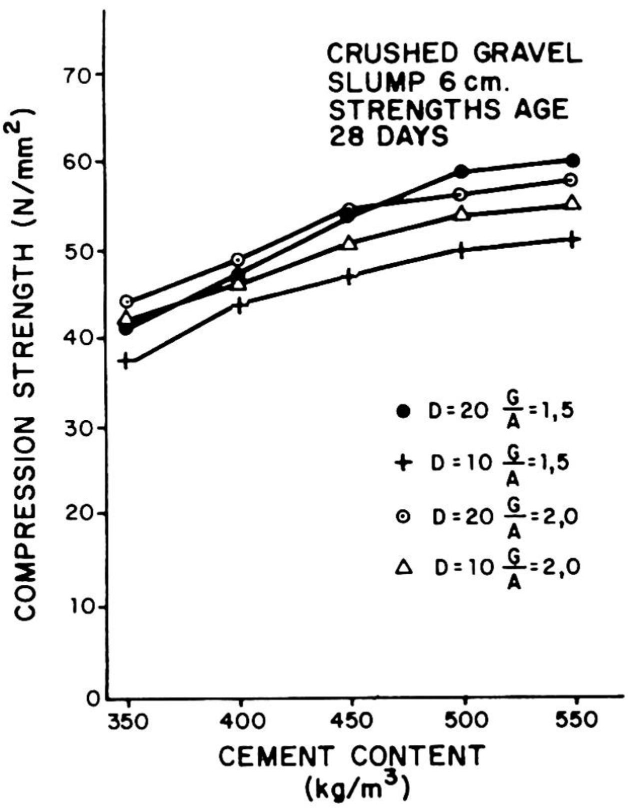

Fig.2

3.1.3. Conclusions

It can be observed in this phase of the study how concrets, with growing cement contents, increase their compression strengths in a linear way until a maximum content of 500 kg/m^3 when the strengths tend to stabilize.

It is also observed that aggregates of 20 mm maximum size give the maximum compression strength followed by 10 mm. The worse aggregate was 40 mm. maximum size.

We have also found that concretes with a fine aggregate/coarse aggregate ratio of 1.5 give the best results from the compression strength behaviour.

Observing the behaviour of rounded and crushed aggregates from the tests we conclude that crushed aggregates gave the maximum strengths.

It has been found that cleanness of aggregates is very important; with water washed aggregates the compression strengths reached are higher than with those not subjected to this treatment.

3.2. Second phase

3.2.1. Design

The cement used in this second phase was the same as that used in the first one.

The cement contents were limited to 400, 450, 500 and 550 kg/m^3.

All the concretes used crushed aggregates with 20 mm. maximum size aggregate and with a fine aggregate/coarse aggregate ratio of 1.5.

The coarse aggregates used were crushed limestones from different areas of Spain, natural crushed gravel and crushed ophites.

The fine aggregate were in one case silica river sand with a fineness modulus of 2.98 and water washed ophites with a fineness modulud of 3.00 in other case.

Some concretes used superplasticer admixture type SNF and others used a mix of this admixture plus silica fume in water suspension at 50 %.

The water content in concretes were the necessary for reaching a good workability with slumps between 5 and 8 cm.

The ages for compression tests of concretes were 28 and 60 days.

3.2.2. Test results

The results of compression tests at 28 and 60 days, together with the cement contents, type of aggregate, admixture and silica fume per cents, are shown in table 1.

Concrete type	Cement content kg/m^3	Aggregate type	Admixture %	Silica fume %	Compression strength N/mm^2 28 days	60 days
D	400	Limest. 1	2.0	-	56.8	66.2
	450	"	1.5	-	59.9	67.6
	500	"	1.5	-	60.1	71.7
E	400	Limest. 1	2.0	10	57.4	70.6
	450	"	1.5	10	62.6	73.8
	500	"	1.5	10	64.7	76.6
F	400	Limest. 2	2.0	10	59.3	70.5
	450	"	1.5	10	64.5	71.5
	500	"	1.5	10	65.9	74.8
G	400	Gravel	2.0	10	59.8	72.0
	450	"	1.5	10	63.2	73.5
	500	"	1.5	10	63.7	74.1
H	400	Ophite	2.0	-	62.5	74.6
	450	"	1.5	-	69.8	81.2
	500	"	1.5	-	72.3	86.3
J	400	Ophite	2.0	10	69.3	82.5
	450	"	1.5	10	84.2	98.0
	500	"	1.5	10	85.3	102.2

Table 1

The results of tests on concrete of types H and J are presented in the figures 3 and 4.

3.2.3. Conclusions

In this second phase it is observed how the use of superplasticers produces a notable increase in the compression strength of the concrete with reference to the first phase and how the simultaneous use of superplasticer and silica fume permits strengths of approximately 100 N/mm^2 to be reached, especially when high quality and clean aggregates are used.

4. FINAL CONSIDERATIONS

In our study we have tested on hundred and sixty different concrete mixes. These tests have led us to the following final conclusions necessary for obtaining high strength concretes:

- Use high strength Portland cement.
- High strength, crushed and clean aggregates are necessary.

- The cement content must be between 450 and 500 kg/m^3.
- Good quality fine aggregate with a fineness modulus less or equal to 3.00 are recommended.
- The fine aggregate/coarse aggregate ratio used must be near to 1.5.
- Reduce the quantity of mix water by using superplasticers, so that the water/cement ratio is near to 0.30.
- Use silica fume in order to improve the workability of concretes and to increase the strength especially at ages greater than 28 days.
- Vibrate the concrete energitically.
- Carry out a well controlled wet curing of concrete, especially during the first fifteen days.

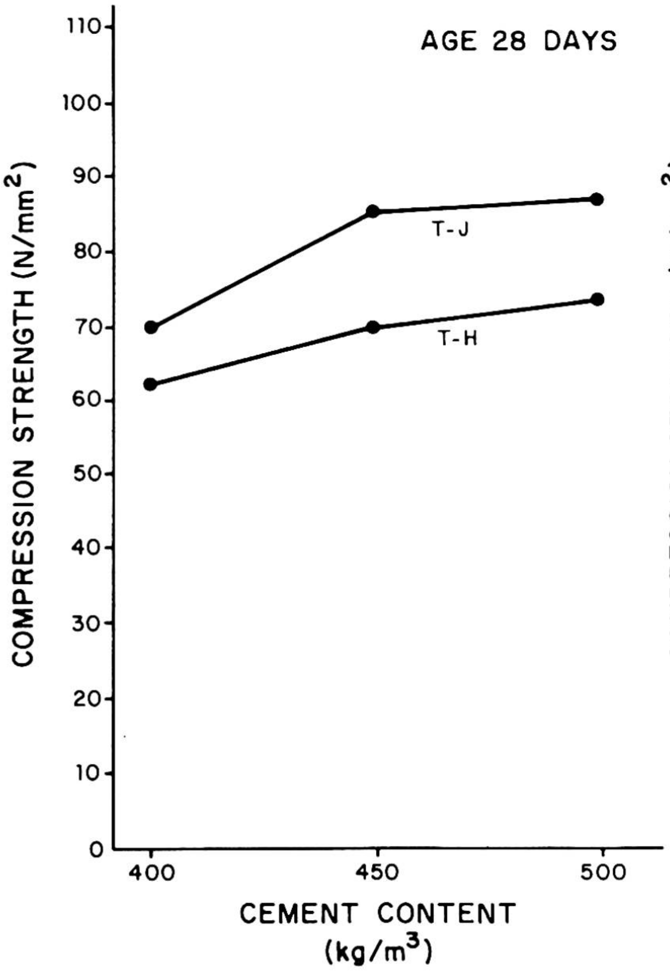

Fig.3

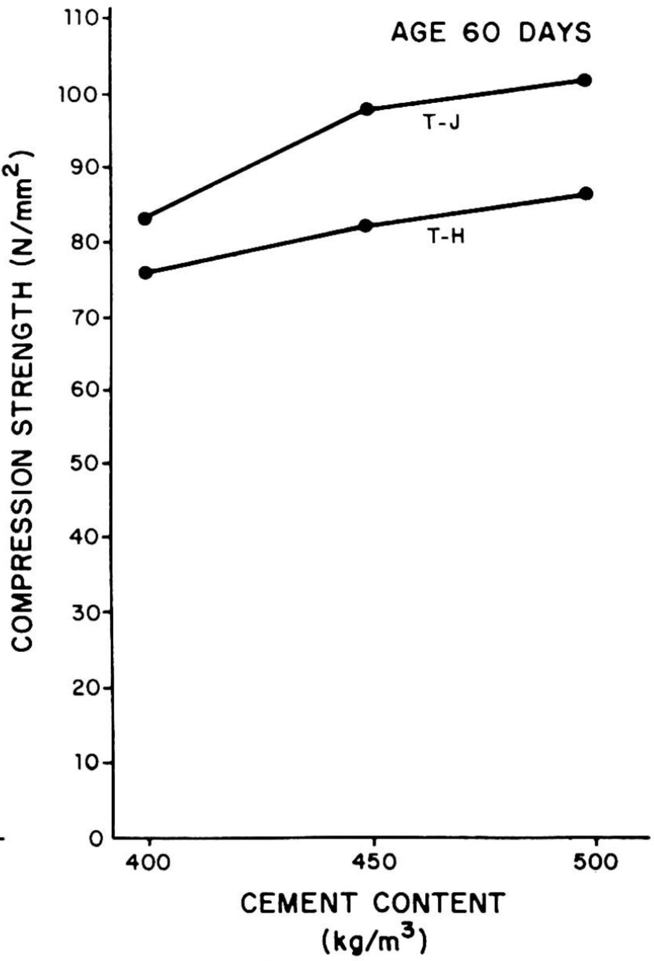

Fig.4

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