On the Influence of Different Load Application Techniques on the Lateral Strain and Fracture of Concrete Specimens

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1. The problem of friction at the end faces

The standard uniaxial test methods are characterized by applying the load to the test specimens with rigid steel platens. It is generally known that thereby not uniaxial but actually triaxial states of stress are produced. Therefore the strength results based on the fracture of the specimens are in this case higher than in the case of free deformability of the specimens.

The friction between steel platens and specimen leads to restrained lateral strains, inducing forces in the concrete specimen added to the nominal test load. This results in a multiaxial state of stress which is not well defined, as the frictional forces in the contact zone of steel platen and concrete specimen end face depend on a large number of influences and the distribution of the frictional forces on said end face is unknown. A controllable definite state of stress, as it is absolutely necessary for multiaxial strength tests among others, can thus only be obtained with a specimen deformability that is in no direction restrained by frictional forces.

2. Methods of reducing end face friction

In the year 1900 A. Föppl already reported experiments with wax and stearin as lubricants. With them applied the compressive strength of specimens of different materials, as expected, was lower than in case of direct contact between the dry steel platen and the specimen. Simple lubrication, however, is not satisfactory, since stress is reduced near the specimen edge by the lateral extrusion of lubricant, which is not hindered there, and thus load application to the specimen is not uniform. There are also qualified objections as to the lateral pressure in voids, which the lubricants may cause [1].

Better suited though are interposed packs of thin, lubricated sheets. But here also it must be taken into account that the frictional forces yet present are much stronger shortly before fracture occurs than at the start of the load application [2] .

The pressure platen developed by Hilsdorf called steel brush represents another possibility for a load application to the specimen without substantial restraint of lateral strain. Applicability of this technique is limited by the allowed maximum pressure load of only about 50 N/mm^2 (500 kp/cm^2) above which for uniaxial testing brush bending occurs [3].

A further possibility to avoid frictional forces between platen and test specimen finally is to deform the platen during the compression test exactly as the specimen wants to deform under the influence of the load. The pressure platen is resolved into individual stamps with a pressure area of 6.25 cm^2, arranged close to one another. These stamps are supported by a rubber plate that acts as a hydraulic cushion. Thus all stamps transmit the same load to the specimen [4].

Fig. 1 shows the four techniques of load application to cubic concrete specimens, treated here. In the following results from experiments with lubricated aluminum sheets are communicated and compared to corresponding results from measurements performed with dry pressure platens. Comparative tests with the last two techniques of Fig. 1 have not yet been concluded. Also results for the specimen fracture are missing at the present time (September 1972). This will be supplemented in an oral report at the congress in Munich.

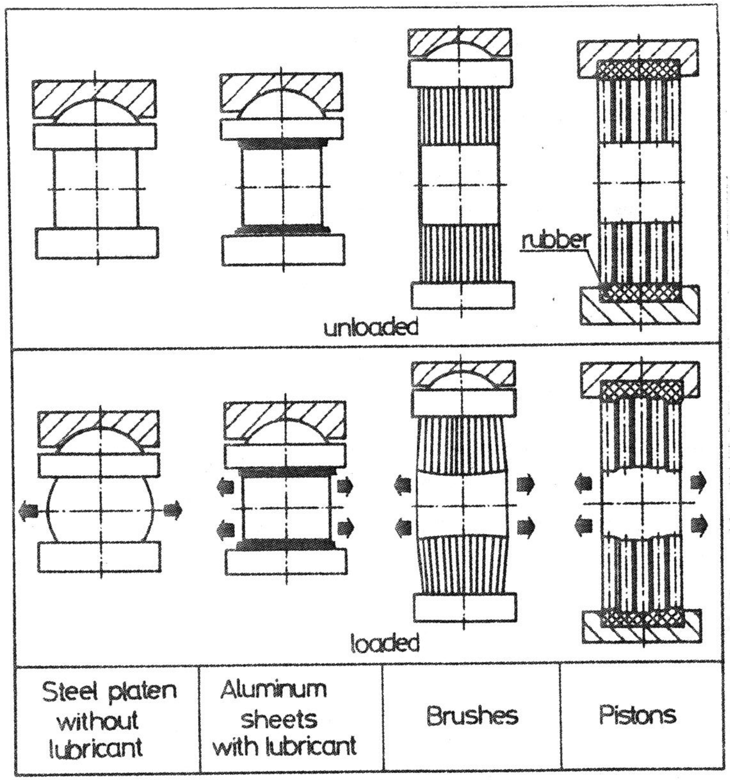

Fig. 1: Methods of load application

3. Reducing end face friction with lubricated aluminum sheets

The experiments were carried out with 10 cm concrete cubes 150 days of age. The 28 day strength was 51 N/mm^2 (510 kp/cm^2). The tests were run automatically under always the same experimental conditions with a rate of load application of 0.3 N/mm^{2}s. Each of the 7 test series embraced 6 specimens. The measuring positions were in pairs (to the right and left) at half height, quarter height and near the bottom end face of the cube. Starting from an initial load of 10 kN (1 Mp) the load was applied and the deformations were recorded in 10 load steps up to the maximum load of 250 kN (25 Mp).

In Fig. 2 the average values of the test results are compiled. The slide effect of the following packs of lubricated aluminum sheets was examined in 7 test series:

1: steel pressure platens without lubrication
2: 6 aluminum sheets each 0.1 mm thick, lubricated
3: 12 aluminum sheets each 0.1 mm thick, lubricated
4: 6 aluminum sheets each 0.05 mm thick, lubricated
5: 12 aluminum sheets each 0.05 mm thick, lubricated
6: 6 aluminum sheets each 0.02 mm thick, lubricated
7: 12 aluminum sheets each 0.02 mm thick, lubricated

In all cases a mixture of 2 sorts of molybdenum disulfide with an addition of vaseline was used as lubricant.

From the deformations (microstrains) given in Fig. 2 the slide effect of the examined packs of aluminum sheets is obvious. The strains in quarter height were 8 %, those near the end face 10 % larger than the ones on the cubes that lacked lubrication at the end faces. The variation of the slide effect for the different sheet packs was small. None of the test series with the aluminum sheet interlayers, however, yielded approximate agreement of the lateral strain values at half height, quarter height and end face of the cube. For further trials the slide packs with the 0.02 mm thick aluminum sheets were selected.

[1] Föppl, A.: Die Abhängigkeit der Bruchgefahr von der Art des Spannungszustandes. Mitteilungen aus dem Mechanisch-Technischen Laboratorium der TH München (1900), No. 27
[2] Bremer, F.: Festigkeits- und Verformungsverhalten des Betons bei mehrachsiger Beanspruchung. Beton- und Stahlbetonbau (1971), No. 1
[3] Hilsdorf, H.: Die Bestimmung der zweiachsigen Festigkeit des Betons. Deutscher Ausschuß für Stahlbeton (1965), No. 173
[4] Schickert, G.: Design of a testing apparatus for short time testing of concrete under triaxial load. ACI Seminar Berlin 10/1970

test series		1			2			3			4			5			6			7		
alu-sheets		without			6 x 0,1 mm			12 x 0,1 mm			6 x 0,05 mm			12 x 0,05 mm			6 x 0,02 mm			12 x 0,02 mm		
strain position		h	qu	e	h	qu	e	h	qu	e	h	qu	e	h	qu	e	h	qu	e	h	qu	e
load [kN]		strains [μm/m]																				
10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25		20	19	10	24	23	5	35	30	18	28	25	15	20	20	9	23	22	10	24	23	11
50		51	41	22	73	64	30	85	72	42	69	61	41	64	56	28	68	60	37	72	62	28
75		90	73	48	115	101	60	133	113	75	107	93	64	109	94	55	111	97	67	117	102	59
100		127	102	70	153	136	90	175	149	104	137	119	87	147	124	80	144	126	91	159	141	91
125	abs.	160	132	93	194	174	126	212	181	136	177	158	126	186	161	113	182	161	124	190	166	113
	relative	100 %	83 %	58 %	100 %	90 %	65 %	100 %	85 %	64 %	100 %	89 %	71 %	100 %	86 %	61 %	100 %	88 %	68 %	100 %	87 %	59 %
150		187	153	108	235	211	163	248	211	166	217	194	156	219	191	139	214	188	149	224	197	142
175		220	181	128	267	241	191	283	244	197	250	226	187	249	217	163	242	214	173	259	230	171
200		245	203	146	299	268	215	314	271	222	280	252	210	286	251	196	280	250	206	293	260	202
225		275	229	167	328	292	243	348	302	253	303	274	230	319	283	226	307	273	228	323	289	229
250	abs.	302	253	185	359	326	270	384	336	285	332	300	254	351	311	248	334	299	250	352	316	253
	relative	100 %	84 %	61 %	100 %	91 %	75 %	100 %	87 %	74 %	100 %	90 %	77 %	100 %	89 %	71 %	100 %	90 %	75 %	100 %	90 %	72 %

h: half height of the cube qu: quarter height of the cube e: near the bottom endface of the cube

Fig. 2: Slide effect of packs of lubricated aluminum sheets in the strength testing of concrete (10 cm cubes)