

Concrete research news

from four Belgian Universities

Influence of long-term loading upon the behaviour of reinforced concrete beams

BACKGROUND AND SPONSORSHIP

This is part of a comprehensive research programme, which is being carried out under the auspices of the Nationaal Opzoekingscentrum der Burgerlijke Bouwkunde (National Civil Engineering Research Centre) and subsidized by the Fund for Collective Fundamental Research. The programme is being undertaken jointly by the following laboratories at four universities in Belgium:

Liège State University, Laboratoire des Constructions du Génie Civil, Director: Professor R. Baus

Public University of Brussels, Laboratoire des Constructions Civiles, Director: Professor P. Moenaert

Roman Catholic University of Louvain, Laboratorium voor Proeven op Materialen, Director: Professor C. G. Reyntjens

Ghent State University, Laboratorium Magnel voor Gewapend Beton, Director: Professor F. G. Riessauw

The subject of the whole programme (Research No. 547 of the Fund for Collective Fundamental Research) is the influence of long-term loading upon the behaviour and resistance of concrete constructions, reinforced or prestressed concrete structures, and of composite (steel-concrete) structures as well as of metal structures.

PRESENT STAGE

The first stage of the research now in process includes the study of the influence of long-term loading upon the behaviour of reinforced concrete beams. The number of parameters is limited to two: the percentage of reinforcement and the percentage of the service load.

For this stage of the research, both concrete and steel quality are being kept practically constant (cube strength after 28 days = 350 kg/cm²; hard-grade deformed steel bars of 14 mm diameter with warranted yield point 40 kg/cm²).

The beams being tested, which all have the dimensions $l = 3.2$ m, $b = 150$ mm and $h_t = 280$ mm, vary in reinforcement as follows.

Type I: 0.82% tensile reinforcement (Brussels)

Type II: 2.17% tensile reinforcement (Ghent)

Type III: 3.52% tensile reinforcement (Liège)

Type IV: 2.17% tensile reinforcement and 1.23% compression reinforcement (Louvain)

On each type of beam six different tests are made, and each test is carried out twice. The six tests are as follows.

- (1) A static test up to rupture (equal concentrated loads at each third-point of the 2.80 m span).
- (2) A shrinkage test on an unloaded beam.
- (3) Four creep tests. The applied load is either a fraction of the failure load P_r determined by the static test or the service load P_{serv} of the beam, determined by ultimate load analysis (CEB method). Thus the four loads will be $0.9P_r$, $0.8P_r$, $0.7P_r$ and P_{serv} .

During the various tests, the following measurements are made:

- (1) deflection (at mid-span and under the loads).
- (2) concrete deformation (central cross-section, top and bottom fibre).
- (3) the width of a certain number of cracks.

NEXT STAGE

The tests described above have recently been in progress. A second stage of the research programme is contemplated, namely a study of the influence of long-term loading upon the behaviour of prestressed concrete beams. The programme for this is now being studied.

CONTACTS

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The bearing strength of reinforced concrete blocks under concentrated loading

PREVIOUS WORK ON UNREINFORCED BLOCKS

In many structures concentrated loading occurs. In 1969 an investigation of the strength of unreinforced concrete blocks under concentrated loading was carried out, 135 blocks being tested. The variables in this investigation were the dimensions of the blocks and the area over which the concentrated loading was applied.

PRESENT INVESTIGATION

Reinforced concrete is used to increase the bearing capacity under concentrated loading. An investigation of the most suitable reinforcement is being carried out at the moment. In the first stage of this investigation, the variables are:

- (1) area over which the concentrated loading is applied;
- (2) type of reinforcement: stirrups, spiral or mat;
- (3) position of the reinforcement;
- (4) amount of reinforcement;
- (5) distribution of the reinforcement.

In the first stage, the concrete blocks have constant dimensions of $200 \times 200 \times 500$ mm. The quality of the concrete is K350 (cube strength in kg/cm^2 at 28 days). The quality of the steel is Qr 24 (minimum yield strength = 2400 kg/cm^2). Both cracking load and ultimate load are being measured.

In the second stage, the variables will be:

- (1) area over which the loading is applied;
- (2) position of loading (symmetrical or asymmetrical);
- (3) external and internal (cone) loading;
- (4) type of reinforcement;
- (5) amount of reinforcement.

Behaviour of reinforced concrete slender columns under sustained load

REASON FOR RESEARCH

The creep of concrete is very important for the stability of structures. The deformation of eccentrically loaded columns is increased by creep. Because of this, the ultimate load will be reduced. To complement a method of calculation developed by CUR-TNO, this phenomenon is being investigated in a programme which began in May 1971.

PRESENT PROGRAMME

The following factors are varied:

- (1) slenderness (length/side) = 25.7, 15.7, 8 and 4;
- (2) reinforcement (Qr 40) on each face: 0.2%, 0.4%, 0.8% and 1.6%;
- (3) eccentricity
 - (a) symmetrical single curvature at eccentricities of 10, 30, 50 and 100 mm;
 - (b) symmetrical double curvature at eccentricities of 10, 30, 50 and 100 mm;
- (4) load $P = 55\%$, 70% and 85% of the short-term strength.

The cross-section of the specimens is 150×150 mm and the stirrup reinforcement is of 4 mm diameter steel (Qr 24) at 100 mm spacing. The quality of the concrete is K 300. The investigation will be done in a room with a relative humidity of 60% and a temperature of 20°C .

The programme of measurements is as follows:

- (1) horizontal displacements;
- (2) compression and tension strains;
- (3) position and width of cracks;
- (4) the duration of the test.

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Behaviour of lightweight concrete under uniaxial loading

REASON FOR RESEARCH

In the past four years an investigation has been carried out into the behaviour of normal concrete under biaxial loading. To investigate whether there is any difference in behaviour in deformation and rupture between normal and lightweight concrete and also to investigate the consequences of this for our structures, a similar programme on various types of lightweight concrete has been planned.

PRESENT PROGRAMME

A series of uniaxial tests is being carried out to study the influence of the following factors:

- (1) quality of concrete: K 200 and K 325 (cube strength in kg/cm² at 28 days);
- (2) type of aggregate: Argex, Argex S, Hollith, Korlin;
- (3) rate of stressing $\partial\sigma/\partial t = 200, 20, 2, 0.2$ and 0.02 kg/cm² s;
- (4) rate of deformation:
 - (a) $\partial\varepsilon_1/\partial t = 1000, 100, 10, 1$ and $0.1 \times 10^{-6}/s$;
 - (b) $\partial\varepsilon_2/\partial t = 200, 20, 2$ and $0.2 \times 10^{-6}/s$;
- (5) uniaxial compression and uniaxial tension.

The dimensions of the specimens are $100 \times 100 \times 300$ mm.

From the measurements taken, the following diagrams will be prepared:

$$\sigma/\varepsilon_1, \sigma/\varepsilon_2, \sigma_1/\nu \text{ and } \sigma_1/(\varepsilon_1 + 2\varepsilon_2)$$

In the above,

σ = stress in kg/cm²

ε_1 = longitudinal strain

ε_2 = transverse strain

$$\nu = \left| \frac{\varepsilon_2}{\varepsilon_1} \right|$$

t = time in seconds

FUTURE WORK

After the results of the uniaxial tests have been studied, a programme for a series of biaxial tests will be planned.

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Thermodynamics of sorption in porous building materials: measurement of sorption isosteres

BACKGROUND

Surface thermodynamic data are indispensable in a scientific approach to the technology of porous building materials. Almost all the important technical and physical properties of these porous—sometimes microporous—substances are influenced significantly by the nature of their porous texture. This porous texture is characterized in terms of pore statistical parameters (e.g. pore size distribution functions), as well as the nature of the internal surface. Both of these structure parameters can be obtained from sorption data.

PRESENT PHASE OF RESEARCH PROGRAMME

The material system that is being investigated at the present time, in this continuing research programme at the Building Materials Laboratory of the Technical University of Denmark, is the system hardened-cement-paste-water. Sorption isosteres (vapour pressure as a function of temperature, at constant moisture content) are measured directly; sorption isotherms are generated from the isosteres; thermodynamic data (such as entropy and enthalpy of sorption) are computed.

APPARATUS AND MEASUREMENTS

The experimental techniques for a vacuum apparatus, in which sorption isosteres will be measured automatically, were developed during a pilot programme. The isosteres obtained with the help of this apparatus were measured by a dynamic procedure: the temperature was changed 10°C every hour and the pressure was read just before the temperature change. The extent of hysteresis between cooling and heating curves is a measure of departure from equilibrium.

That we can obtain isosteres dynamically is of great practical importance. It means that this mode of the operation can be automated, and equilibrium can be approached as closely as desired by adjusting the heating and cooling rates. A new apparatus operating on these principles has been designed and is being assembled. The major features of this apparatus are as follows:

- (1) pressure range $\approx 10^{-4}$ to 300 Torr;
- (2) temperature range ≈ -30 to $+150^\circ\text{C}$;
- (3) automatically controlled heating and cooling rates;
- (4) high precision of temperature control and read-out;
- (5) high precision of pressure read-out;
- (6) digital recording of temperature and pressure.

The temperature and pressure ranges could probably be extended to $\pm -200^{\circ}\text{C}$ and 10^{-6} Torr, respectively. Investigations at very low pressures are particularly interesting, since in this region adsorbed water and other adsorbates will act as true 'surface probes'. On the other hand, measurements at sub-zero temperatures will help to establish a definite thermodynamic theory for the freezing process.

ANALYSIS OF RESULTS

The sorption data will be analysed by using regression techniques. The sorption data from the pilot project are at present being analysed. The results of this analysis, together with a more detailed description of the experimental techniques will be published shortly.

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Low-frequency dynamic mechanical testing of hardened cement paste

An experimental programme is being undertaken to discover the dynamic mechanical response of hardened cement paste (hcp) beams in bending in the frequency range from 10^{-3} to 10^2 Hz. Other experimental variables will be temperature, hcp structural characteristics and equilibrium moisture content. The structure of the hcp will be controlled by the water/cement ratio and the curing temperature, thus producing well hydrated pastes with different total porosities, pore size distributions, internal surface areas etc. Appropriate parameters characterizing these properties will be derived from water sorption isotherms.

The central goal of the research is to relate deformational behaviour to the structure of hcp. The response curves will be characterized with viscoelastic parameters, thus allowing quantitative comparison of the response of different pastes. Apparent activation energies will be computed as an aid to the identification of diffusion or flow processes responsible for the deformation.

Low-frequency tests have been chosen because previous short-term creep recovery tests* have established the presence of a deformational mechanism within this time range. The present experiments will

extend the time range of the previous tests, and also provide a unique opportunity to test the applicability of linear viscoelastic theory in this system.

In the creep recovery research project, the tentative conclusion was drawn that the deformation was caused by a redistribution of 'capillary' water in response to the load. The extension of the time range to shorter times in the present project will make it possible to investigate this hypothesis further.

The experiments will be performed using an electromagnetic exciter and a nontouching displacement transducer. A special electronic circuit has been designed which is able to measure the phase difference between the applied load and the resulting displacement to an absolute accuracy of 0.1° .

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Future 'Concrete research news'

The Editor will welcome submissions for future editions of 'Concrete research news'. Entries should relate to programmes of research which are just starting, or which are just entering a substantially new phase. Each item must be submitted, or at least authorized in its final form, by the head of department or director of research concerned.

Entries for 'Concrete research news' will be considered by the Editorial Advisory Board in the usual way and so, if it is convenient to submit up to eight copies (at least two, please), this is helpful. It is hoped to publish all items accepted in one of the two issues following the date of their receipt. As a general guide only, items for the March issue should reach the Editor by the end of January at the latest, and so on quarterly.

*SELLEVOLD, E. J. *Anelastic behaviour of hardened portland cement paste*. Thesis submitted to Stanford University, California, Department of Civil Engineering, for the degree of PhD. Stanford Report No. 113.