Behaviour of Concrete under Triaxial Loading

Dipl.-Ing. Diethelm Linse
Institut für Massivbau, Technische Universität München
Direktor: o. Prof. Dr.-Ing. Herbert Kupfer

The triaxial stress-strain behaviour of concrete is an important factor to gain a better knowledge of the nature of concrete and to compute massive concrete structures.

To study the influence of triaxial stress on strength and deformation of concrete a testing apparatus was built in 1972. The frame consists of prestressed concrete (see fig. 1). The maximum jack-loading in each three directions is 200 Mp (= 2000 kN) compression and approx. 20 Mp (= 200 kN) tension. The specimens are cubes of 10 x 10 x 10 cm. To avoid any restraint of the specimen's lateral deformation "brush bearing platens" were used. They consist of several single filaments which are clamped together. In the case of lateral deformation of the specimen the tops of the filaments can follow these dilatations due to their flexibility. Tests and calculations have shown that the sum of all horizontal brush-forces is less than 1% of the vertical loading and, therefore, does not influence the test results significantly.

The ratio of the press forces remains constant during the test. The highest loading was normally reached within 20 minutes.

The press forces were measured by electric strain gauges, the deformation of the specimens by mechanical meters (they can be substituted by inductive meters) which are attached to the tops of the brush bearing platens (fig. 2), /2/.

Up to now approx. 20 triaxial compression tests have been undertaken. The uniaxial strength (βc) of the concrete specimens was about 300 kp/cm^2 (= 30 N/mm^2). The characteristic results of these tests are as follows:

1. Extreme deformation was observed in all three directions.

It can reach approx. 25 °/oo without any visible fracture of the specimen. Reloaded specimens with this deformation had a uniaxial strength of approx. 50% of their original uniaxial strength.

2. Creep was very extensive at high loading. It can be assumed that the ultimate load for sustained forces is reached when creep increases rapidly (fig. 3; /3/).

3. At a stress ratio of min σ/max σ > ≈0,20 fracture could not be reached within 20 minutes. The uniaxial strength of such a preloaded specimen was about 80% of the original uniaxial strength.

4. If an unbroken specimen was reloaded with the same stress-ratio the plastic deformation was less than under the first loading. In this case, the specimen failed at a stress level which was less than the ultimate strength of a specimen which was not preloaded (see fig. 4).

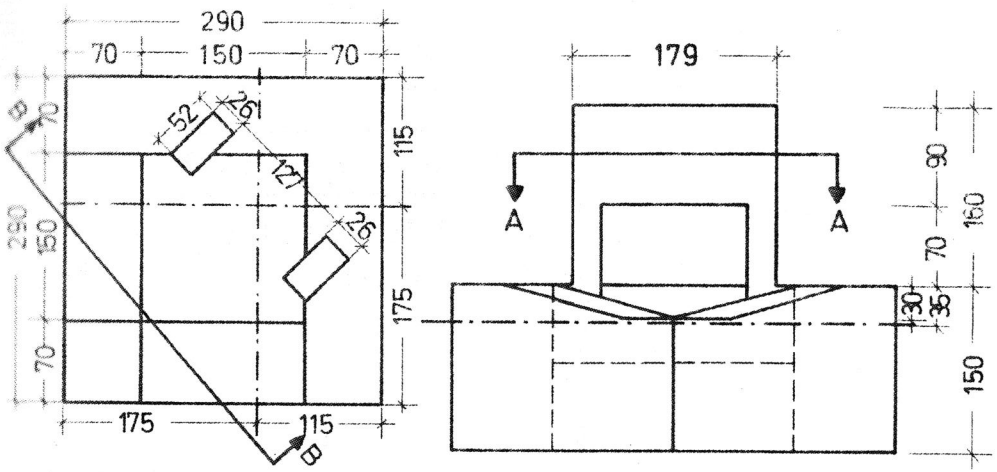
These tests have shown that the triaxial strength of concrete can be much higher than the uniaxial and biaxial strength. At high stress levels concrete is subject to extreme deformation. It is, also, evident that the problem of multiaxial strength under sustained or repeated loading is of great importance. More extensive tests are necessary on this subject.

Bibliography

/1/ Kupfer, H., Hilsdorf, H. and Rüsch H.: Behaviour of Concrete under Biaxial Stresses. ACI Journal, V.66, No. 8, 1969

/2/ Linse, D and Stegbauer A.: Triaxial Stress-Strain-Behaviour of Concrete: Testing Equipment. RIIEM Colloquium "The Deformation and the Rupture of Solids", Cannes 1972

/3/ Launay, P., Gachon, H. and Poitevin, P.: Deformation et Resistance Ultime du Beton sous Etreinte Triaxiale; FIP Congress, Prague 1970



Frame; section A-A View of frame; section B-B

Fig. 1

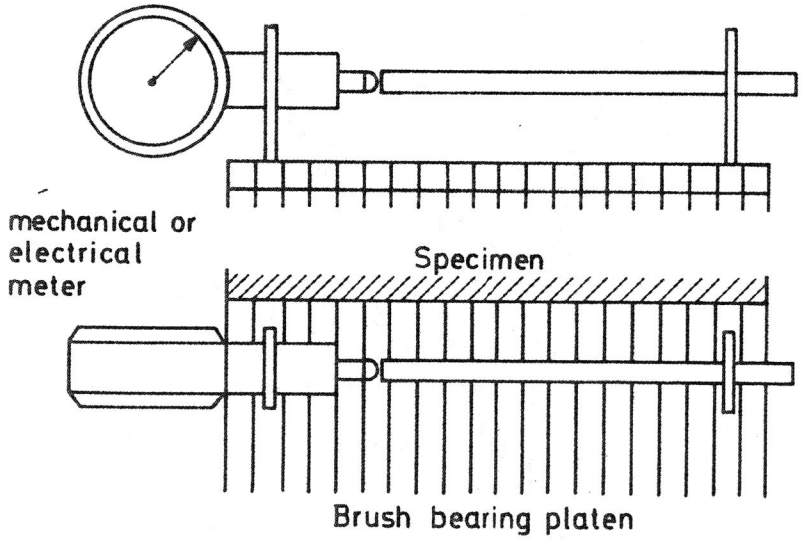


Fig. 2: Measuring of deformations

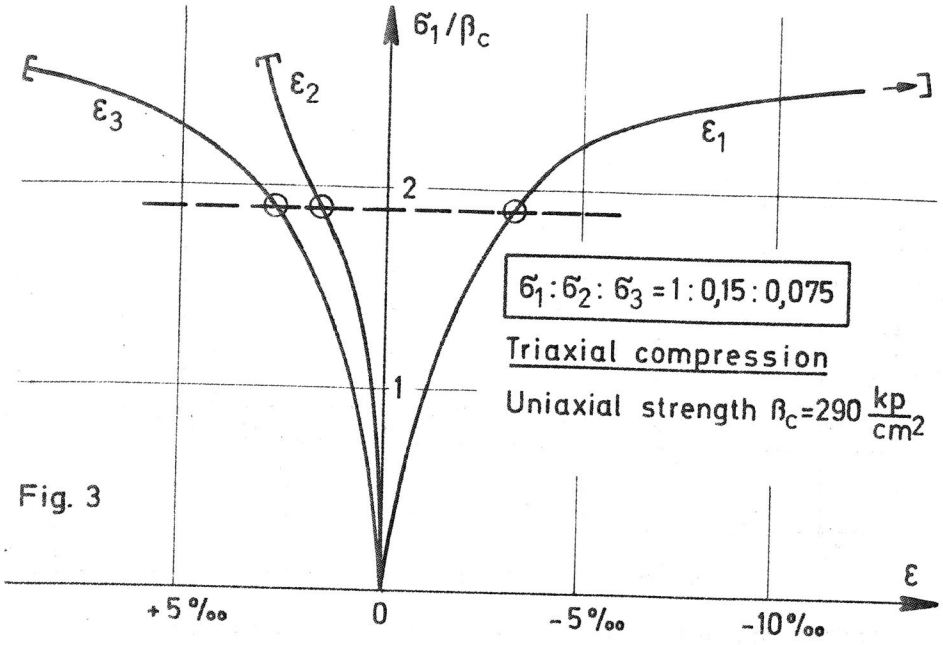

σ1/βc
ε3
ε2
ε1
2
1
σ1 : σ2 : σ3 = 1 : 0,15 : 0,075
Triaxial compression
Uniaxial strength βc=290 kp/cm2
ε
+5‰
0
-5‰
-10‰

Fig. 3

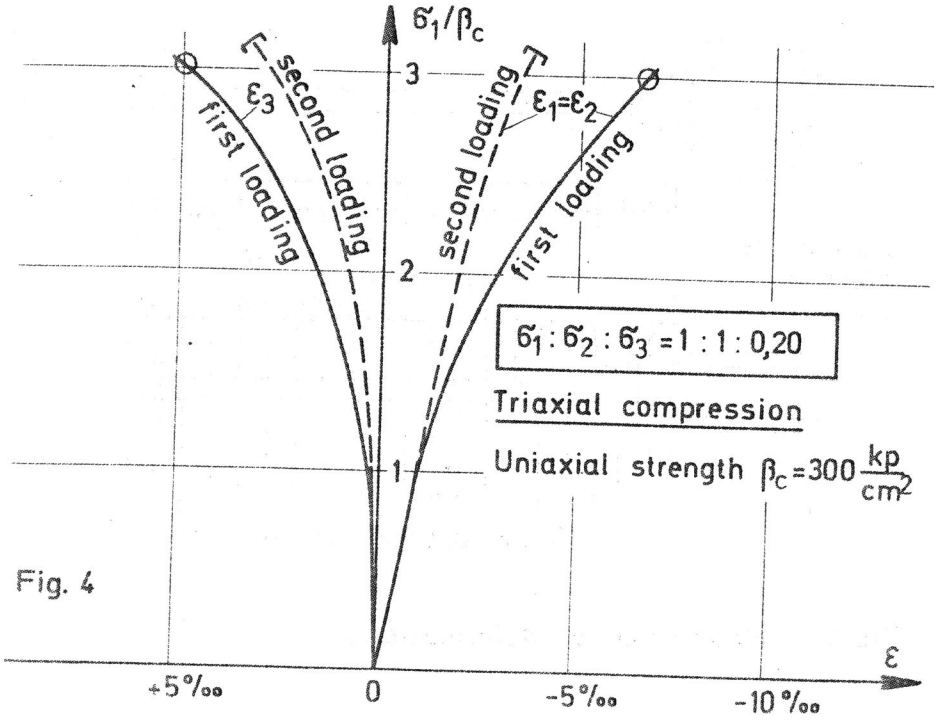

σ1/βc
3
2
1
second loading
first loading
ε3
ε1=ε2
σ1 : σ2 : σ3 = 1 : 1 : 0,20
Triaxial compression
Uniaxial strength βc=300 kp/cm2
ε
+5‰
0
-5‰
-10‰

Fig. 4