Anders Andalen
Tang Lupin
Göran Ohlsson

Application of the Strain-cylinder Test for Calibration of Compression Testing Machines

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Abstract

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A new European standard, prEN 12390 "Testing concrete - Determination of compressive strength - Specification for compression testing machines" will soon be implemented in the Scandinavian countries. According to this standard compression testing machines should be verified by the strain-cylinder test and the force calibration. In order to improve the knowledge in applications of the strain-cylinder test and to check if the compression testing machines used in the Scandinavian countries could meet the requirements specified in prEN 12390 , some pilot strain-cylinder tests were carried out at SP and concrete industrial laboratories. The test results show that the strain-cylinder test is a useful tool to find out some defects of a compression testing machine, such as defective self-alignment of the upper platen and/or significant eccentricity in the machine. The eccentricity in a machine could be estimated by applying some additional eccentric positions in the test. This additional eccentricity test is a useful auxiliary tool for checking if there is a significant eccentricity in the machine. According to the eccentricity test results, significant eccentricity was found in some machines from which the test results of concrete compressive strength in some cases did not fulfil the requirements in comparison tests according to the Swedish regulations BBK 94, even though these machines were calibrated in accordance with EN 10002-2 and SS 13 11 10. Some additional testing procedures for identifying the eccentricity in a machine are suggested in this report.

Key words: Calibration, compression testing machine, concrete, standard methods, strain cylinder test.

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SP Swedish National Testing and Research Institute
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Postal address:
Box 857, S-501 15 BORÅS
Sweden
Telephone +46 33 16 50 00
Telex 36252 Testing S
Telefax +46 33 13 55 02

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1 Introduction

At the present the machines for testing concrete compressive strength are verified by calibrating the applied force according to EN 10002-2 and national standards, for instance, SS 13 11 10 in Sweden. Recently, a new European standard, prEN 12390 "Testing concrete - Determination of compressive strength - Specification for compression testing machines" has been approved and will soon be implemented in the Scandinavian countries. A new feature in this standard compared with the existing standards is that a so called "strain-cylinder test" is carried out as an introduction to verification of compression testing machines. The strain-cylinder test implies a control of testing machine behaviour in giving a specimen homogeneous deformation during the test. In practice, it has been found that, even though the machines are correctly calibrated for force, they may sometimes give different test results when testing identical specimens. These different test results might be caused from defective self-alignment of the upper machine platen and/or significant eccentricity in the machine. Through the strain-cylinder test these defects could possibly be detected. Therefore, some problem with compressive strength results associated with differences in testing machine behaviour could be reduced by verifying testing machines according to the standard prEN 12390.

In the Scandinavian countries the experience in using strain-cylinders is very limited, although there exist a number of different strain-cylinders (see Table 1.1). In Norway, a simple type of strain cylinder was used at the Norwegian Building Research Institute (NBI) since 1985, but the application is limited to measuring eccentricity on its own testing machine. In Denmark, a strain-cylinder for tension testing machine was built up at the FORCE Institute in 1988, but the applications are limited. In Finland, two strain-cylinders were used at the Technical Research Centre (VTT) five years ago for its own compression testing machines, but were not in use in the past years. In Sweden, a strain-cylinder for compression testing machines was built up at SP, Swedish National Testing and Research Institute, in 1997 and the applications are also very limited.

In order to improve the knowledge in applications of the strain-cylinder test and to check if the compression testing machines used in the Scandinavian countries could meet the requirements specified in prEN 12390 , the Nordtest sponsored this project. Two institutions, SP and VTT, participated in the strain-cylinder test and NBI participated in the constructive discussions.

Table 1.1. Current status of the strain-cylinder test in the Scandinavian countries.

	Denmark	Sweden	Norway	Finland
Acquaintance of prEN 12390	Yes	Yes	Yes	Yes
Equipment acc. to prEN 12390	No	Yes	No	Yes
Calibration acc. to prEN 12390	No	No	No	No
Ready for application of prEN 12390	in 1999	Now	in 1999	Now

2 Equipment for the Strain-cylinder Test

2.1 Equipment at SP

The equipment for the strain-cylinder test used at SP consists of a strain-cylinder (Fig. 2.1), a positioning plate with different sizes of gauge blocks and a data sampling/display system (Fig. 2.2).

SP's strain-cylinder was designed and manufactured in accordance with prEN 12390, Annex A. Owing to the reason that most of the compression testing machines in Sweden are designed for testing 150 mm concrete cubes, the height of SP's strain-cylinder is 150 mm rather than 200 mm as described in prEN 12390.

The positioning plate is similar to that described in DIN 51 302. The commercial gauge blocks with the size 2, 4, 5 and 6 ± 0.05 mm were used to confine different eccentric positions of the strain-cylinder.

The data sampling/display system consists of four channels of amplifier, signal conditioner and display screen with the functions of zero setting before testing and data exporting at an expected loading level.

Each strain bridge was calibrated by using two mechanical dial gauges under different load levels on the compression testing machine TONI Pro 5000 at SP in Borås.

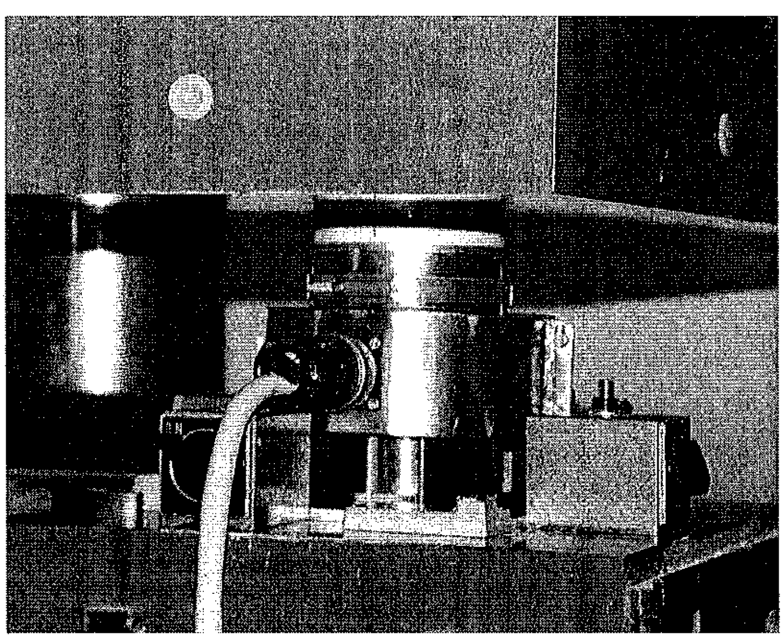

Fig. 2.1. SP's strain-cylinder.

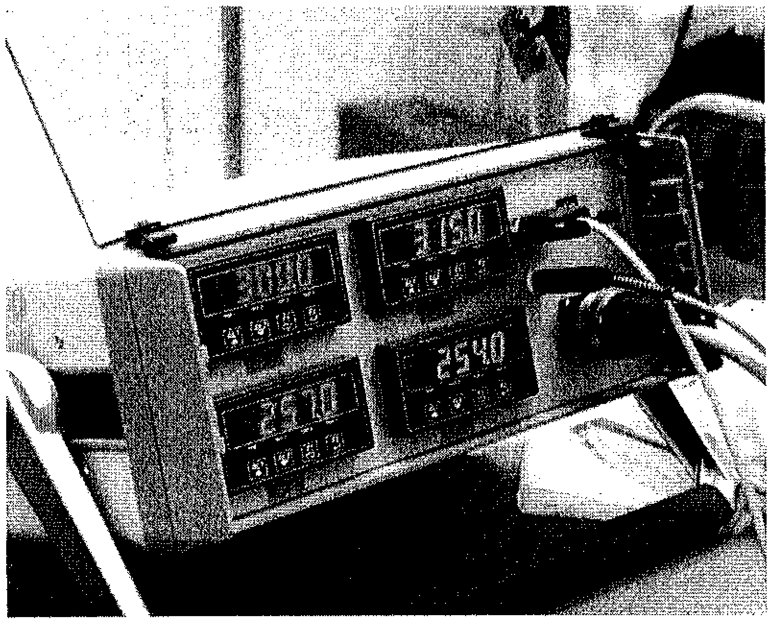

Fig. 2.2. SP's data sampling/display system.

2.2 Equipment at VTT

There are two strain-cylinders at the Technical Research Centre (VTT) in Finland for compression testing machines. One of them was made in Tampere (Fig. 2.3) and another was bought from Italy. Both of the strain-cylinders were designed according to DIN 51302 or BS 1881, Part 115:1986. The one bought from Italy was currently damaged probably due to over loading. Therefore, only the one made in Tampere was used in this project.

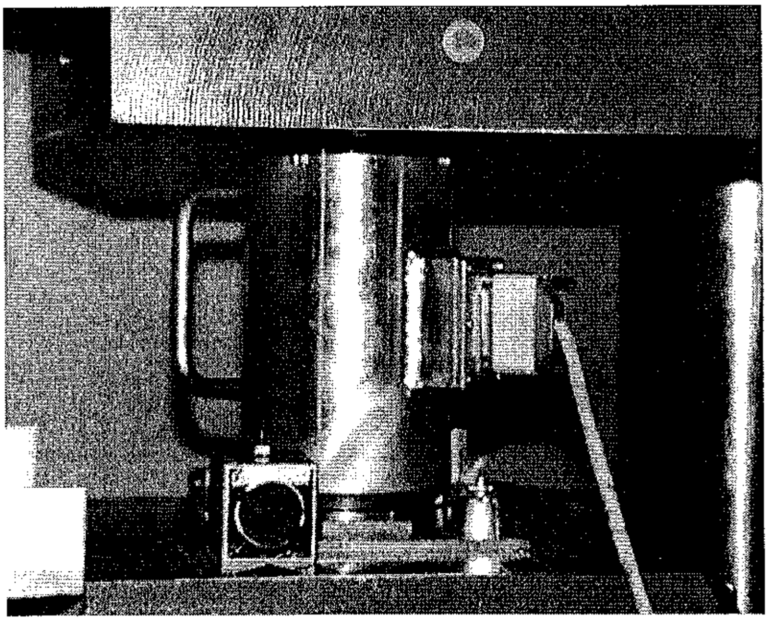

Fig. 2.3. VTT's strain-cylinder made in Tampere.

3 Pilot Tests

3.1 Pilot tests at SP's concrete laboratory in Stockholm

3.1.1 Sensitivity control of strain bridges

The sensitivity of four strain bridges gauged on SP's strain-cylinder was examined twice on the compression testing machine, TONI Technik 3000 at SP's concrete laboratory in Stockholm. The test procedure was in accordance with DIN 51 302, Part 2, Clause 4.3. The test results are shown in Tables 3.1 and 3.2. It can be seen that the results from two tests correspond very well. All four strain bridges meet the requirements specified in DIN 51 302. From the sensitivity control the systematic measurement error of each strain bridge, e_i - e_m, could be estimated. The estimated systematic errors in Table 3.1 were later used to correct the all measured values.

Table 3.1. Sensitivity control of the strain bridges (the first running).

Sensitivity control of straing bridges
According to DIN 51 302, Part 2, Clause 4.3

Machine Type: TONI Technik 3000
Location: SP, Stockholm
Test date: 1998-09-19
Tested by: Göran Ohlsson

Loading: 200 kN									
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
I (A_1)	296	254	280	284	*279*	0.06	-0.09	0.00	0.02
II (B_1)	271	280	263	298	*278*	-0.03	0.01	-0.05	0.07
III (C_1)	258	291	292	271	*278*	-0.07	0.05	0.05	-0.03
IV (D_1)	283	267	301	260	*278*	0.02	-0.04	0.08	-0.06
e_m	**277**	**273**	**284**	**278**	**r_{mean}**	**-0.01**	**-0.02**	**0.02**	**0.00**
e_i - e_m	**-1**	**-5**	**6**	**0**	(Criterion: ± 0.02)	**OK**	**OK**	**OK**	**OK**
Loading: 2000 kN									
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
I (A_1)	2259	2032	2153	2141	*2146*	0.05	-0.05	0.00	0.00
II (B_1)	2139	2142	2035	2267	*2146*	0.00	0.00	-0.05	0.06
III (C_1)	2035	2256	2150	2142	*2146*	-0.05	0.05	0.00	0.00
IV (D_1)	2147	2137	2275	2028	*2147*	0.00	0.00	0.06	-0.06
e_m	**2145**	**2142**	**2153**	**2145**	**r_{mean}**	**0.00**	**0.00**	**0.00**	**0.00**
e_i - e_m	**-1**	**-4**	**7**	**-1**	(Criterion: ± 0.01)	**OK**	**OK**	**OK**	**OK**

Table 3.2. Sensitivity control of the strain bridges (the second running).

Sensitivity control of straing bridges
According to DIN 51 302, Part 2, Clause 4.3

Machine Type: TONI Technik 3000
Location: SP, Stockholm
Test date: 1998-12-01
Tested by: Göran Ohlsson

Loading: 200 kN									
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
I (A_1)	285	265	275	292	*279*	0.02	-0.05	-0.01	0.05
II (B_1)	266	287	277	291	*280*	-0.05	0.03	-0.01	0.04
III (C_1)	269	285	296	271	*280*	-0.04	0.02	0.06	-0.03
IV (D_1)	290	262	292	273	*279*	0.04	-0.06	0.05	-0.02
e_m	**278**	**275**	**285**	**282**	r_{mean}	**-0.01**	**-0.02**	**0.02**	**0.01**
e_i - e_m	**-2**	**-5**	**5**	**2**	(Criterion: ± 0.02)	**OK**	**OK**	**OK**	**OK**

Loading: 2000 kN									
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
I (A_1)	2122	2175	2092	2212	*2150*	-0.01	0.01	-0.03	0.03
II (B_1)	2082	2208	2194	2125	*2152*	-0.03	0.03	0.02	-0.01
III (C_1)	2181	2119	2218	2087	*2151*	0.01	-0.01	0.03	-0.03
IV (D_1)	2212	2077	2132	2185	*2152*	0.03	-0.03	-0.01	0.02
e_m	**2149**	**2145**	**2159**	**2152**	r_{mean}	**0.00**	**0.00**	**0.00**	**0.00**
e_i - e_m	**-2**	**-6**	**8**	**1**	(Criterion: ± 0.01)	**OK**	**OK**	**OK**	**OK**

3.1.2 Strain-cylinder test according to prEN 12390

Two compression testing machines at SP's concrete laboratory in Stockholm, TONI Technik 3000 and TONI 2000, were tested according to the test procedures described in prEN 12390, Annex A. The test results are shown in Tables 3.3 and 3.4, respectively. According to the requirements specified in prEN12390 (see Table 3 in Appendix 1), the maximum permissible difference in the strain ratio, r_{max} - r_{min}, is 0.10, the maximum permissible mean strain ratio, r_{mean}, is ± 0.10, and the maximum permissible strain ratio per mm of displacement is 0.06 at 200 kN force and 0.04 at 2000 kN force or at the maximum capacity of the machine, whichever is the lesser. It can be seen from the results that both of the machines fulfil the requirements specified in prEN 12390.

Table 3.3. Strain-cylinder test results from the TONI Technik 3000 at SP, Stockholm.

Strain-cylinder Test

According to EN 12390, Annex A

Machine Type: TONI Technik 3000
Location: SP, Stockholm
Test date: 1998-10-30
Tested by: Göran Ohlsson

					Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_down	297	252	281	283	278	0.072	-0.076	-0.011	0.018
C_down	299	251	278	289	279	0.075	-0.082	-0.025	0.036
B_down	301	250	275	291	279	0.082	-0.086	-0.036	0.043
D_down	298	252	280	285	279	0.072	-0.079	-0.018	0.022
Alignment of machine components					r_{mean}	**0.075**	**-0.081**	**-0.023**	**0.030**
					(Criterion: ± 0.10)	**OK**	**OK**	**OK**	**OK**
Self-alignment of upper machine platen					$r_{max} - r_{min}$	**0.010**	**0.010**	**0.025**	**0.025**
					(Criterion: 0.10)	**OK**	**OK**	**OK**	**OK**

Verifying restraint on movement of upper machine platen

Eccentric position:		6.0 mm		(200 kN)	Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	229	327	279	269	276	-0.167	0.203		
C_towards	388	164	267	286	276	0.409	-0.388		
B_towards	287	240	212	363	276			-0.254	0.315
D_towards	296	242	368	208	279			0.297	-0.254
					Change in strain ratio per mm along AC:	**0.049**	***<=0.06, Approved***		
					Change in strain ratio per mm along BD:	**0.047**	***<=0.06, Approved***		

Eccentric position:		6.0 mm		(2000 kN)	Correct Δe	1	4	-7	1
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	1825	2442	2145	2107	2130	-0.143	0.148		
C_towards	2606	1659	2113	2146	2131	0.223	-0.220		
B_towards	2184	2049	1761	2500	2123			-0.174	0.178
D_towards	2235	2018	2533	1738	2131			0.189	-0.184
					Change in strain ratio per mm along AC:	**0.031**	***<=0.04, Approved***		
					Change in strain ratio per mm along BD:	**0.030**	***<=0.04, Approved***		

Table 3.4. Strain-cylinder test results of the TONI 2000 at SP, Stockholm.

Strain-cylinder Test

According to EN 12390, Annex A

Machine Type: TONI 2000
Location: SP, Stockholm
Test date: 1998-11-11
Tested by: Göran Ohlsson

Self-alignment of the upper machine platen					Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_down	267	259	275	271	268	0.000	-0.015	0.004	0.011
C_down	267	260	275	271	268	0.000	-0.011	0.004	0.011
B_down	272	258	285	267	271	0.007	-0.030	0.030	-0.015
D_down	263	262	274	269	267	-0.011	0.000	0.004	0.007
Alignment of machine components					r_{mean}	-0.001	-0.014	0.011	0.004
					(Criterion: ± 0.10)	OK	OK	OK	OK
Self-alignment of upper machine platen					$r_{max} - r_{min}$	0.018	0.030	0.026	0.026
					(Criterion: 0.10)	OK	OK	OK	OK

Verifying restraint on movement of upper machine platen									
Eccentric position:		6.0 mm		(200 kN)	Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	225	307	291	275	275	-0.178	0.135		
C_towards	310	221	266	287	271	0.148	-0.166		
B_towards	278	260	215	326	270			-0.226	0.207
D_towards	271	272	326	226	274			0.168	-0.175
				Change in strain ratio per mm along AC:		0.026	*<=0.06, Approved*		
				Change in strain ratio per mm along BD:		0.032	*<=0.06, Approved*		
Eccentric position:		6.0 mm		(2000 kN)	Correct Δe	1	4	-7	1
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	1920	2342	2149	2137	2137	-0.101	0.098		
C_towards	2404	1864	2078	2202	2137	0.125	-0.126		
B_towards	2147	2118	1884	2392	2135			-0.121	0.121
D_towards	2116	2147	2374	1902	2135			0.112	-0.109
				Change in strain ratio per mm along AC:		0.019	*<=0.04, Approved*		
				Change in strain ratio per mm along BD:		0.019	*<=0.04, Approved*		

3.1.3 Estimation of eccentricity

In order to estimate the eccentricity of compression testing machines some additional eccentric positions, rather than only 6 mm specified in prEN 12390, were used in the test. Under ideal conditions, the strain ratio r should be linearly proportional to the eccentric position x. If there is no eccentricity, the plot r-x should cross the origin. The intercept on the x-axis is, therefore, an indication of eccentricity. The average value of intercept of Bridges 1 and 2 indicates the eccentricity along the AC direction and that of Bridges 3 and 4 indicates the eccentricity along the BD direction. Some examples of the plot r-x are shown in Figs. 3.1 and 3.2. The results of eccentricity analysis are shown in Tables 3.5 and 3.8 and illustrated in Figs. 3.3 and 3.6. It can be seen that the eccentricity measured under the load 200 kN is quite comparable with that measured under the load 2000 kN. To simplify the test procedure and reduce the risk of over loading on the strain-cylinder, it is suggested that the load 200 kN is used for the estimation of eccentricity.

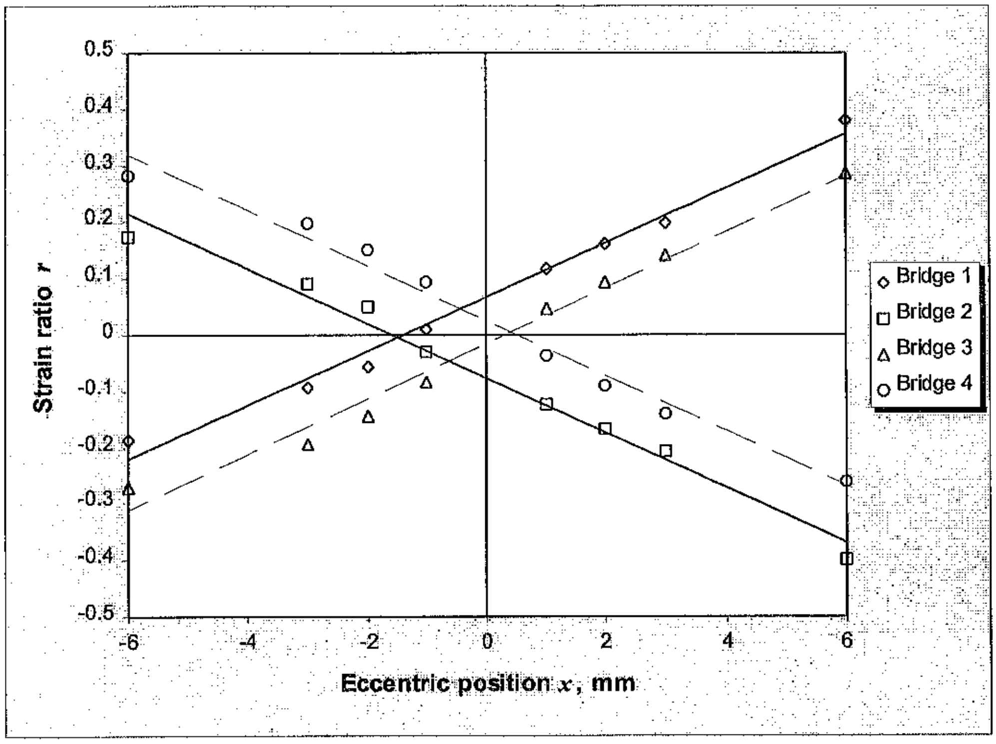

Fig. 3.1. Plot r-x tested on the TONI Technik 3000 at SP, Stockholm (under the load 200 kN).

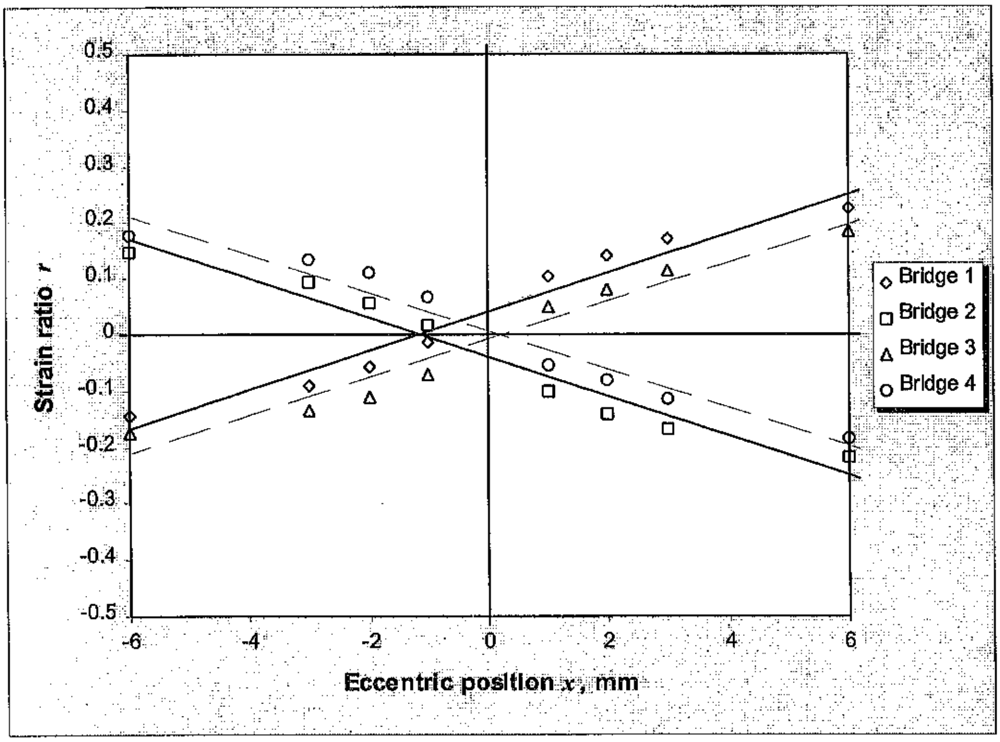

Fig. 3.2. Plot r-x tested on the TONI Technik 3000 at SP, Stockholm (under the load 2000 kN).

Table 3.5. Results of eccentricity analysis from the TONI Technik 3000 at SP, Stockholm (under the load 200 kN).

Eccentricity Analysis

Machine Type: TONI Technik 3000 SP, Stockholm

x, mm	e_1	e_2	e_3	e_4	e_m	e_m	r_1	r_2	r_3	r_4
-6	230	332	206	363	276	276	-0.167	0.203	-0.254	0.315
-3	255	306	226	337	278	277	-0.083	0.101	-0.184	0.217
-2	264	294	240	322	279	278	-0.054	0.054	-0.137	0.158
-1	282	271	256	305	277	279	0.018	-0.022	-0.082	0.093
1	312	244	292	269	279	279	0.118	-0.125	0.047	-0.036
2	325	233	306	255	279	278	0.165	-0.165	0.101	-0.083
3	337	223	321	241	279	278	0.208	-0.201	0.155	-0.133
6	389	169	362	208	276	279	0.409	-0.388	0.297	-0.254

Statistic analysis $y = ax + b$

					R_1	R_2	R_3	R_4
a	0.049	-0.050	0.049	-0.051				
b	0.077	-0.068	-0.007	0.035	0.988	0.995	0.989	0.994
$x_{(y=0)}$	**-1.571**	**-1.360**	**0.143**	**0.686**				

Real centre of the lower platen

-1.5 mm (along AC direction towards A)

0.4 mm (along BD direction towards D)

Table 3.6. Results of eccentricity analysis from the TONI Technik 3000 at SP, Stockholm (under the load 2000 kN).

Eccentricity Analysis

Machine Type: TONI Technik 3000 SP, Stockholm

x, mm	e_1	e_2	e_3	e_4	e_m	e_m	r_1	r_2	r_3	r_4
-6	1826	2446	1754	2501	2130	2123	-0.143	0.148	-0.174	0.178
-3	1949	2344	1857	2428	2144	2141	-0.091	0.093	-0.133	0.134
-2	2023	2270	1907	2384	2145	2145	-0.057	0.058	-0.111	0.111
-1	2115	2179	1997	2291	2145	2145	-0.014	0.016	-0.069	0.068
1	2368	1926	2255	2032	2145	2145	0.104	-0.102	0.051	-0.053
2	2448	1847	2316	1973	2146	2145	0.141	-0.139	0.080	-0.080
3	2511	1783	2392	1897	2145	2145	0.171	-0.169	0.115	-0.116
6	2607	1663	2526	1739	2131	2131	0.223	-0.220	0.185	-0.184

Statistic analysis $y = ax + b$

					R_1	R_2	R_3	R_4
a	0.035	-0.035	0.034	-0.034				
b	0.042	-0.039	-0.007	0.007	0.978	0.978	0.977	0.978
$x_{(y=0)}$	**-1.20**	**-1.11**	**0.21**	**0.21**				

Real centre of the lower platen

-1.16 mm (along AC direction towards A)

0.21 mm (along BD direction towards D)

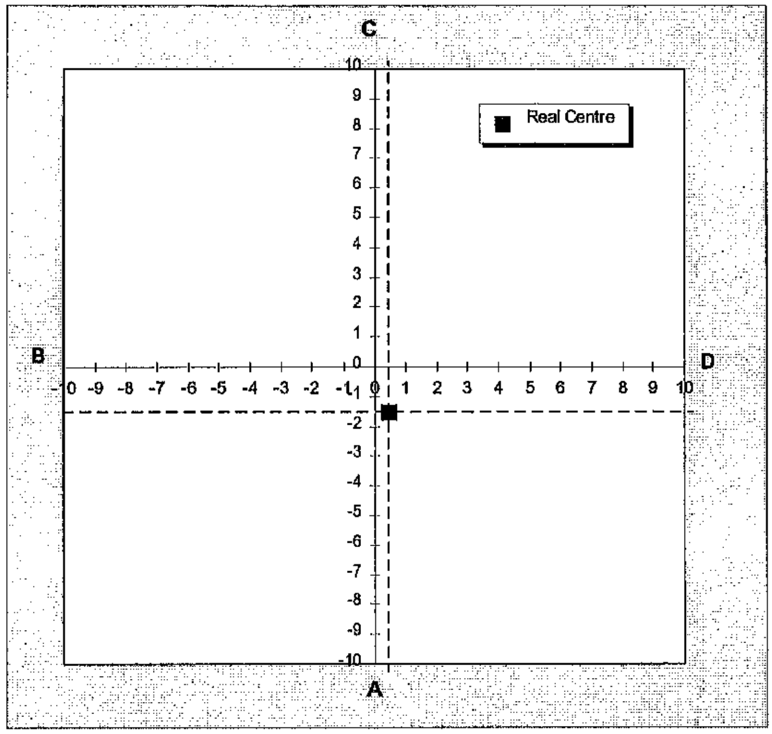

Fig. 3.3. Illustration of the real centre of the TONI Technik 3000 at SP, Stockholm (under the load 200 kN).

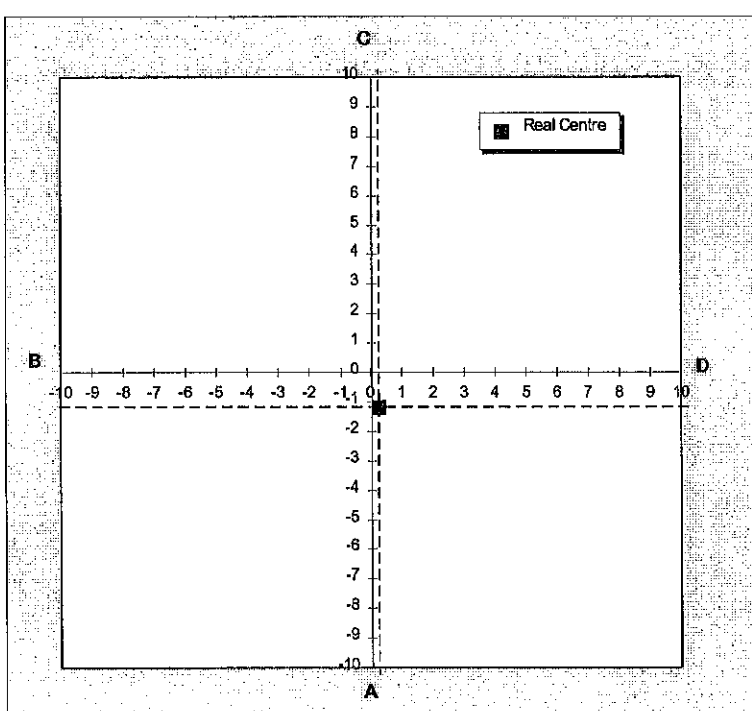

Fig. 3.4. Illustration of the real centre of the TONI Technik 3000 at SP, Stockholm (under the load 2000 kN).

Table 3.7. Results of eccentricity analysis from the TONI 2000 at SP, Stockholm (under the load 200 kN).

Eccentricity Analysis

Machine Type: TONI 2000 **SP, Stockholm**

x, mm	e_1	e_2	e_3	e_4	e_m	e_m	r_1	r_2	r_3	r_4
-6	226	312	209	326	275	270	-0.178	0.135	-0.226	0.207
-3	245	292	247	292	271	270	-0.096	0.077	-0.085	0.081
-1	265	267	266	275	269	270	-0.015	-0.007	-0.015	0.019
1	273	259	277	264	267	269	0.022	-0.030	0.030	-0.019
3	279	256	284	264	268	273	0.041	-0.045	0.040	-0.033
6	311	226	320	226	271	274	0.148	-0.166	0.168	-0.175

Statistic analysis $y = ax + b$

					R_1	R_2	R_3	R_4
a	0.026	-0.024	0.030	-0.029				
b	-0.013	-0.006	-0.015	0.013	0.989	0.98	0.979	0.98
$x_{(y=0)}$	**0.500**	**-0.250**	**0.500**	**0.448**				

Real centre of the lower platen

0.1 mm (along AC direction towards C)

0.5 mm (along BD direction towards D)

Table 3.8. Results of eccentricity analysis from the TONI 2000 at SP, Stockholm (under the load 2000 kN).

Eccentricity Analysis

Machine Type: TONI 2000

x, mm	e_1	e_2	e_3	e_4	e_m	e_m	r_1	r_2	r_3	r_4
-6	1921	2347	1878	2392	2137	2135	-0.101	0.098	-0.120	0.120
-3	1992	2273	1969	2304	2135	2136	-0.067	0.065	-0.078	0.079
0	1	5	-6	0	0	0				
-1	2062	2206	2058	2215	2135	2136	-0.034	0.033	-0.037	0.037
1	2182	2092	2172	2101	2138	2136	0.021	-0.022	0.017	-0.016
0	1	5	-6	0	0	0				
3	2287	1984	2238	2034	2136	2135	0.071	-0.071	0.048	-0.047
6	2405	1869	2368	1902	2137	2135	0.125	-0.125	0.109	-0.109

Statistic analysis $y = ax + b$

					R_1	R_2	R_3	R_4
a	0.020	-0.020	0.020	-0.020				
b	0.002	-0.004	-0.010	0.011	0.99	0.99	0.997	0.996
$x_{(y=0)}$	**-0.10**	**-0.20**	**0.50**	**0.55**				

Real centre of the lower platen

-0.2 mm (along AC direction towards A)

0.5 mm (along BD direction towards D)

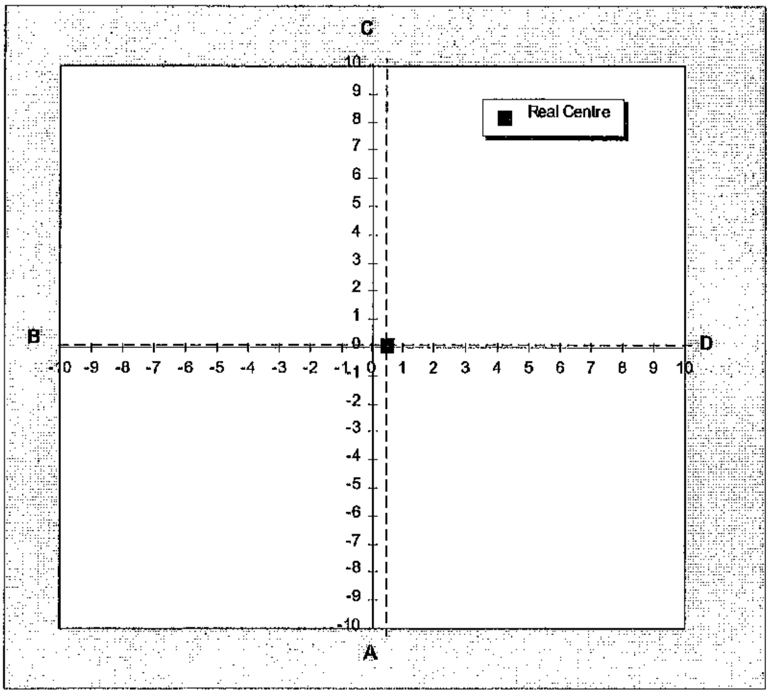

Fig. 3.5. Illustration of the real centre of the TONI 2000 at SP, Stockholm (under the load 200 kN).

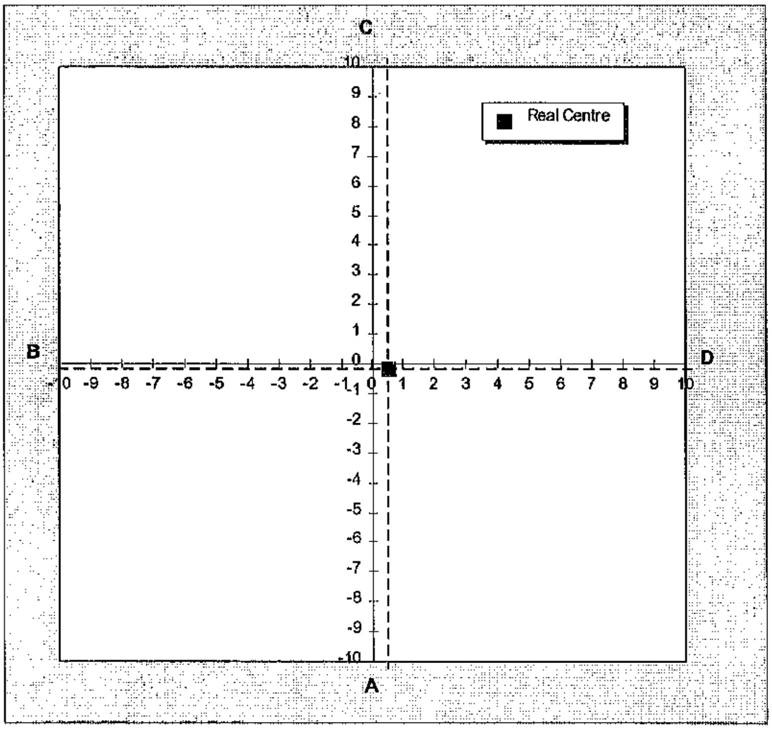

Fig. 3.6. Illustration of the real centre of the TONI 2000 at SP, Stockholm (under the load 2000 kN).

3.2 Pilot tests at concrete industrial laboratories

According to the Swedish regulations for testing concrete strength (BBK 94), the test results from a concrete industrial laboratory should be comparable with those from a reference laboratory in a comparison test. SP is one of the reference laboratories in Sweden. In our practice it has been found that the compressive strength test results from a number of concrete industrial laboratories in some cases did not fulfil the requirements specified in the Swedish regulations BBK 94, even though the machines in these industrial laboratories were correctly calibrated according to EN 10002-2 and SS 13 11 10. In order to find the reasons why the deviations are so large, two industrial laboratories from where the test results are not comparable with those from SP were chosen to control their compression testing machines according to prEN 12390. The strain-cylinder test results from these two laboratories are shown in Tables 3.9 and 3.10. It can be seen that both of the machines were failed according to the specifications given in prEN 12390. From the eccentricity examinations it was found that both of the machines reveal significant eccentricity, especially the machine at Industrial Lab 1, as shown in Figs. 3.7 and 3.8. Due to the significant eccentricity, overflow of strain under the load 2000 kN was found. An interesting thing is that the verification of restraint on movement of the upper machine platen might be approved even if the machine shows a significant eccentricity, e.g. the one at Industrial Lab 1 under the load 200 kN.

Table 3.9. Strain-cylinder test results of the machine at Industrial Lab 1.

Strain-cylinder Test

According to EN 12390, Annex A

Machine Type: Seidner WP 200
Location: [redacted]
Test date: 1998-10-22
Tested by: Göran Ohlsson

					Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_down	288	244	283	274	*272*	0.063	-0.085	0.018	0.007
C_down	96	417	221	329	*266*	-0.635	0.586	-0.192	0.237
B_down	139	381	337	213	*268*	-0.478	0.440	0.235	-0.205
D_down	109	408	220	333	*268*	-0.590	0.541	-0.201	0.243
Alignment of machine components					r_{mean}	**-0.410**	***0.371***	***-0.035***	**0.071**
					(Criterion: ± 0.10)	**Failed**	**Failed**	**OK**	**OK**
Self-alignment of upper machine platen					$r_{max} - r_{min}$	**0.698**	***0.671***	***0.436***	**0.448**
					(Criterion: 0.10)	**Failed**	**Failed**	**Failed**	**Failed**

Verifying restraint on movement of upper machine platen

Eccentric position:		6.0 mm		(200 kN)	Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	73	446	241	315	*269*	-0.725	0.677		
C_towards	232	304	230	322	*272*	-0.143	0.136		
B_towards	155	372	210	345	*271*			-0.247	0.273
D_towards	181	348	388	163	*270*			0.415	-0.396

Change in strain ratio per mm along AC: **0.047** ***<=0.06, Approved***

Change in strain ratio per mm along BD: **0.055** ***<=0.06, Approved***

Eccentric position:		6.0 mm		(2000 kN)	Correct Δe	1	4	-7	1
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards		Overflow!			*#Division/0!*	########	########		
C_towards	2391	1781	1985	2209	*2091*	0.144	-0.146		
B_towards	1944	2226	1579	2619	*2092*			-0.249	0.252
D_towards	2004	2167	2609	1591	*2093*			0.247	-0.240

Change in strain ratio per mm along AC: **########** ***#######***

Change in strain ratio per mm along BD: **0.041** ***>0.04, Failed***

Table 3.10. Strain-cylinder test results of the machine at Industrial Lab 2.

Strain-cylinder Test

According to EN 12390, Annex A

Machine Type: TECNOTEST 461
Location: [redacted]
Test date: 1998-11-13
Tested by: Göran Ohlsson

					Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_down	403	181	500	91	*294*	0.374	-0.367	0.680	-0.690
C_down	70	500	458	131	*290*	-0.755	0.741	0.559	-0.548
B_down	276	307	373	228	*296*	-0.064	0.054	0.240	-0.230
D_down	97	466	227	374	*291*	-0.663	0.619	-0.241	0.285
Alignment of machine components					r_{mean}	**-0.277**	***0.262***	***0.310***	**-0.296**
					(Criterion: ± 0.10)	**Failed**	**Failed**	**Failed**	**Failed**
Self-alignment of upper machine platen					$r_{max} - r_{min}$	**1.129**	***1.108***	***0.921***	**0.975**
					(Criterion: 0.10)	**Failed**	**Failed**	**Failed**	**Failed**

Verifying restraint on movement of upper machine platen

Eccentric position:		6.0 mm		(200 kN)	Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	59	594	23	585	*315*	-0.810	0.902		
C_towards					*#Division/0!*	########	########		
B_towards					*#Division/0!*			########	########
D_towards					*#Division/0!*			########	########

Change in strain ratio per mm along AC: ######## #######

Change in strain ratio per mm along BD: ######## #######

Eccentric position:		6.0 mm		(2000 kN)	Correct Δe	1	4	-7	1
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	944	overflow!	1365	2391	*1566*	-0.397	########		
C_towards					*#Division/0!*	########	########		
B_towards					*#Division/0!*			########	########
D_towards					*#Division/0!*			########	########

Change in strain ratio per mm along AC: ######## #######

Change in strain ratio per mm along BD: ######## #######

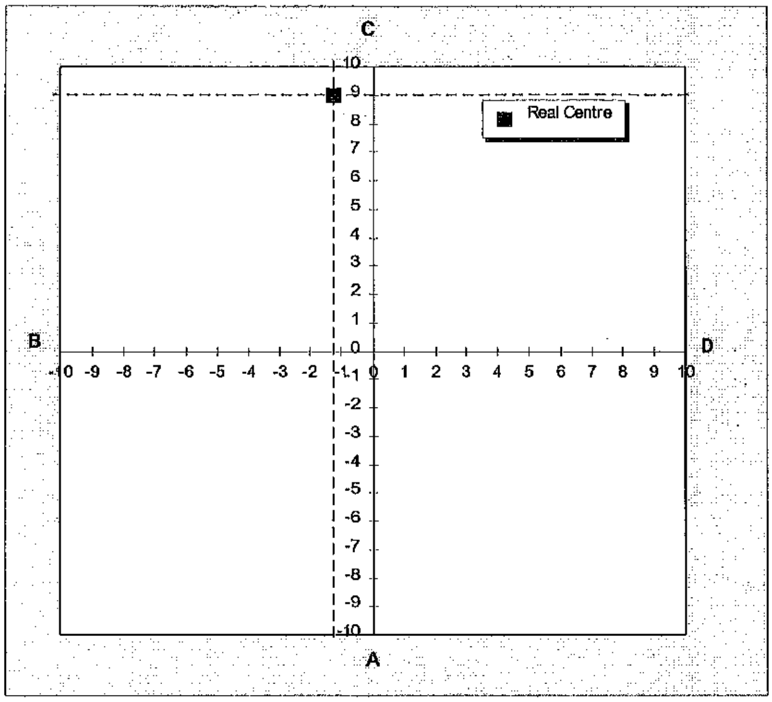

Fig. 3.7. Illustration of the real centre of the machine at Industrial Lab 1.

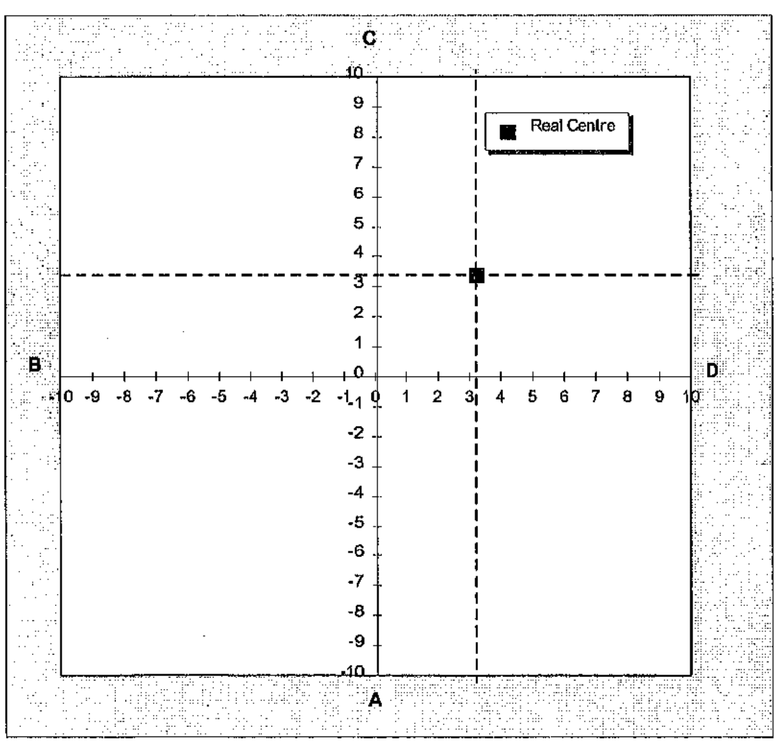

Fig. 3.8. Illustration of the real centre of the machine at Industrial Lab 2.

4 Comparison Tests between SP and VTT

4.1 Comparison tests according to prEN 12390

In order to compare the test results from different strain-cylinders, two compression testing machines, TONI Pro 5000 with automatic operation system and TONI 2000 with manual operation system, both machines are located at SP's concrete laboratory in Borås, were tested by using SP's strain cylinder and VTT's strain cylinder. The test results from SP's strain cylinder are shown in Tables. 4.1 and 4.3, and those from VTT's strain cylinder are shown in Tables 4.2 and 4.4, respectively.

Table 4.1. SP's strain-cylinder test results of the TONI Pro 5000 at SP, Borås.

Strain-cylinder Test

According to EN 12390, Annex A

Machine Type: TONI Pro 5000
Location: SP, Borås
Test date: 1998-12-09
Tested by: SP Göran Ohlsson

					Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_down	296	258	298	275	*282*	0.053	-0.067	0.035	-0.025
C_down	290	260	296	275	*280*	0.039	-0.054	0.036	-0.018
B_down	289	259	302	269	*280*	0.036	-0.057	0.057	-0.039
D_down	292	260	294	279	*281*	0.043	-0.057	0.025	-0.007
Alignment of machine components					r_{mean}	**0.043**	**-0.059**	**0.038**	**-0.022**
					(Criterion: ± 0.10)	**OK**	**OK**	**OK**	**OK**
Self-alignment of upper machine platen					$r_{max} - r_{min}$	**0.017**	**0.013**	**0.032**	**0.032**
					(Criterion: 0.10)	**OK**	**OK**	**OK**	**OK**

Verifying restraint on movement of upper machine platen

Eccentric position:	6.0 mm	(200 kN)			Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	255	309	286	279	*282*	-0.092	0.113		
C_towards	341	219	298	274	*283*	0.208	-0.208		
B_towards	281	253	264	329	*282*			-0.085	0.167
D_towards	307	252	331	241	*283*			0.148	-0.148

Change in strain ratio per mm along AC: **0.026** ***<=0.06, Approved***

Change in strain ratio per mm along BD: **0.023** ***<=0.06, Approved***

Eccentric position:	6.0 mm	(2000 kN)			Correct Δe	1	4	-7	1
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	2018	2272	2146	2140	*2144*	-0.058	0.062		
C_towards	2279	1988	2133	2168	*2142*	0.064	-0.070		
B_towards	2132	2111	2039	2284	*2141*			-0.051	0.067
D_towards	2153	2125	2268	2028	*2143*			0.058	-0.054

Change in strain ratio per mm along AC: **0.011** ***<=0.04, Approved***

Change in strain ratio per mm along BD: **0.010** ***<=0.04, Approved***

Table 4.2. VTT's strain-cylinder test results of the TONI Pro 5000 at SP Borås.

Strain-cylinder Test

According to EN 12390, Annex A

Machine Type: TONI Pro 5000
Location: SP, Borås
Test date: 1998-12-09
Tested by: VTT, Kalevi Kantojärvi
(with under-disc, 1st running)

					Correct Δe	-1	3	-4	3
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_down	240	165	230	176	203	0.177	-0.172	0.113	-0.118
C_down	222	183	227	180	203	0.089	-0.084	0.099	-0.099
B_down	230	166	258	142	199	0.151	-0.151	0.276	-0.271
D_down	226	179	213	193	203	0.108	-0.103	0.030	-0.034
Alignment of machine components					r_{mean}	**0.131**	**-0.128**	**0.130**	**-0.131**
					(Criterion: ± 0.10)	**Failed**	**Failed**	**Failed**	**Failed**
Self-alignment of upper machine platen					$r_{max} - r_{min}$	**0.088**	**0.088**	**0.246**	**0.237**
					(Criterion: 0.10)	**OK**	**OK**	**Failed**	**Failed**

Verifying restraint on movement of upper machine platen

Eccentric position:	6.0 mm		(200 kN)		Correct Δe	-1	3	-4	3
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	205	203	210	198	204	0.000	0.010		
C_towards	227	175	239	163	201	0.124	-0.114		
B_towards	210	188	213	193	201			0.040	-0.025
D_towards	248	157	240	167	203			0.163	-0.163
					Change in strain ratio per mm along AC:	**0.010**	***<=0.06, Approved***		
					Change in strain ratio per mm along BD:	**0.011**	***<=0.06, Approved***		

Eccentric position:	6.0 mm		(2000 kN)		Correct Δe	-13	21	1	-9
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	1941	2052	1997	2006	1999	-0.036	0.037		
C_towards	2108	1870	2046	1945	1992	0.052	-0.051		
B_towards	2034	1943	1945	2058	1995			-0.025	0.027
D_towards	2054	1925	2092	1993	2016			0.038	-0.011
					Change in strain ratio per mm along AC:	**0.007**	***<=0.04, Approved***		
					Change in strain ratio per mm along BD:	**0.004**	***<=0.04, Approved***		

Table 4.3. SP's strain-cylinder test results of the TONI 2000 at SP, Borås.

Strain-cylinder Test

According to EN 12390, Annex A

Machine Type: TONI 2000
Location: SP, Borås
Test date: 1998-12-09
Tested by: SP Göran Ohlsson

					Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_down	274	284	273	290	*280*	-0.018	0.032	-0.046	0.036
C_down	293	262	282	276	*278*	0.058	-0.040	-0.007	-0.007
B_down	278	275	272	287	*278*	0.004	0.007	-0.043	0.032
D_down	282	270	264	297	*278*	0.018	-0.011	-0.072	0.068
Alignment of machine components					r_{mean}	**0.016**	**-0.003**	**-0.042**	**0.032**
					(Criterion: ± 0.10)	**OK**	**OK**	**OK**	**OK**
Self-alignment of upper machine platen					$r_{max} - r_{min}$	**0.076**	**0.072**	**0.065**	**0.075**
					(Criterion: 0.10)	**OK**	**OK**	**OK**	**OK**

Verifying restraint on movement of upper machine platen

Eccentric position:		6.0 mm		(200 kN)	Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	211	352	271	285	*280*	-0.243	0.275		
C_towards	367	202	265	291	*281*	0.310	-0.263		
B_towards	305	250	208	361	*281*			-0.281	0.285
D_towards	275	277	359	214	*281*			0.256	-0.238

Change in strain ratio per mm along AC: **0.045** ***<=0.06, Approved***

Change in strain ratio per mm along BD: **0.044** ***<=0.06, Approved***

Eccentric position:		6.0 mm		(2000 kN)	Correct Δe	1	4	-7	1
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	1716	2520	2152	2093	*2120*	-0.190	0.191		
C_towards	2407	1835	2123	2117	*2120*	0.136	-0.133		
B_towards	2072	2158	1883	2365	*2119*			-0.115	0.117
D_towards	2127	2106	2379	1872	*2121*			0.122	-0.117

Change in strain ratio per mm along AC: **0.027** ***<=0.04, Approved***

Change in strain ratio per mm along BD: **0.020** ***<=0.04, Approved***

Table 4.4. VTT's strain-cylinder test results of the TONI 2000 at SP, Borås.

Strain-cylinder Test

According to EN 12390, Annex A

Machine Type: TONI 2000
Location: SP, Borås
Test date: 1998-12-09
Tested by: VTT, Kalevi Kantojärvi
(with under-disc)

					Correct Δe	-1	3	-4	3
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_down	303	96	182	222	201	0.502	-0.507	-0.114	0.119
C_down	185	213	157	249	201	-0.085	0.075	-0.239	0.254
B_down	243	147	247	150	197	0.228	-0.239	0.234	-0.223
D_down	203	185	94	301	196	0.031	-0.041	-0.541	0.551
Alignment of machine components					r_{mean}	0.169	-0.178	-0.165	0.175
					(Criterion: ± 0.10)	Failed	Failed	Failed	Failed
Self-alignment of upper machine platen					$r_{max} - r_{min}$	0.587	0.582	0.775	0.774
					(Criterion: 0.10)	Failed	Failed	Failed	Failed

Verifying restraint on movement of upper machine platen

Eccentric position:		6.0 mm		(200 kN)	Correct Δe	-1	3	-4	3
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	141	261	178	227	202	-0.307	0.307		
C_towards	257	148	204	200	203	0.261	-0.256		
B_towards	248	149	151	259	202			-0.272	0.297
D_towards	195	195	221	188	200			0.085	-0.045
					Change in strain ratio per mm along AC:	0.047	*<=0.06, Approved*		
					Change in strain ratio per mm along BD:	0.029	<=0.06, Approved		

Eccentric position:		6.0 mm		(2000 kN)	Correct Δe	-13	21	1	-9
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	1696	2227	2062	1870	1964	-0.143	0.145		
C_towards	2457	1510	2129	1843	1985	0.231	-0.229		
B_towards	2054	1909	1662	2314	1985			-0.162	0.161
D_towards	2030	1904	2449	1524	1977			0.239	-0.229
					Change in strain ratio per mm along AC:	0.031	*<=0.04, Approved*		
					Change in strain ratio per mm along BD:	0.033	<=0.04, Approved		

According to SP's strain-cylinder test results (Tables 4.1 and 4.3), both of the machines fulfil the requirements specified in prEN 12390, while according to VTT's strain-cylinder test results (Tables 4.2 and 4.4) both of the machines failed in the verification of alignment of machine components and self-alignment of upper platen. It should be noted that a 16 mm thick disc was used under VTT's strain-cylinder to facilitate the positioning. After discussions at a meeting with the participates from NBI, SP and VTT, the under-disc is suspected of distorting the stress distributions in the strain-cylinder. For instance, if the disc has any convex surface, the stress distributions in the strain-cylinder will be changed, resulting in different strain behaviours on the side surface of the strain-cylinder. This could be seen later in the eccentricity tests. Since VTT's strain-cylinder has a total height of 216 mm (including the thickness 16 mm of the under-disc) which is over the maximum space between the upper and the lower platens of the TONI 2000, thus the lower platen was taken away when using VTT's strain-cylinder. After the test it was found that the place where VTT's strain-cylinder was put on has been indented by the strain-cylinder. Therefore, the results in Table 4.4 may not be valid due to the deformation of the steel on the machine.

In order to check if the machine has changed its behaviour, after VTT's strain-cylinder test, the TONI Pro 5000 was tested once more by using SP's strain-cylinder. The test results are shown in Table 4.5. It can be seen that the results are quite comparable with those shown in Table 4.1. This implies that the machine's behaviour was stable. This also implies that the repeatability of the strain-cylinder test is fairly good.

Table 4.5. SP's strain-cylinder test results of the TONI Pro 5000 at SP, Borås, (the 2nd running).

Strain-cylinder Test

According to EN 12390, Annex A

Machine Type: TONI Pro 5000
Location: SP, Borås
Test date: 1998-12-10
Tested by: SP Göran Ohlsson

					Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_down	302	257	297	274	283	0.071	-0.074	0.028	-0.032
C_down	296	261	300	272	282	0.053	-0.057	0.043	-0.035
B_down	298	259	304	269	283	0.057	-0.067	0.053	-0.049
D_down	299	259	300	273	283	0.060	-0.067	0.039	-0.036
Alignment of machine components					r_{mean}	**0.060**	**-0.066**	**0.041**	**-0.038**
					(Criterion: ± 0.10)	**OK**	**OK**	**OK**	**OK**
Self-alignment of upper machine platen					$r_{max} - r_{min}$	**0.018**	**0.017**	**0.025**	**0.017**
					(Criterion: 0.10)	**OK**	**OK**	**OK**	**OK**

Verifying restraint on movement of upper machine platen

Eccentric position:		6.0 mm		(200 kN)	Correct Δe	1	5	-6	0
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	263	304	288	272	282	-0.064	0.096		
C_towards	345	219	300	271	284	0.218	-0.211		
B_towards	283	252	267	328	283			-0.078	0.159
D_towards	311	248	339	240	285			0.168	-0.158
				Change in strain ratio per mm along AC:		**0.025**	***<=0.06, Approved***		
				Change in strain ratio per mm along BD:		**0.023**	***<=0.06, Approved***		

Eccentric position:		6.0 mm		(2000 kN)	Correct Δe	1	4	-7	1
Operation	e_1	e_2	e_3	e_4	e_m	r_1	r_2	r_3	r_4
A_towards	2027	2269	2161	2129	2146	-0.055	0.059		
C_towards	2287	1987	2145	2159	2144	0.067	-0.071		
B_towards	2138	2114	2046	2282	2145			-0.049	0.064
D_towards	2159	2118	2275	2025	2144			0.061	-0.056
				Change in strain ratio per mm along AC:		**0.011**	***<=0.04, Approved***		
				Change in strain ratio per mm along BD:		**0.010**	***<=0.04, Approved***		

4.2 Eccentricity tests

For SP's strain-cylinder, the eccentric positions 0, 1, 2, 3, 4, and 6 mm were tested and for VTT's strain-cylinder, the eccentric positions 2, 4 and 6 mm were tested. According to SP's results, no significant difference was found in eccentricity when tested at the eccentric positions 1, 2, 3 and 4 mm and at 0, 2, 4 and 6 mm, as shown in Tables 4.6 and 4.7. It is apparent that the test procedure is simpler when using the eccentric positions 0, 2, 4 and 6 mm. The results from VTT's strain-cylinder seem very abnormal (see Table 4.8). From the *r-x* plots (see Fig. 4.1) it can be seen that most of the measured points are out of the linear relationship between strain ratio and eccentric position. This might be a support to the suspicion that the under-disc has distorted the stress distributions in the strain-cylinder. Consequently, the distorted stress distributions have, in return, distorted the linear relationship between *r* and *x*. Therefore, only the results from SP's strain-cylinder are illustrated in Figs. 4.2 and 4.3.

Table 4.6. Eccentricity test results from SP's strain cylinder on the TONI Pro 5000 at SP, Borås. (Eccentric positions 1, 2, 3 and 4 mm).

Eccentricity Analysis

Machine Type: TONI Pro 5000 **SP, Borås**

x, mm	e_1	e_2	e_3	e_4	e_m	e_m	r_1	r_2	r_3	r_4
-4	268	291	272	305	281	281	-0.046	0.036	-0.032	0.085
-3	273	284	273	296	281	279	-0.028	0.011	-0.022	0.061
-2	277	280	276	299	281	281	-0.014	-0.004	-0.018	0.064
-1	284	273	279	293	281	281	0.011	-0.028	-0.007	0.043
1	306	256	300	269	283	283	0.081	-0.095	0.060	-0.049
2	311	248	303	262	280	281	0.111	-0.114	0.078	-0.068
3	321	241	308	254	282	281	0.138	-0.145	0.096	-0.096
4	330	232	316	248	282	283	0.170	-0.177	0.117	-0.124

Statistic analysis $y = ax + b$

a	0.028	-0.027	0.020	-0.028	R_1	R_2	R_3	R_4
b	0.053	-0.065	0.034	-0.010	0.994	0.997	0.983	0.984
$x_{(y=0)}$	**-1.893**	**-2.407**	**-1.700**	**-0.357**				

Real centre of the lower platen

-2.2 mm (along AC direction towards A)

-1.0 mm (along BD direction towards B)

Table 4.7. Eccentricity test results from SP's strain cylinder on the TONI Pro 5000 at SP, Borås. (Eccentric positions 0, 2, 4 and 6 mm).

Eccentricity Analysis

Machine Type: TONI Pro 5000 **SP, Borås**

x, mm	e_1	e_2	e_3	e_4	e_m	e_m	r_1	r_2	r_3	r_4
-6	256	314	258	329	282	282	-0.092	0.113	-0.085	0.167
-4	268	291	272	305	281	281	-0.046	0.036	-0.032	0.085
-2	277	280	276	299	281	281	-0.014	-0.004	-0.018	0.064
0	293	265	287	279	281		0.043	-0.057	0.021	-0.007
2	311	248	303	262	280	281	0.111	-0.114	0.078	-0.068
4	330	232	316	248	282	283	0.170	-0.177	0.117	-0.124
6	342	224	325	241	283	283	0.208	-0.208	0.148	-0.148

Statistic analysis $y = ax + b$

a	0.026	-0.027	0.020	-0.027	R_1	R_2	R_3	R_4
b	0.054	-0.059	0.033	-0.004	0.996	0.997	0.994	0.993
$x_{(y=0)}$	**-2.077**	**-2.185**	**-1.650**	**-0.148**				

Real centre of the lower platen

-2.1 mm (along AC direction towards A)

-0.9 mm (along BD direction towards B)

Table 4.8. Eccentricity test results from VTT's strain cylinder on the TONI Pro 5000 at SP, Borås. (Eccentric positions 0, 2, 4 and 6 mm).

Eccentricity Analysis

Machine Type: TONI Pro 5000 **SP, Borås**

x, mm	e_1	e_2	e_3	e_4	e_m	e_m	r_1	r_2	r_3	r_4
-6	201	206	206	203	204	203	-0.015	0.010	0.015	0.000
-4	223	182	211	195	203	202	0.099	-0.103	0.045	-0.035
-2	229	180	211	196	204	204	0.123	-0.118	0.034	-0.039
0	225	182	209	196	203		0.108	-0.103	0.030	-0.034
2	230	178	212	193	203	204	0.133	-0.123	0.039	-0.054
4	224	182	213	191	203	203	0.103	-0.103	0.049	-0.059
6	218	188	228	176	203	202	0.074	-0.074	0.129	-0.129

Statistic analysis $y = ax + b$

a	0.005	-0.005	0.006	-0.008	R_1	R_2	R_3	R_4
b	0.089	-0.088	0.049	-0.050	0.446	0.432	0.742	0.877
$x_{(y=0)}$	**-17.80**	**-17.60**	**-8.17**	**-6.25**				

Real centre of the lower platen

-17.7 mm (along AC direction towards A)

-7.2 mm (along BD direction towards B)

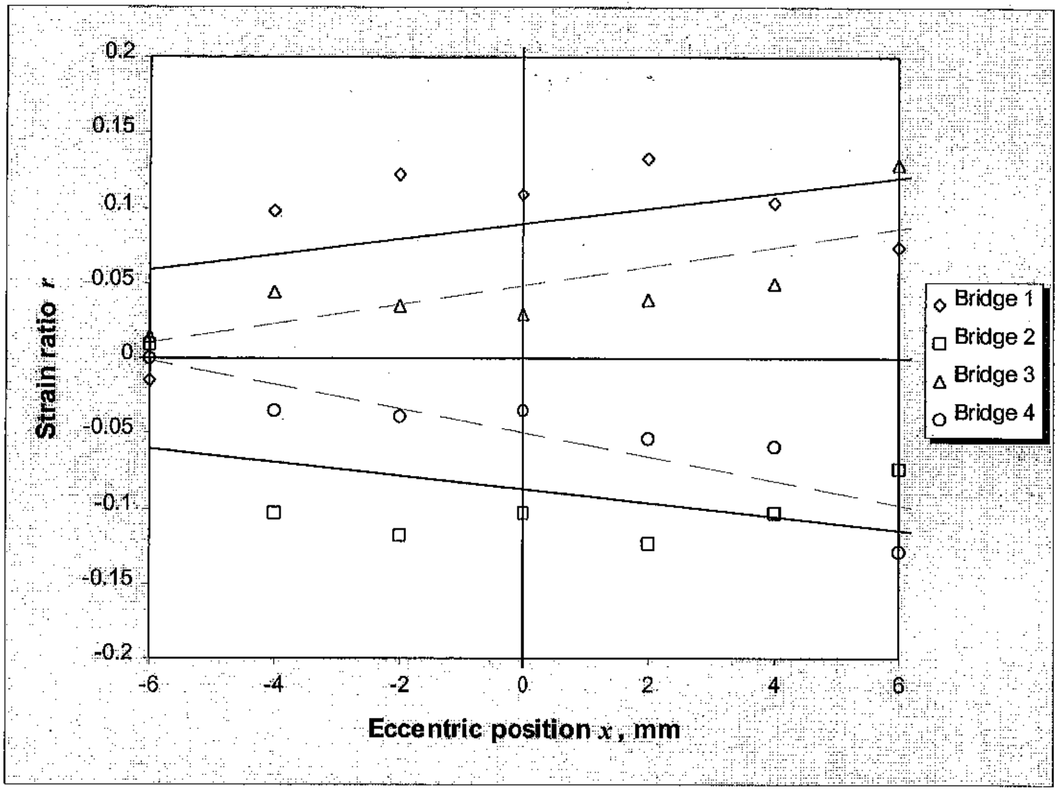

Fig. 4.1. Plot r-x tested on the TONI Pro 5000 at SP, Borås, using VTT's strain-cylinder (under the load 200 kN).

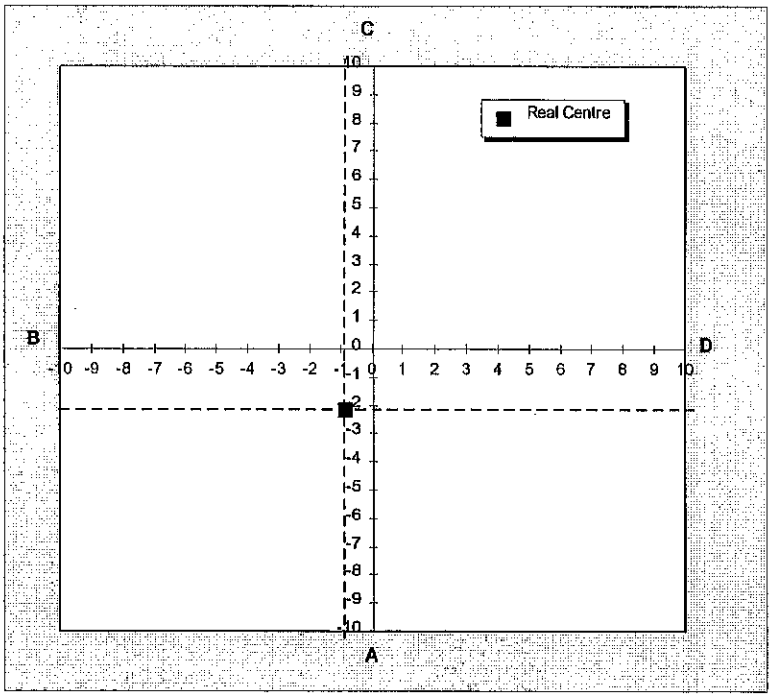

Fig. 4.2. Illustration of the real centre of the TONI Pro 5000 at SP, Borås.

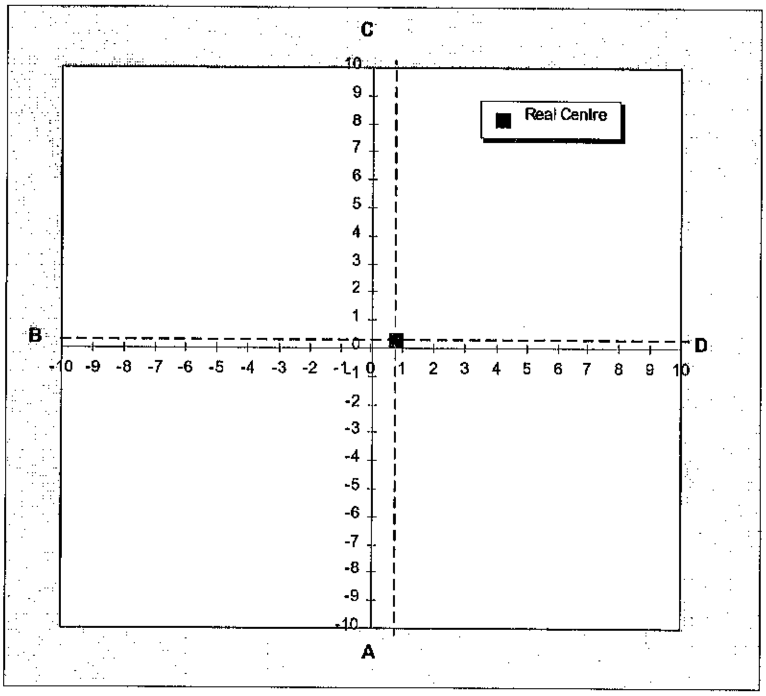

Fig. 4.3. Illustration of the real centre of the TONI 2000 at SP, Borås.

5 Concluding Remarks

According to the results from the strain-cylinder tests as well as the additional eccentricity tests the following conclusions could be drawn:

- The strain-cylinder test according to prEN 12390 is a useful tool to find out some defects of a compression testing machine, such as defective self-alignment of the upper platen and/or significant eccentricity in the machine.
- The additional eccentricity test is a useful auxiliary tool for quantitatively determining the eccentricity in a machine.
- Significant eccentricity was found in some machines from which the test results of concrete compressive strength in some cases did not fulfil the requirements in comparison tests according to the Swedish regulations BBK 94, even though these machines were calibrated in accordance with EN 10002-2 and SS 13 11 10.
- If there exists extreme eccentricity in a machine, the strain-cylinder may risk over-loading, especially at the load 2000 kN. In this case, it is suggested that the additional eccentricity test should be carried out and possible measures should be taken to reduce the eccentricity in the machine.
- The additional eccentricity test can be achieved by applying additional eccentric positions in the strain-cylinder test, as described in Appendix 2.
- Any extra disc under or over the strain-cylinder might distort the stress distributions in the strain-cylinder, resulting in distorted strain ratios.

Appendix 1 Draft prEN 12390 (Dec. 12, 1997)

CEN

Committee CEN/TC 104 - CONCRETE

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Testing concrete - Determination of compressive strength - Specification for compression testing machines

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

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Essais sur béton - Détermination de la résistance en compression - Caractéristiques des machines d'essais de compression

Prüfung von Beton - Bestimmung der Druckfestigkeit - Technische Beschreibung von Druckfestigkeitsprüfmaschinen

This draft European Standard is submitted to CEN members for approval. It has been drawn up by Technical Committee CEN/TC 104 and circulated for CEN Enquiry.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard was established by CEN in three official versions (English, French, German). A version in any other language made, by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CEN

European Committee for Standardization
Comité Europeen de Normalisation
Europaisches Komittee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

CONTENTS

0. FOREWORD

This standard has been prepared by CEN Technical Committee TC104 - Concrete and was circulated for CEN Enquiry in April 1996. It received ratification from the CEN Technical Board on 199*Month**.

This Standard is one of a series concerned with testing concrete and no existing European Standard is superseded.

During the 1980s a number of countries found it necessary to introduce standards to specify more precisely the performance of compression machines for testing concrete specimens. This standard has been written to continue this movement and to overcome the present lack of a European Standard.

Three classes of testing machine are currently recognized, corresponding to scale accuracies of 1 %, 2 % and 3 %. It is evident that these accuracy classes have a direct impact upon the accuracy of the test result and it is a matter for each country to decide whether to limit the range of machine classes to, for example, 1 % and 2 %.

The requirement in this standard for the manner of force transfer is also important with regard to the effect upon measured compressive strength. However, the requirement may be difficult to satisfy on some older testing machines. It is therefore a matter for each country to decide whether, at present, this requirement shall apply only to new machines as written in this standard or whether it shall apply immediately to all machines.

The requirements for testing machines set out in this standard have been formulated to satisfy the needs of those compressive tests on concrete specimens which are specified in EN 206. Machines conforming to this standard may be suitable for other uses, but this needs to be carefully considered on an individual test basis. Particular care needs to be taken before using machines conforming to this standard for compressive tests on small specimens e.g. these with lateral dimensions significantly less than 100 mm. The main concern is that the ball-seating fitted to the upper platen may be too large to align satisfactorily on the top of such small specimens and special adaptations may be required. Another concern is the ability to accurately determine the failure load of small or low strength specimens.

Testing concrete - Determination of compressive strength - Specification for compression testing machines

1. SCOPE

This Standard specifies the requirements for the performance of compression testing machines for the measurement of the compressive strength of concrete.

2. REFERENCES

This European Standard incorporates by dated and undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 10002-2	Metallic materials - Tensile testing - Part 2: Calibration of the force measuring system of the tensile testing machine.
EN 10002-3	Metallic materials - Tensile testing - Part3: Calibration of force proving instruments for the verification of uniaxial testing machines.
ISO 409-1:	Metallic materials - Hardness test - Tables of Vickers hardness values for use in tests made on flat surfaces- Part 1 - HV5 to HV100.
ISO 6507-1:	Metallic materials - Hardness test - Vickers test- Part 1- HV5 to HV100.
ISO/ R468	Surface roughness - Parameters, their values and general rules for specifying requirements.

3. DEFINITIONS

For the purposes of this standard the following definitions apply:

3.1 **auxiliary platen**: separate platen used to protect the machine platens, usually of a size equal to the designated size of the specimen being tested

3.2 **contact area**: the part of the platen that comes into contact with the specimen

3.3 **indicated force**: the force indicated on the machine scale(s) or display

3.4 **indication range**: the total force range, from zero to maximum, displayed on the machine

3.5 **machine platens**: lower platen and upper platen with spherical seating both centred on the central vertical axis of the machine

3.6 **measuring range**: that part of an indication range over which the machine conforms with the accuracy values specified in this standard

3.7 **relative accuracy error**:

- 3.7.1 *true force:* the difference between the average indicated force and the true force expressed as a percentage of the true force
- 3.7.2 *indicated force:* the difference between the average true force and the indicated force expressed as a percentage of the indicated force

3.8 **relative repeatability error**:

- 3.8.1 *true force*: the greatest difference between the indicated forces corresponding to repeated applications of a true force expressed as a percentage of the true force
- 3.8.2 *indicated force*: the greatest difference between the true forces corresponding to repeated applications of an indicated force expressed as a percentage of the indicated force

3.9 **resolution of force**: the smallest increment of force that can be assessed, estimated, or read on any force indication range.(see annex B).

3.10 **spacing block**: metal block used to adjust the space available to test specimens

3.11 **true force**: the force indicated on a calibrated force proving device

4. CONSTRUCTION OF MACHINES

4.1 Machine platens, auxiliary platens and spacing blocks

NOTE 1. The use of auxiliary platens is optional.

4.1.1 Machine and auxiliary platens shall be made of a material which shall not deform irreversibly when the machine is used.

4.1.2 Machine and auxiliary platens shall have a hardness value of at least 550 HV 30 (HRC 53).when tested in accordance with ISO 6507 - 1,

4.1.3 The flatness tolerance for machine platens and auxiliary platens shall be 0,03 mm for the area in contact with the specimen.

NOTE 2. For the purpose of this European Standard, flatness can be assessed by the measurement of straightness in four positions. [see Annex B of EN 12356]

4.1.4 The roughness value (R_a) for the surface texture of machine and auxiliary platens shall be in the range 0,4 μm to 3,2 μm, when assessed in accordance with ISO: R468, for the area in contact with the specimens.

4.1.5 The area of machine platens in contact with the specimen shall be at least as great as the area of the specimen being tested.

4.1.6 The distance between either pair of opposite edges of a square auxiliary platen, or the diameter of a circular auxiliary platen, shall be not less than the designated size of the specimen.

4.1.7 The two contact faces of an auxiliary platen shall be parallel to a tolerance of 0,05 mm.

4.1.8 Auxiliary platens shall be at least 23 mm thick.

4.1.9 If there is a requirement to reduce the distance between the machine platens, up to four spacing blocks may be used.

4.1.10 A spacing block may be either circular or square in section and shall be adequately supported from below.

NOTE 3. A minimum diameter or length of side of 200 mm is recommended for spacing blocks.

4.1.11 Spacing blocks shall comply with the flatness and parallelism tolerances required for auxiliary platens. (see clauses 4.1.4 and 4.1.8)

4.1.12 Spacing blocks shall not be placed in contact with the specimen.

4.1.13 Spacing blocks shall be positively located, centrally on the vertical machine axis.

4.2 Force measurement

4.2.1 *Force indicator*

4.2.1.1 The machine shall be provided with:

- dials or digital displays which allow the force to be read to the required accuracy. [see B1.2];
- a system which allows the maximum force sustained to be read after completion of the test, until reset;
- displays readable from the operating position.

4.2.1.2 The lowest verifiable value (see B1.4) of each measuring range shall be less than or equal to 20 % of the maximum value of the range. If the machine is equipped with several indication ranges the above requirement shall apply to each range.

4.2.1.3 The machine force indication system shall not be affected by explosive failure of the specimen.

4.2.2 *Force indicator calibration*
Force indicators shall be verified and shall conform to the requirements of Table 1 for the particular class of testing machine.

Table 1. Force scale tolerances
The tabulated percentages are the maximum permitted for the related machine classes

Machine class	Relative accuracy error %	Relative repeatability error %	Relative zero error (% of scale maximum) %	*Machine resolution %
1	± 1,0	1,0	± 0,2	0,5
2	± 2,0	2,0	± 0,4	1,0
3	± 3,0	3,0	± 0,6	1,5

*see definition in 5.3 of EN 10002 - 2

4.2.3 *Force indicator repeatability*
The requirements of Table 1, appropriate to a machine's class, shall apply to each measuring range.

4.2.4 The accuracy of force indication shall be maintained under any or all of the following circumstances:
mains voltage fluctuations of -14 % to +10 %;
at a temperature of (20 ± 10) °C;
at a relative humidity of up to 80 %.

NOTE: Where electrical or other interference exists this may affect the accuracy of force indication and special provisions to overcome this interference may be necessary.

4.2.5 *Deviation in linearity*
If a DC output, proportionate to the indicated force is provided, the linearity deviation of the output voltage - expressed as a percentage of the maximum output voltage - shall not exceed the value shown in Table 2.

Table 2. Deviation in the linearity of the output voltage

Maximum permissible deviation in linearity in relation to the maximum output voltage	
Machine class	**%**
1	± 0,1
2	± 0,2
3	± 0,3

4.3 Force control

4.3.1 The compression testing machine shall be provided with a control system. The control system shall enable the machine to be verified and to allow force to be applied smoothly and without shock. It shall also allow the force to be applied at prescribed constant rates.

4.3.2 The control system may be operated either by manual or automatic means.

4.3.3 If the machine is not equipped with automatic application of force, a pacer shall be fitted to enable the operator to maintain the specified rate. The pacer shall indicate a rate within ± 5 % of the specified rate.

4.4 Force transfer

4.4.1 Unless national provisions state otherwise, clauses 4.4.5, 4.4.6, 4.4.7 and 4.4.8 shall apply only to new machines delivered after this standard is implemented.

4.4.2 The upper platen shall incorporate a ball seating. The upper platen and the ball seating may be constructed separately or in one piece.

4.4.3 At the design stage, the manufacturer shall ensure that the centre of rotation of the ball seating shall coincide with the centre of the contact area of the machine platen and permit a rotation of at least three degrees.

4.4.4 At the start of a test, the upper platen shall align itself with the surface of the specimen, or an auxiliary platen, when the initial contact is made, before locking into position for the remainder of the test.

4.4.5 The design shall ensure that the requirements of Table 3 shall be met.

4.4.6 The force transfer shall be evaluated by means of a strain-gauged column as described in Annex A, or by an equivalent device.

4.4.7 The machine shall be designed to enable devices as set out in annexes A and B, or similar, to be used for verifying:

- accuracy of force indication;
- self alignment of the upper machine platen;
- similar, to be used for verifying:
- alignment of component parts of the machine;
- restraint of movement of the upper platen.

4.4.8 When tested in accordance with Annex A, or equivalent method, the machine shall conform to Table 3.

Table 3. Maximum permissible values for the mean strain ratio, the greatest difference in the strain ratio, and the strain ratio per mm of displacement.

Force kN	Self alignment of upper machine platen	Alignment of machine components	Restraint on movement of upper platen
	Maximum permissible difference in the strain ratio	Maximum permissible mean strain ratio	Maximum permissible strain ratio per mm of displacement
200	0,10	± 0,10	0,06
2000	N/A	N/A	0,04

NOTE: The highest force (used only in the examination of restraint of movement of the upper platen) shall be the maximum capacity of the machine or 2000 kN whichever is the lesser.

4.5 Specimen location

4.5.1 To ensure correct positioning of the specimen in relation to the loading axis, the lower machine platen shall be provided with centring lines, locating cams or other fixtures for centring specimens.

4.5.2 If positive physical location is used for positioning specimens or auxiliary platens, then any locating device shall not restrict the deformation of the specimen during the test.

4.5.3 Centring lines, if provided, shall be no more than 0,5 mm wide and no more than 1,0 mm deep.

5. MACHINE CALIBRATION

5.1 Characteristics to be assessed

The examination for correct operation of a testing machine shall consist of calibrating:

- the accuracy of the force indication;
- the force transfer, (stability); (only for new machines, unless national provision requires otherwise);
- flatness of the platens;
- control of rate of application of force.

5.2 Frequency of calibration

5.2.1 Calibrate according to 5.1 when the machine is first installed

5.2.2 Re-calibration shall be undertaken at a rate stipulated by an accredited quality system or annually and after:

- relocating the machine or;
- repair or replacement of any part likely to affect the characteristics verified in 5.1.

6. DETAILS TO BE PROVIDED BY THE SUPPLIER/MANUFACTURER

6.1 Specification

The supplier/manufacturer shall indicate at least the following details in the specification of the test machine:

a) testing machine class according to this Standard;
b) indication range (or ranges);
c) measuring range (or ranges);
d) description of the measuring indicator;
e) dimensions of the platens;
f) dimensions of the auxiliary platens (if appropriate);
g) minimum and maximum height between the platens, and the maximum lateral access;
h) maximum usable ram stroke;
i) description of the maximum force indicator (e.g.: slip pointer, peak value detector).

6.2 Installation and connection

The supplier/manufacturer shall provide at least the following installation and connection details:

a) dimensions of the machine;
b) weight of the machine;
c) drawing of the foundations, if appropriate;
d) details of electrical requirements;
e) detailed operating instructions.

6.3 Maintenance

The supplier/manufacturer shall provide at least the following maintenance details:

a) maintenance schedule, including the requirements for the ball-seating;
b) details of the oil to be used in the hydraulic sections.

NORMATIVE ANNEX A -

STRAIN GAUGED COLUMN AND PROVING PROCEDURE FOR COMPRESSION TESTING MACHINES

NOTE 1. These procedures should be carried out by experts. They are included to give a standard form of proving device and procedure for those laboratories qualified to conduct the test.

NOTE 2. Where it can be demonstrated that other devices and methods of verification will provide comparable verification of the requirements, the use of these alternatives is permitted.

A.1. The strain gauged column

The strain gauged column shall be a cylinder of nickel-chrome steel and tempered to a hardness value of at least 370HV 30. It shall be (100 $\pm$ 1) mm in diameter and (200 $\pm$ 1) mm high. The flatness tolerance for the ends, shall be 0,03 mm but the surfaces shall not be convex. The parallelism tolerance shall be 0,06 mm. The squareness tolerance of the cylinder, with respect to one end as datum face, shall be 0,03 mm. The roundness tolerance of the ends of the cylinder shall be 0,02 mm, and the whole cylinder shall be within a cylindricity tolerance of 0,04 mm. Centre holes of maximum size 15 mm diameter by 15 mm deep are permitted in the ends of the cylinder.

The column shall be gauged using matched temperature-compensated electrical resistance strain gauges. Four complete bridges, each centred at one of the ends of a pair of orthogonal diameters half-way up the cylinder shall be used. Each bridge shall consist of two elements measuring axial strain and two measuring circumferential strain as shown in Figure A1. Each bridge shall be electrically and thermally balanced.

The column shall be supported in a carrying box by circumferential shoulders near the ends of the cylinder. The edge of each shoulder nearest the centre of the cylinder shall be not further than 15 mm from the nearest end of the cylinder. Vertical lines shall be inscribed on the cylinder walls so that they are visible outside the carrying case to indicate the position of the centre lines of the bridges. These lines shall not extend further than 20 mm from the lower end of the cylinder.

The column shall be used with a switch and balance unit which enables the outputs of each of the four bridges to be balanced in the unforced condition and the bridge outputs to be selected thereafter by operation of a switch.

NOTE Alternatively, simultaneous display of the four bridge outputs may be used if means are provided to enable the sensitivity of the four channels to be checked and, if necessary, equalized immediately prior to taking a series of readings.

The strain gauged column shall be used in conjunction with dedicated strain measuring equipment.

The maximum limit of error for strain measuring equipment shall be $\pm$ 0,1 % or 5 micro strain, whichever is greater.

The strain gauged column with its dedicated strain measuring equipment shall be calibrated to national standards at least every two years.

A.2 Procedure for verifying the self-alignment of the upper machine platen and the component parts of the machine

Locate the device centrally on the lower machine platen or a 150 mm square auxiliary platen as shown in figure A2. Designate the mid-points of the edges of the platen, or auxiliary platen, as A, B, C and D and the four bridge positions on the device 1, 2, 3 and 4.

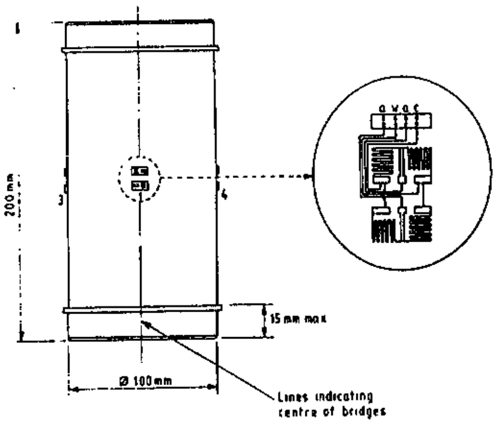

Figure A1 - Gauging of device

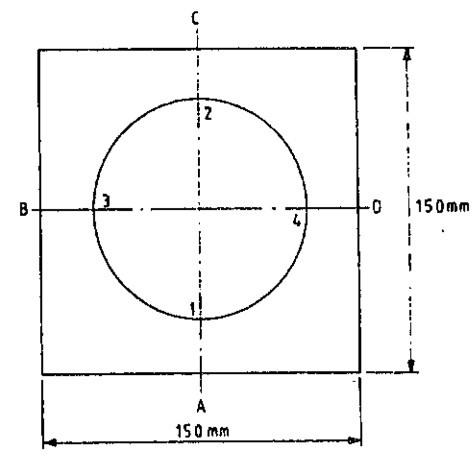

Figure A2 - Positioning

Measure the distances from the centre of each top edge of the positioning platen to the nearest point on the bottom edge of the device and adjust the position of the device until the differences between pairs of measurements from opposite edges of the platen to the device do not exceed 0,10 mm.

NOTE. This may be conveniently achieved by fitting a stop to the edge of the platen and providing accurately machined spacers to centralize the device, or by the use of a jig unique to a given device.

Operate the machine to bring the top of the device no closer than 5 mm to the upper machine platen and tilt the upper machine platen down towards A about axis BD either to its fullest extent or until it touches the device. Gently release the upper machine platen and operate the machine so that the upper machine platen aligns with the device. Increase smoothly the indicated force onto the device up to a nominal value of at least 200 kN. Hold the force constant and read the outputs of the four bridges. If the force exceeds 200 kN but does not exceed 220 kN before it can be held constant, do not reduce it before taking the readings. If the force exceeds 220 kN restart the test.

Use the mean e_m of the four bridge outputs e_1, e_2, e_3 and e_4 to calculate the strain ratio $(e_n - e_m)/e_m$ for each bridge, where e_n is the strain at the bridge position under consideration.

Repeat the test; firstly with the upper machine platen tilted down towards C about an axis BD, secondly with the upper machine platen tilted down towards B about an axis AC and thirdly with the upper machine platen tilted down towards D about an axis AC.

If the device is correctly machined and gauged, the sensitivity of the four bridges will be equal. However, if this is in doubt, repeat the readings, first with bridge 1 adjacent to B, then with bridge 1 adjacent to C and finally with bridge 1 adjacent to D (see Figure A2).

The readings so obtained, together with those obtained with bridge 1 opposite A, shall be meaned to eliminate differences in bridge sensitivity on the device. This shall be done for the readings on all four bridges.

A.3. Self-alignment of the upper machine platen

Obtain the strain ratios at 200 kN for the four different directions of initial platen tilt and compare them with the requirements set out in Table 3.

A.4 Alignment of the component parts of the machine

If the self-alignment is correct (see **A.3**), calculate the mean strain ratios for each of the four bridges and compare them with the requirements set out in Table 3.

A.5 Procedure for verifying restraint on movement of the upper platen

If the self-alignment and alignment are correct (see **A.3** and **A.4**) displace the device by (6 ± 0,05) mm from the central position along AC towards A. Without further adjustment of the upper machine platen, operate the machine to bring the device into contact with it and apply the force smoothly. Record the outputs of the four bridges at nominal forces of 200 kN and 2000 kN. If the machine capacity is less than 2000 kN, take readings at 200 kN and at maximum capacity. Take care to ensure that the output of each of the four bridges is read while the force is held constant. If either nominal force is exceeded, but by 10 % or less, before it can be held constant do not reduce it before taking the readings. If either nominal force is exceeded by more than 10 %, restart the test.

Repeat these readings with the device displaced (6 ± 0,05) mm from the central position, firstly along AC towards C, secondly along BD towards B and thirdly along BD towards D. Let r represent a strain ratio. Use subscripts 1, 2, 3 and 4 to denote the positions of the bridges on the strain cylinder (as in Figure 2), and use subscripts a, b, c and d to denote displacement of the cylinder towards A, B, C and D, so that, for example, r_{1a} denotes the strain ratio for bridge number 1 when the cylinder is displaced 6 mm towards A.

For each force, calculate the change in strain ratio per millimetre offset for displacement along AC as:

$$\frac{(r_{1c} - r_{2c}) - (r_{1a} - r_{2a})}{24} \qquad (1)$$

and calculate the change in strain ratio per millimetre offset for displacement along BD as:

$$\frac{(r_{3d} - r_{4d}) - (r_{3b} - r_{4b})}{24} \qquad (2)$$

A.6 Safety requirements

When using the device, particularly when it is at an eccentric setting, care shall be taken to ensure that the indicated force does not exceed the specified value of the device.

The device shall be clearly marked indicating the '*maximum permitted force when applied centrally*'

NOTE If the device is overloaded in an eccentric position, there is a danger that the horizontal motive forces resulting from a one-side compression of the device, may exceed the retaining friction forces between the compression surfaces of the testing machine and those of the device, which would cause the device to be projected violently from the testing zone.

NORMATIVE ANNEX B -
FORCE CALIBRATION PROCEDURES

B.1. General

B.1.1 The forces applied by uni-axial materials testing machines shall be calibrated according to the procedures described, to allow a categorization for repeatability and error of force. To ensure that the class is consistent with the resolution of the force indication, a lower limit of calibration shall be determined.

B.1.2 Resolution (see Table 1)

B.1.2.1 Analogue scale The width of the graduation marks defining the smallest scale interval on the scale shall be uniform and approximately equal to the width of the pointer. If the force indication is made by means of a chart recorder, the width of the lines defining the smallest scale interval on the chart should be uniform and approximately equal to the width of the trace.

NOTE The width of a graduation mark should not exceed the resolution allowable for a considered scale.

A scale interval shall be subdivided by estimation to determine the resolution (r) as follows:

a) when the scale interval is at least 2,5 mm wide, the resolution is one-tenth of a scale interval;

b) when the scale interval is at least 1,25 mm wide and less than 2,5 mm wide the resolution is one fifth of a scale interval;

c) when the scale interval is less than 1,25 mm wide, the resolution is one-half of a scale interval.

The resolution shall be expressed in units of force.

If the force indication is by means of a chart record, the nominal width and the graduation interval of the chart paper used shall be recorded. The grading of the machine is applicable only when chart paper of the same type is used. If there is no facility for generating an electrical calibration input to a chart recorder so that small changes in the width of the chart paper may be accommodated, then the overall width of the chart used during the calibration shall be measured to an accuracy equivalent to the resolution and shall be recorded. The width of chart paper subsequently used shall be within $\pm 2r$ of this width.

B.1.2.2 Digital scale The resolution shall be determined when there is no force applied by the materials testing machine and shall be equal to one-half of the range of fluctuation on the digital read-out but shall be not less than one increment of count.

The resolution shall be expressed in units of force.

B.1.3 Calibration

Calibration shall be carried out for each force-measuring system for which a class is sought.

B.1.4 Lower limit of calibration

Calibration shall not be performed below the lower limit F_V on any force-measuring system determined as follows:

$$F_V = a \cdot r$$

where:

a has the following values:

200 for class 1 machine;
100 for class 2 machine;
66,6 for class 3 machine.

r is the resolution determined in accordance with B.1.2.

NOTE Calibration should not be started unless the testing machine is in good working order.

B.2. Calibration equipment

The force calibration equipment shall conform to EN 10002-3 when calibrated in the increasing load mode.. The requirement in EN 10002-3 for calibration in decreasing load mode is not applicable to force verification equipment used for the verification of compression testing machines specified in this standard. The class of the force calibration equipment shall be equal or superior to the proposed class of the machine to be verified.

The calibration equipment shall be calibrated to national standards at least every two years.

B.3. Preliminary procedure

B.3.1 Alignment

The calibration equipment shall be mounted in the machine so that the forces are applied along the loading axis of the machine.

B.3.2 Temperature compensation

Sufficient time shall be allowed for the calibration equipment to attain a stable temperature. The temperature at the beginning and end of the application of each series of forces shall be recorded. Where necessary, temperature corrections shall be applied to the deflections of proving devices.

B.3.3 Machine conditioning

The materials testing machine and calibration equipment shall be exercised three times between zero force and the maximum force to be measured. The machine's force indicator shall then be reset to zero.

A spherical seated platen satisfying the requirements of Annex A shall be deemed to provide the necessary alignment of machine platens and proving devices; no additional, auxiliary, alignment provision should be required.

B.4. Calibration procedure

B.4.1 Method

One of the following calibration methods shall be used:

a) True force The machine shall be operated to balance a given true force as determined by the calibration equipment. The machine's indicated force shall then be recorded;

b) Indicated force The machine shall be operated to apply a given indicated force and the true force measured by the calibration equipment recorded.

B.4.2 Selection of test forces

B.4.2.1 *General* The total number of forces required to calibrate a materials testing machine depends on the number of ranges over which the machine is constructed to operate, the appropriate number of forces given in B4.2.2 to B4.2.4 shall be used.

B.4.2.2 *Single-range materials testing machines* A series of at least five approximately equi-spaced forces, upwards from 20 % of the scale maximum or the lower limit of calibration, whichever is greater shall be used.

When the lower limit of calibration is below 20 % of the scale maximum, additional forces may be applied below 20 % of the scale maximum down to and including the lower limit of calibration. Working downwards from 20 % of the scale maximum, consecutive forces shall not differ by more than 6 % of the scale maximum.

B.4.2.3 *Multi-range materials testing machines* Each range shall be verified as described in B4.2.2.

B.4.2.4 *Materials testing machines with auto ranging digital indicators* A series of at least five approximately equi-spaced forces, upwards from 20 % of the maximum reading of the digital indicator shall be applied. At least one additional force for each 6 % of the maximum reading, working downwards from the 20 % point to the lower limit of calibration (see B4.2.3) shall be applied. At least two forces shall be verified on each part of the range where the increment of count does not change.

B.4.3 Application of test forces

B.4.3.1 *Procedure* For each range, the series of forces in ascending order shall be applied and each series repeated to give three series of such forces. The force shall be completely removed after each series of applications. The zero reading shall be recorded not less than 30 s and not more than 2 min after removing the force.

The reading of the force indicator shall be zeroed after removing the force with the machine in the same mechanical condition, as it was in before applying the series of forces.

If necessary, the force indicator shall be reset to zero at the commencement of each series of readings but a correction to readings already taken shall not be applied.

NOTE. In some testing machines difficulty may be experienced in maintaining a steady force; in such circumstances measurements may then be made under conditions of slowly increasing force.

B.4.3.2 *Maximum-reading facility* When the force indicator is fitted with a maximum-reading facility which could introduce friction, e.g.: a pointer-arresting mechanism or slave pointer, one of the series of forces with the facility in operation for each range of the machine shall be applied. The reading of the force indicator shall be zeroed with the facility disengaged.

B.4.3.3 *Force indication by hydraulic pressure*: for machines employing a hydraulic ram and a method of force measurement derived from the hydraulic pressure, the series of forces shall be applied three times with the ram, where possible, in the normal working position.

B.5 Calculation of results

At each nominal force, the repeatability and error from the results of all the applications of forces shall be calculated and expressed as a percentage of the nominal force.

The error of zero force for each series of forces shall be calculated and expressed as a percentage of the maximum force of the machine range.

The forces indicated by the materials testing machine shall not be corrected for the error of zero force.

B.6 Classes

B.6.1 Single range machines

At least five consecutive forces, from the maximum to be verified downwards, shall not exceed the values given in Table 1 for a specific class.

The class shall cease to apply below the last force that conforms to these requirements.

It is possible for a range to be given more than one class, but for each such category, all forces from the maximum downwards shall be considered. Thus a more exacting class shall not be introduced to cover some intermediate part of the range.

B.6.2 Multi-range machines

Each range shall be a category according to B.6.1.

NOTE. The resolution and hence the lower limit of calibration, may change when a new range is selected.

A machine with an auto-ranging digital indicator, (i.e. an indicator where the increment of count of the indicated force changes automatically at given points between zero and the maximum reading), shall be categorized as a single-range machine as described in B.6.1. However, a class can only apply if, throughout the range category, the ratio of the indicated force to the increment of count at that force is not less than the following values:
67 for class 3 machine;
100 for class 2 machine;
200 for class 1 machine.

B.6.3 Class certificate

When a materials testing machine has been categorised and calibrated in accordance with this annex, a certificate shall be issued stating the following:

a) the identity and location of the materials testing machine and the date of calibration;
b) the resolution, class, mode and range of forces on each force-measuring system calibrated;
c) where appropriate, any force-measuring systems that were not calibrated;
d) the method of calibration used and the identity, class and date of the certificate of grading of the calibration equipment used;
e) whether or not a maximum-reading facility was used;
f) the average temperature of the calibration equipment at the time of calibration;
g) where appropriate, the type of chart paper used during the calibration and an accurate measurement of the width of the paper.

Appendix 2 Suggestions to the Additional Eccentricity Test

- After the strain-cylinder test according to prEN 12390 , place the strain-cylinder back to the central position (zero eccentric position). Without further adjustment of the upper machine platen, operate the machine to bring the strain-cylinder into contact with it and apply the force smoothly to a nominal force of 200 kN and record the outputs of the four bridges.
- Repeat these readings with the strain-cylinder displaced by 2 ± 0.05 mm and 4 ± 0.05 mm from the central position, respectively, firstly along AC towards A, secondly along AC towards C, thirdly along BD towards B and finally along BD towards D.
- Regress the measured data according to the equation $r_i = ax + b$, where r is the strain ratio; the subscript i is defined in Table A2.1 and x is the eccentric position, see Table A2.1.
- The eccentricity of each bridge is equal to $-b/a$. The mean value of the bridges 1 and 2 represents the real centre along AC and the mean value of the bridges 3 and 4 represents the real centre along BD.

Table A2.1. List of the measured data for regression.

x, mm	Measured strain e_i				Mean e_m		Strain ratio r_i			
-6	e_{1A6}	e_{2A6}	e_{3B6}	e_{4B6}	e_{mA6}	e_{mB6}	r_{1A6}	r_{2A6}	r_{3B6}	r_{4B6}
-4	e_{1A4}	e_{2A4}	e_{3B4}	e_{4B4}	e_{mA4}	e_{mB4}	r_{1A4}	r_{2A4}	r_{3B4}	r_{4B4}
-2	e_{1A2}	e_{2A2}	e_{3B2}	e_{4B2}	e_{mA2}	e_{mB2}	r_{1A2}	r_{2A2}	r_{3B2}	r_{4B2}
0	e_{1O}	e_{2O}	e_{3O}	e_{4O}	e_{mO}	e_{mO}	r_{1O}	r_{2O}	r_{3O}	r_{4O}
2	e_{1C2}	e_{2C2}	e_{3D2}	e_{4D2}	e_{mC2}	e_{mD2}	r_{1C2}	r_{2C2}	r_{3D2}	r_{4D2}
4	e_{1C4}	e_{2C4}	e_{3D4}	e_{4D4}	e_{mC4}	e_{mD4}	r_{1C4}	r_{2C4}	r_{3D4}	r_{4D4}
6	e_{1C6}	e_{2C6}	e_{3D6}	e_{4D6}	e_{mC6}	e_{mD6}	r_{1C6}	r_{2C6}	r_{3D6}	r_{4D6}

Definition of the subscript i:
The first number represents the positions of the bridges, the second letter represents the direction in which the strain-cylinder is displaced, and the third number represents the displacement in mm. For example, e_{3D4} means the measured strain of the bridge 3 along BD towards D at the displacement 4 mm from the central position.