THE WORKABILITY OF NO-SLUMP CONCRETE FOR USE IN HOLLOW-CORE SLABS

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The purpose of this paper was to find out the factors affecting the workability of no-slump concrete. The investigation has been performed by compiling information available in literature and by carrying out laboratory and full-scale tests. An equipment has been specifically designed for measuring the workability of no-slump concrete, a so-called Intensive Compaction Tester (IC-tester).

The particle shape of the aggregate used and the amounts of fines, fly ash and silica fume are the most important factors affecting the workability. The workability is reduced by a too high specific area or amount of fine aggregate, and by a too large proportion of crushed aggregate. Because the manufacturing process requires no-slump concrete to be used, its workability can be improved only to a very small extent by adding water. Fly ash or silica fume has been added to improve the workability of fresh concrete.

Keywords: no-slump concrete, workability, hollow-core slabs, aggregates, fly ash, silica fume

1. INTRODUCTION

No-slump concrete is generally used for extruded hollow-core slabs, concrete blocks, road pavements (roller compacted concrete), and concrete pipes.

Until recently no-slump concretes have been investigated only a little. The excellent properties of no-slump concrete have been recognized, but the lack of appropriate test and compaction methods in particular has limited both its use and investigation. No-slump concretes are also sensitive to local conditions, for which reason the results obtained in different places are difficult to compare with one another. Although the manufacturing process of hollow-core slabs is simple in broad outline, about 100 different variables affecting the final result can easily be listed. Thus there are great differences between theory, production in laboratory and practice.

The hollow-core slabs are precast and pre-stressed cored concrete slabs for floors, roofs and walls. They are manufactured by a precision casting process providing dimensional control and uniformity.

Two types of casting technology are available; one method for semi-fluid or semi-stiff mixes and the extrusion method for stiff mixes.

In this research work the hollow-core slabs were made by the extrusion method. This method employs pre-mixed dry concrete containing 300-380 kg/m^3 of cement of a w/c ratio about 0.30. The cement content is about 100 kg/m^3 higher if concrete of semi-fluid or semi-stiff consistency is used.

The strength of the concrete develops rapidly, since the mix does not contain excess water. The slabs are hard enough to cut about 6 hours after casting, when the compressive strength is about 35 MPa.

If the many good properties of hollow-core slab concrete were not known, one could say that the use of no-slump concrete is a way of looking for troubles for the production: it is hard to compact, even small changes in the amount of water or fines could lead to fateful changes in the consistency. Nevertheles, the product is expected to reach its desired shape immediately, be ready for handling not later than 6 hours after casting, and it should possess a high final strength and excellent durability properties. All this should be achieved at as small costs as possible.

The latest advance in the production of hollow-core slabs is the shear compaction method (Figure 1 and 2). In this method, the high vibration force normally used to compact the concrete is replaced by a shear force. The different sectional planes of the slab's cross-section are moved in transverse direction and rubbed against one another. This process takes place under compression - generated by the eccentric rotation of screws. The given quantities of aggregates are in this manner brought into the appropriate position encouraging the air to escape.

The internal vibrators inside the screw are entirely eliminated. They are replaced by the mechanical, movable parts fitted to the rear of the screw. The "cutting parts" move in such a way that both round voids and voids of oval shape can be molded. This reduces the noise level of the machine to below 85 dB(A). The new shear compaction method also uses less energy for compaction than the vibration method, the consumption figures being 1.7 kWh/m^3 compared with 2.1 kWh/m^3.

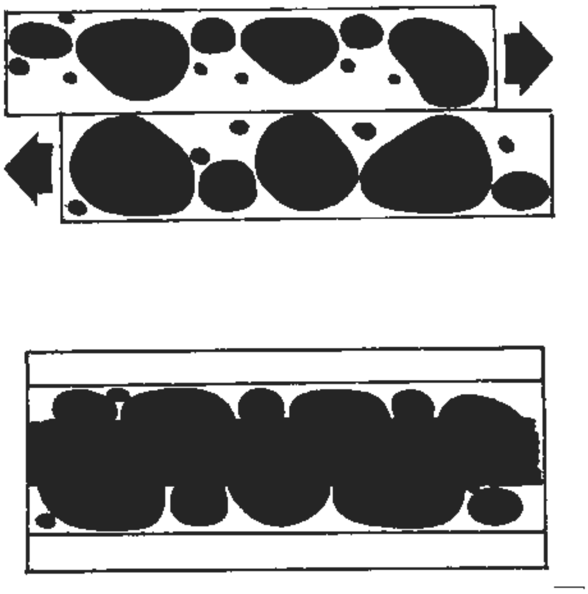

Figure 1. The aggregates are brought into the appropriate positions during shear compaction.

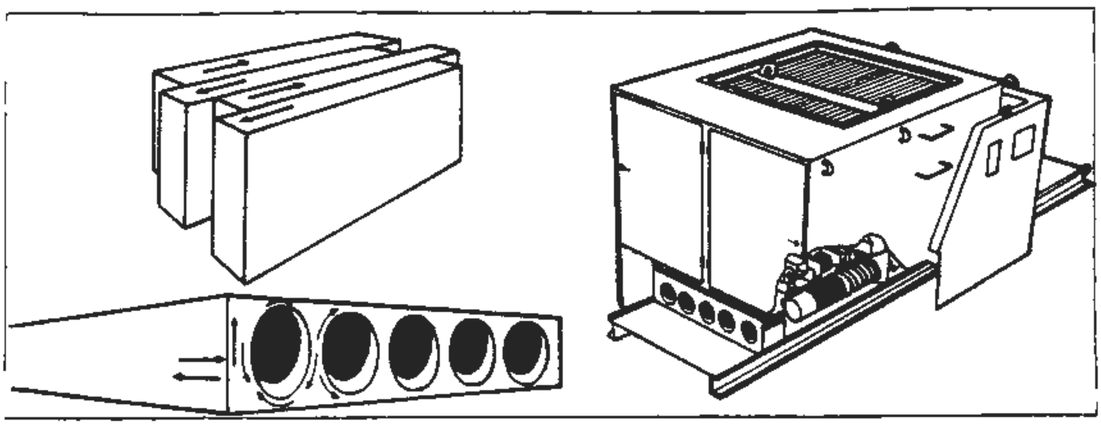

Figure 2. Shear compaction method.

2. TEST METHODS

The investigations were divided into three parts. Preliminary tests were carried out by the aid of the IC-tester (more details about the test method in "Nordic Concrete Research 1986"). The tests were continued in laboratory with access to a pilot plant for hollow-core slabs. The final tests were made at a hollow-core slab factory with the ordinary production machine.

The following was tested:

- the purity of aggregate,
- the amount of crushed aggregate,
- the amount of silica fume and
- the amount of fly ash.

Rapid-hardening cement was used. The aggregate varied from washed, natural gravel to unwashed, crushed aggregate. Dry silica fume was used, and the fly ash consisted of pulverized fuel ash of acceptable quality. The most important tests were as follows:

Aggregate	The specific area and the amount of silt.
Fresh concrete	Workability (IC tester, Photo 1)
Hardened concrete	Compressive strength; ø 50 mm drilled cores were used as test pieces. The bond strength between the concrete and the prestressing strands. 150 mm cubes were used as test pieces.

3. RESULTS

3.1 Washing of aggregate

The effect of washed aggregate on the workability and the development of strength is shown in Figures 3 and 4.

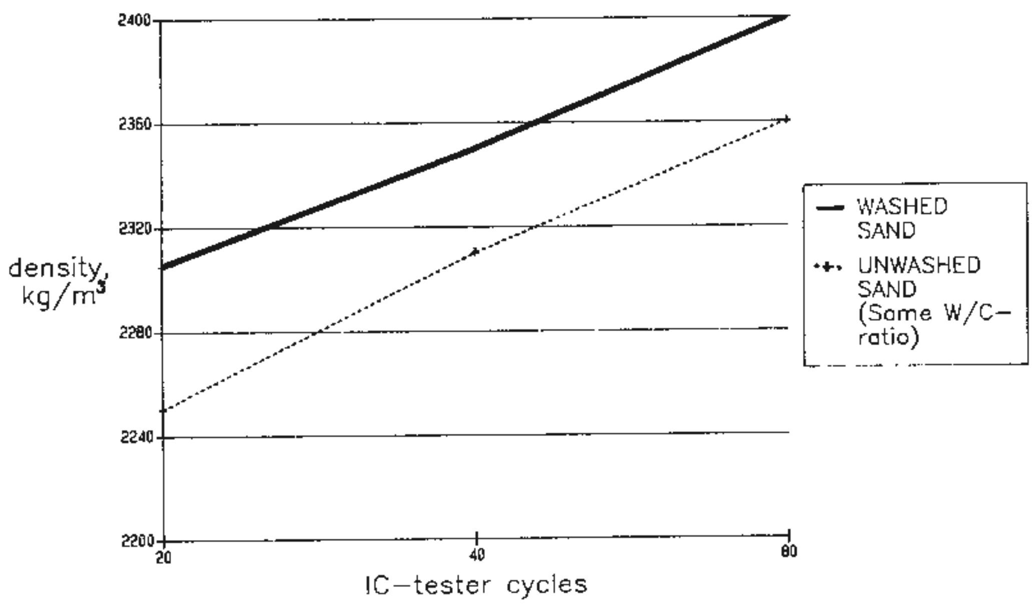

Figure 3. The effect of washed aggregate on the workability of no-slump concrete, measured by IC tester.

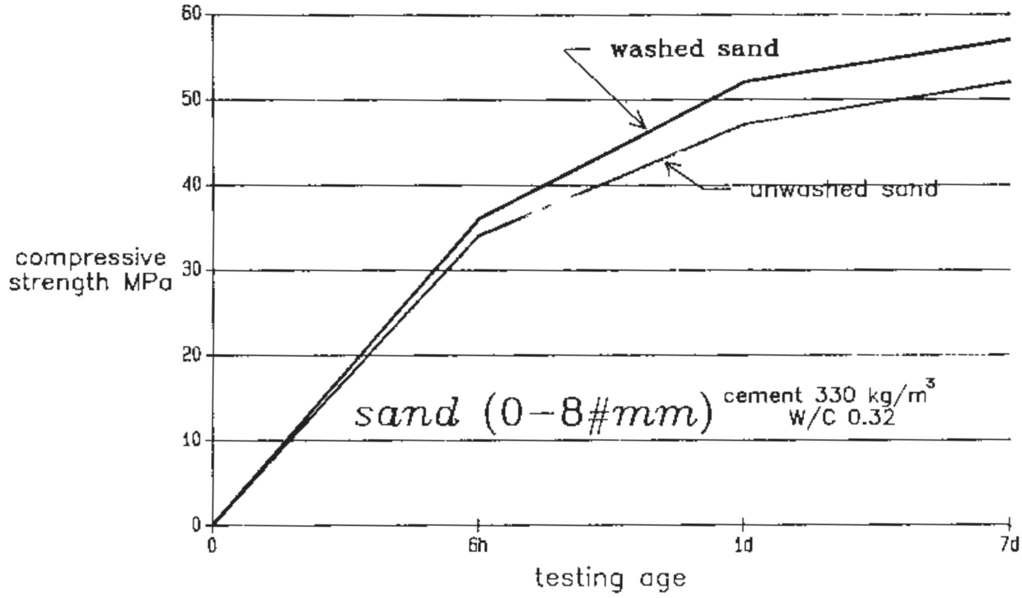

Figure 4. The effect of washed aggregate on the development of the strength of no-slump concrete.

The effect of the silt included in aggregate on the compressive strength can be evaluated on the basis of the amount and the specific area of the silt, as shown in Figure 5.

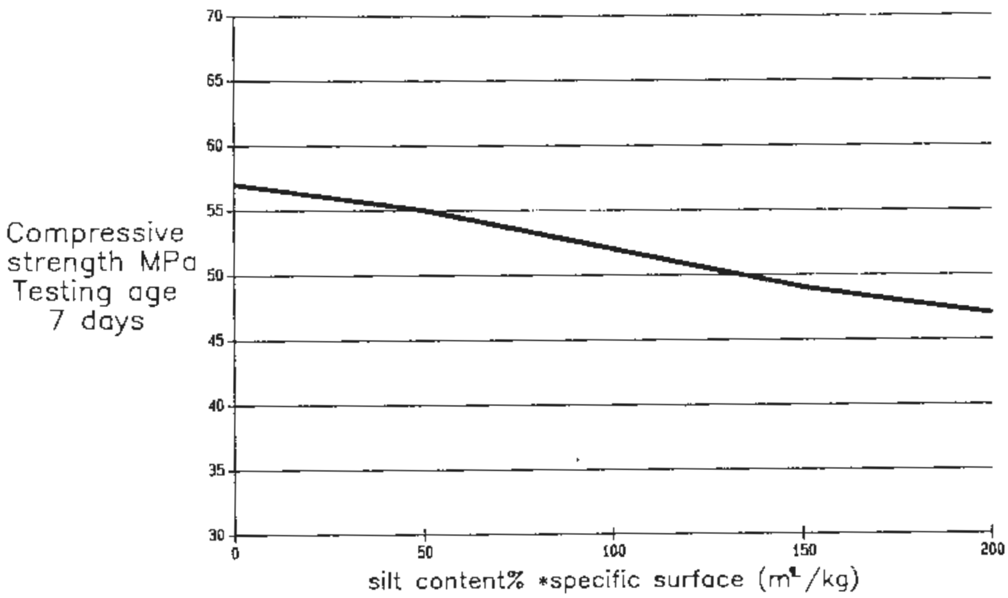

Figure 5. The effect of the silt included in aggregate on the compressive strength of concrete.

3.2 Crushed aggregate

The effect of crushed aggregate on the compressive strength of concrete and on the bond strength between concrete and prestressing strands is shown in Figure 6.

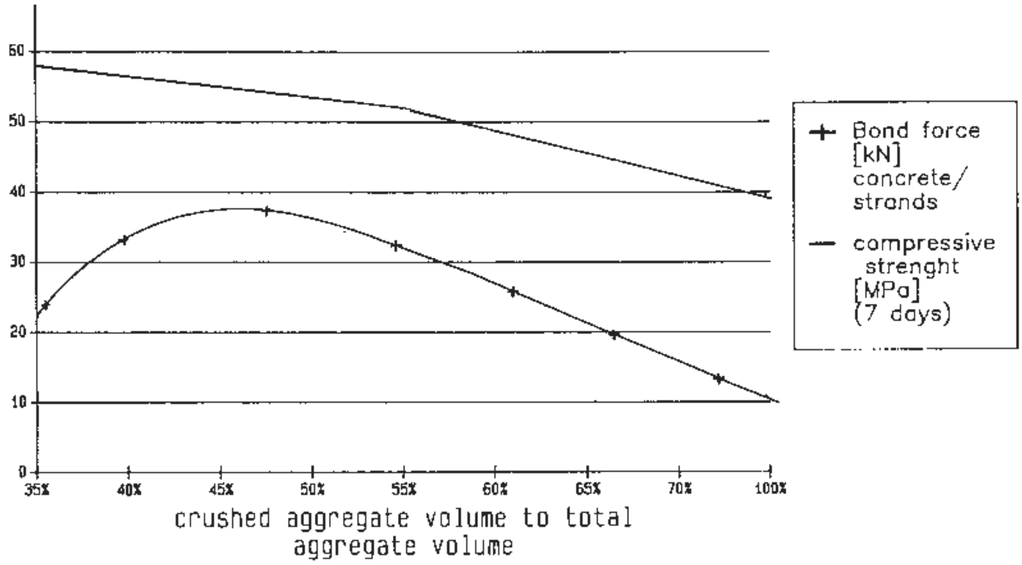

Figure 6. The effect of crushed aggregate on the compressive strength and the adhesion to prestressing strands.

3.3 Silica fume and fly ash

The effect of silica fume and fly ash on the workability and compressive strength of concrete is shown in Figures 7 and 8.

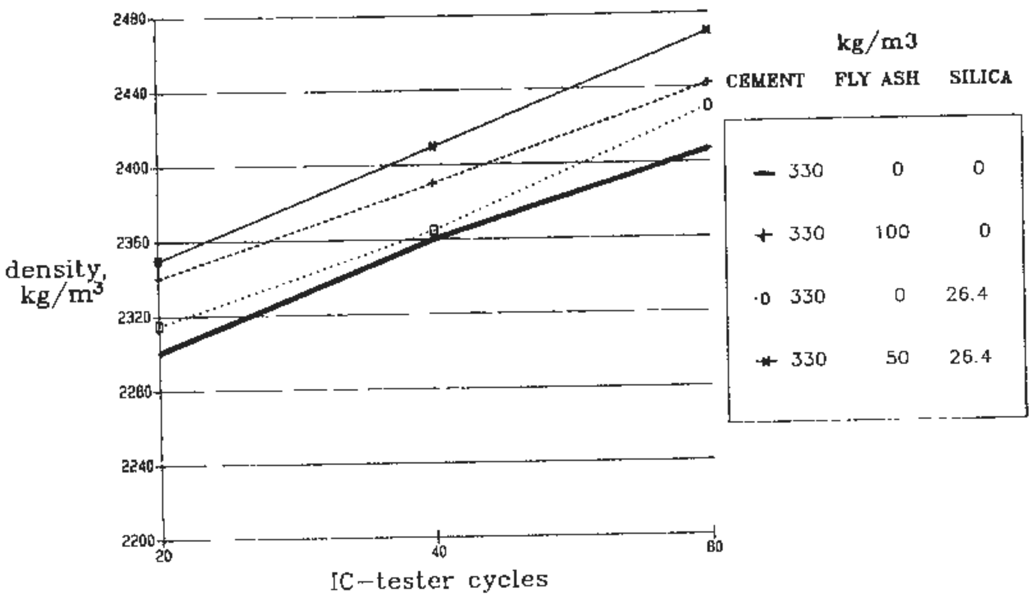

Figure 7. The effect of silica fume and fly ash on the workability of concrete.

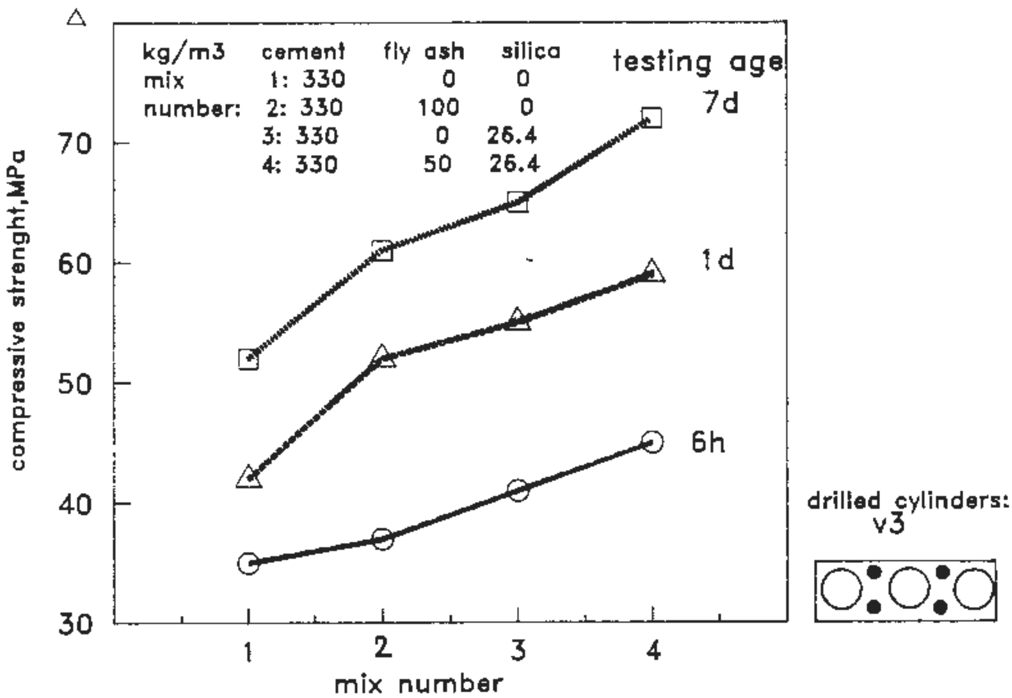

Figure 8. The effect of silica fume and fly ash on the compressive strength of no-slump concrete.

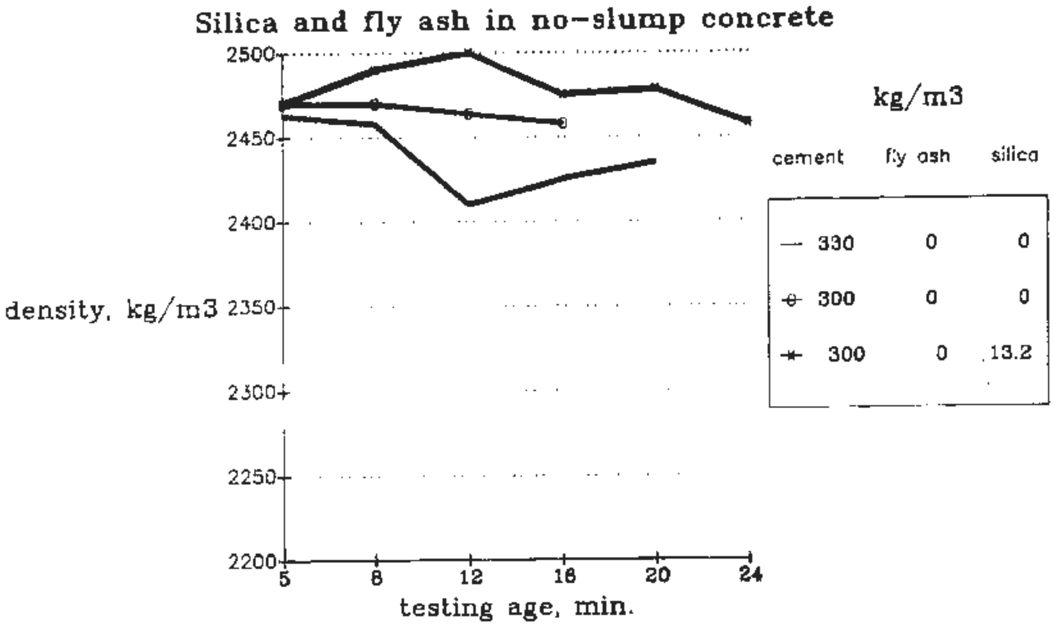

Figure 9. Stiffening of no-slump concrete with fly ash and silica fume.

4. CONCLUSIONS

1. The use of washed aggregate as raw material in no-slump concrete increases its early and final strengths by 5 to 10 per cent. A slight increase in the workability of the fresh concrete is observed.

2. How great the need for washing is can be based on the amount and fineness of the silt. The combined effect of the percentual amount and the specific area of the silt on the strength is obvious.

3. Crushed aggregate can be used in rather large amounts (above 50%) without changing the compressive strength of concrete significantly. The bond between the concrete and the strands will, however, decrease as a result of reduced compactibility, when the amount of crushed aggregate exceeds 50 per cent of the total amount of aggregate.

4. Silica fume has an increasing effect on the workability and the strength of no-slump concrete.

5. The properties of fly ash used in concrete are similar to those of silica fume. Its increasing effect on the strength is not as great as that of silica fume.

6. The intensive compaction tester used in the tests was found suitable for measuring the workability and for preparing test specimens for the compressive strength tests.

7. There is no significant difference in the early stiffening of no-slump concrete containing fly ash, silica fume or without additives.

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Photo 1. The IC-tester in operation.

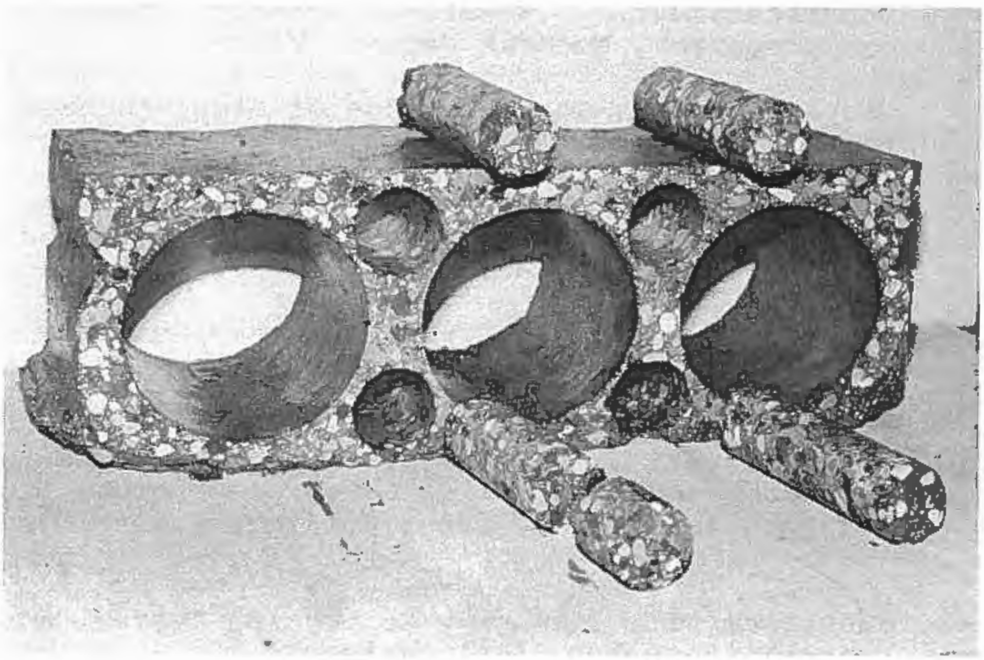

Photo 2. The cross-section of a hollow-core slab with drilled cores, manufactured in laboratory.