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An interpretation of the strain cylinder test for the assessment of concrete cube testing machines

Synopsis

An improved method for the checking and classification of concrete cube testing machines is proposed.

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Introduction

The recent revision of SABS Method 863: 1994 (SABS, 1994) includes, for the first time, the requirement that a concrete cube testing machine must satisfy BS1881: Part 115: 1986 *Specification for compression testing machines for concrete* (BSI, 1986). The main implication is that the ability of a compression testing machine to uniformly strain a cube must be assessed using the 'strain cylinder' described in BS1881 and must meet the standard set in that code.

This standard seems to be high, because of 32 machines in South Africa and Namibia known to me to have been tested with the strain cylinder since 1992, 19 failed to pass in at least one of the four aspects assessed.

The standard is given in BS1881: Part 115 simply as pass/fail borderlines for the four numerical parameters obtained from the strain cylinder's measurements. No guidance is given in the code to 'how bad' a machine may be if it fails the test, which leaves the owner and users of a 'failed' machine unsure of what to do with it. To attempt to solve this problem, a research project was carried out at the University of the Witwatersrand to obtain more information from the strain cylinder.

Behaviour of a compression testing machine

Before describing the project, it may be beneficial to review what happens when a cube is tested. When the cube has been raised by the hydraulic ram until it touches the upper platen of the machine, a force is exerted by the concrete to rotate the platen into intimate contact with the specimen's upper face. This force will put a bending moment on the cube, but ideally it should be small. With the rotating platen now uniformly seated on the cube and the load increasing, the platen should lock and all other aspects of the machine's mechanics remain rigid so that the concrete is uniformly strained until it fails.

There is no such thing as a perfect testing machine, giving an absolutely correct value of cube strength. All machines require a finite force from the side of the cube to initially rotate the upper platen, which initiates non-uniform straining of the cube. All machines are less than fully rigid in response to an eccentric load from inhomogeneous concrete in the cube and consequently do not strain the cube uniformly. Two possibilities are currently available for choosing an appropriate standard for cube testing machines:

1. To choose a particular machine as the standard, and compare others to it using high quality (ie low variance) batches of cubes (BSI, 1990).
2. To use the strain cylinder (BSI, 1986) to assess a machine and interpret the measurements.

Option 1 was used in the UK for many years, but eventually mechanical deterioration of the reference machine caused option 2 to become the ruling factor. The standard set in BS1881: Part 115 for option 2 was based on an evaluation of 17 machines of varying quality with the strain cylinder. The range of the strain cylinder's measurements on the 17 machines was examined, and using a mixture of statistical analysis and common sense the pass/fail borderlines were fixed at the values given in Table 1.

Table 1: Pass/fail borderlines of strain cylinder test according to BS1881: Part 115

Rotation stiffness	*Centrality*	*Locking at 200 kN*	*Locking at 2 000 kN*
< 0,1	< 0,1	< 0,06	< 0,04

Project details

An effort was made in this project to obtain correlations between the strain cylinder's test results and the variation in cube strength from that given by a reference machine, the objective being to be able to convert the strain cylinder's measurements on a particular machine into a guide to the variation in cube strength that the machine gives from an appropriate reference machine.

The machine chosen as the reference for the purpose of this project was the Avery Denison machine at the South African Bureau of Standards. The reasons for this were that:

1. The Bureau was willing to maintain it as a reference machine as defined in BS1881: Part 127
2. It had passed the strain cylinder test when it was bought and, as far as could be judged (because of the lack of a single packing piece of suitable height under the cylinder), it was still able to pass that test

Individual comparative cube tests to BS1881: Part 127 were carried out on the reference machine and 18 other compression testing machines in South Africa. At the same time, strain cylinder tests were done on the same machines.

The full results of the project are described in a report (Luker, 1994) to the Portland Cement Institute, who sponsored the work, but the most useful parts are shown here in Figs 1 to 4. These four graphs plot the mean of the difference in cube strength (between the machines being assessed and the reference machine) against each of the four numerical parameters from the strain cylinder tests on the 18 machines.

The graph points are very scattered, probably because of the wide range of possible influences on the machine's performance both when crushing a cube and when being tested by the strain cylinder. However, some correlation does exist, and this has been shown by lines on the graphs.

Interpretation of results

Based on Figs 1 and 4, the system of classification of concrete cube testing machines given in Table 2 is proposed.

The standards in Table 2 for a grade A machine are very close to those in BS1881 shown in Table 1, except that the values for rotation stiffness and centrality are relaxed from 0,1 to 0,15, and the value for locking at 200 kN is made more stringent, from 0,06 to 0,04.

From the data generated by this project, a tentative interpretation of the grading would be as given in Table 3.

Table 2: Proposed system of classification of concrete cube testing machines

Grading of testing machine	*Values of strain cylinder test parameters*			
	Rotation stiffness	*Centrality*	*Locking at 200 kN*	*Locking at 2 000 kN*
A	0 to 0,15	0 to 0,15	0 to 0,04	0 to 0,04
B	0,15 to 0,3	0,15 to 0,3	0,04 to 0,06	0,04 to 0,06
C	> 0,3	> 0,3	> 0,06	> 0,06
A machine shall have as its nominal grading the worst grading from the four strain cylinder test parameters.				

Table 3: Tentative interpretation of test machine grading as regards effect on concrete cube strength

Grading of test machine	*Likely variation of cube strength from the SABS Avery Denison testing machine*
A	<5%
B	>5%
C	>10%

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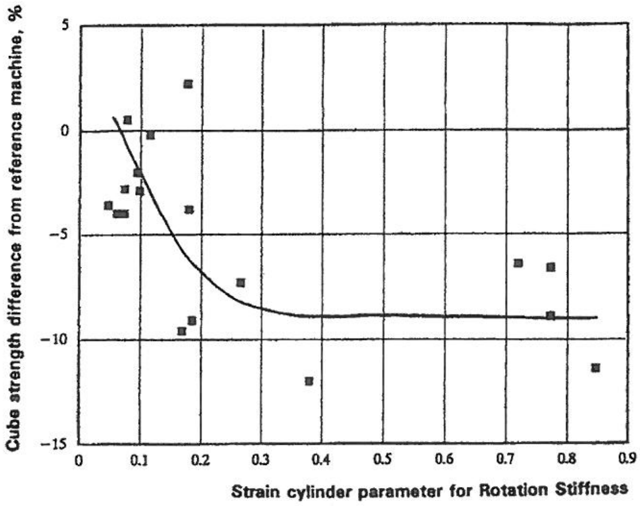


Fig 1: Mean of the difference in cube strength vs rotation stiffness

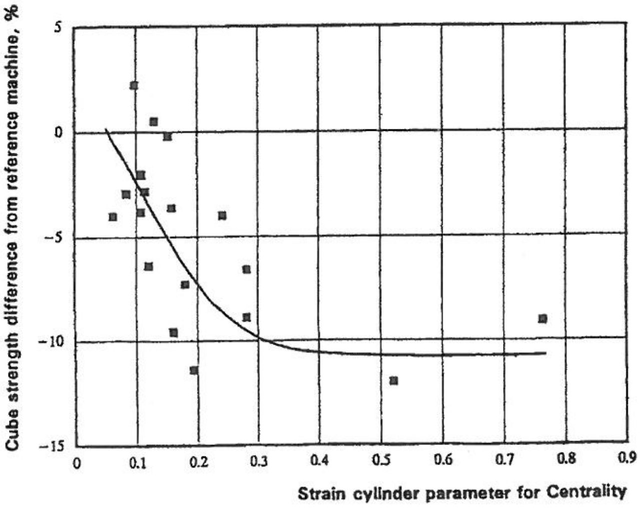


Fig 2: Mean of the difference in cube strength vs centrality

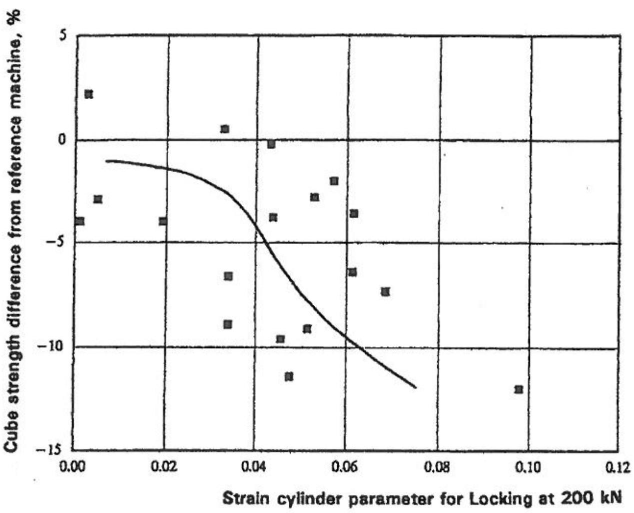


Fig 3: Mean of the difference in cube strength vs locking at 200 kN

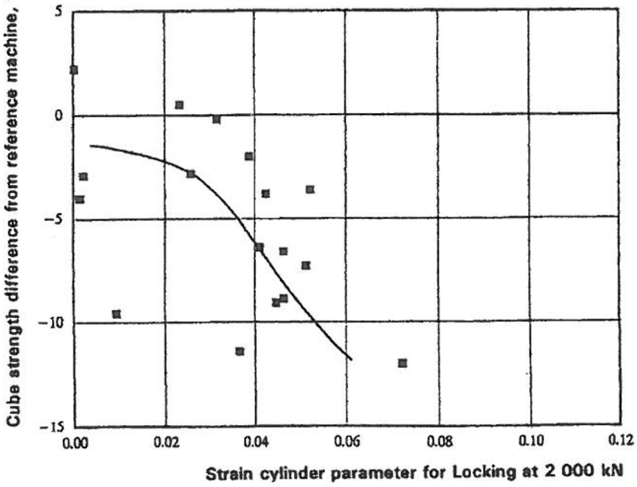
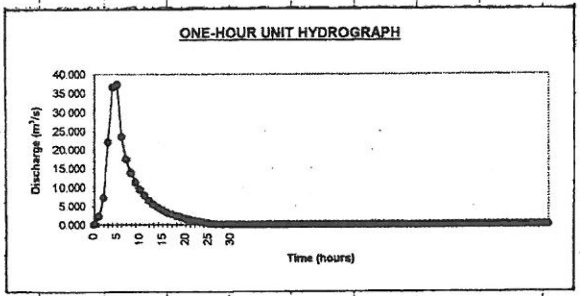


Fig 4: Mean of the difference in cube strength vs locking at 2 000 kN

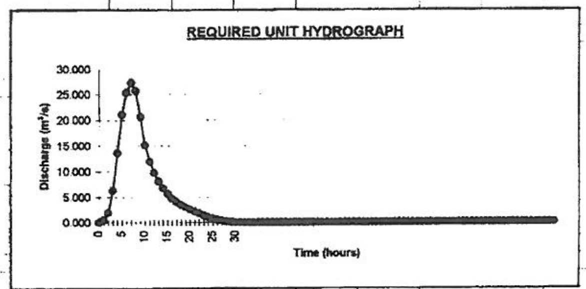
RESULTING ONE-HOUR UNITGRAPH:

T (hrs)	Q (m³/s)	T (hrs)	Q (m³/s)	T (hrs)	Q (m³/s)	T (hrs)	Q (m³/s)	T (hrs)	Q (m³/s)
0	0.000	20	1.643						
1	2.239	21	1.319						
2	7.267	22	1.011						
3	22.070	23	0.756						
4	36.567	24	0.501						
5	37.227	25	0.324						
6	23.588	26	0.108						
7	17.443	27	0.000						
8	13.802	28	0.000						
9	11.323	29	0.000						
10	9.421	30	0.000						
11	7.896	31	0.000						
12	6.519	32	0.000						
13	5.430								
14	4.616								
15	3.897								
16	3.301								
17	2.791								
18	2.359								
19	1.967								



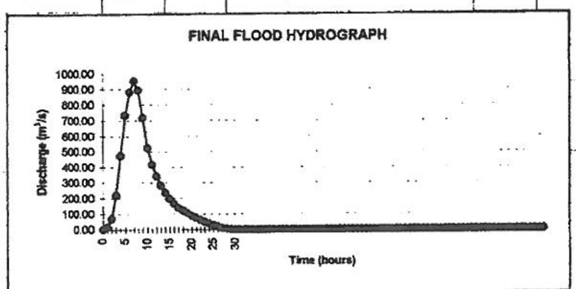
REQUIRED 5 HOUR UNITGRAPH:

T (hrs)	Q (m³/s)	T (hrs)	Q (m³/s)	T (hrs)	Q (m³/s)	T (hrs)	Q (m³/s)	T (hrs)	Q (m³/s)
0	0.000	20	2.577						
1	0.448	21	2.181						
2	1.901	22	1.825						
3	6.315	23	1.418						
4	13.628	24	1.046						
5	21.074	25	0.782						
6	25.344	26	0.540						
7	27.379	27	0.338						
8	25.725	28	0.187						
9	20.677	29	0.086						
10	15.115	30	0.022						
11	11.977	31	0.000						
12	9.792								
13	8.118								
14	6.776								
15	5.672								
16	4.753								
17	4.007								
18	3.479								
19	3.028								



FINAL FLOOD HYDROGRAPH:

T (hrs)	Q (m³/s)	T (hrs)	Q (m³/s)	T (hrs)	Q (m³/s)	T (hrs)	Q (m³/s)	T (hrs)	Q (m³/s)
0	0.00	20	89.84						
1	15.61	21	76.02						
2	66.27	22	63.61						
3	220.14	23	49.42						
4	475.07	24	36.47						
5	734.61	25	27.27						
6	883.45	26	18.83						
7	954.39	27	11.77						
8	896.75	28	6.50						
9	720.76	29	3.01						
10	526.90	30	0.75						
11	417.50	31	0.00						
12	341.34								
13	282.98								
14	236.21								
15	197.70								
16	165.67								
17	139.69								
18	121.29								
19	105.56								



An interpretation of the strain cylinder test for the assessment of concrete cube testing machines

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The words 'likely variation' in Table 3 are vague, but it is not worth using a more precise definition from probability theory given the limited statistics available.

Conclusions and recommendations

A limited degree of correlation has been established between the strain cylinder's measurements and the likely variation in cube strength from that given by the SABS Avery Denison machine. (Note: this cube strength variation figure would not change significantly if another good quality reference machine were used.)

The reliability of the correlation could be improved by continuing the project, preferably on poorer quality machines than those evaluated so far.

References

1. SABS (South African Bureau of Standards). 1994. *South African Bureau of Standards Method 863:1994: Concrete test – Compressive strength of hardened concrete.* SABS, Pretoria.
2. BSI (British Standards Institution). 1986. *BS1881: Part 115: 1986: Specification for compression testing machines for concrete.* BSI, UK.
3. BSI (British Standards Institution). 1990. *BS1881: Part 127: 1990: Method of verifying the performance of a concrete cube compression machine using the comparative cube test.* BSI, UK.
4. Luker, I. 1994. *The assessment of concrete testing machines.* Report to the Portland Cement Institute, Jan.