CALIBRATION OF STRAIN CYLINDERS FOR COMPRESSION TESTING MACHINE AT LNE

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Summary

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- Reminder on cylinder used (EN 12390-4)
- LNE cylinder calibration procedure
- Standard ratios
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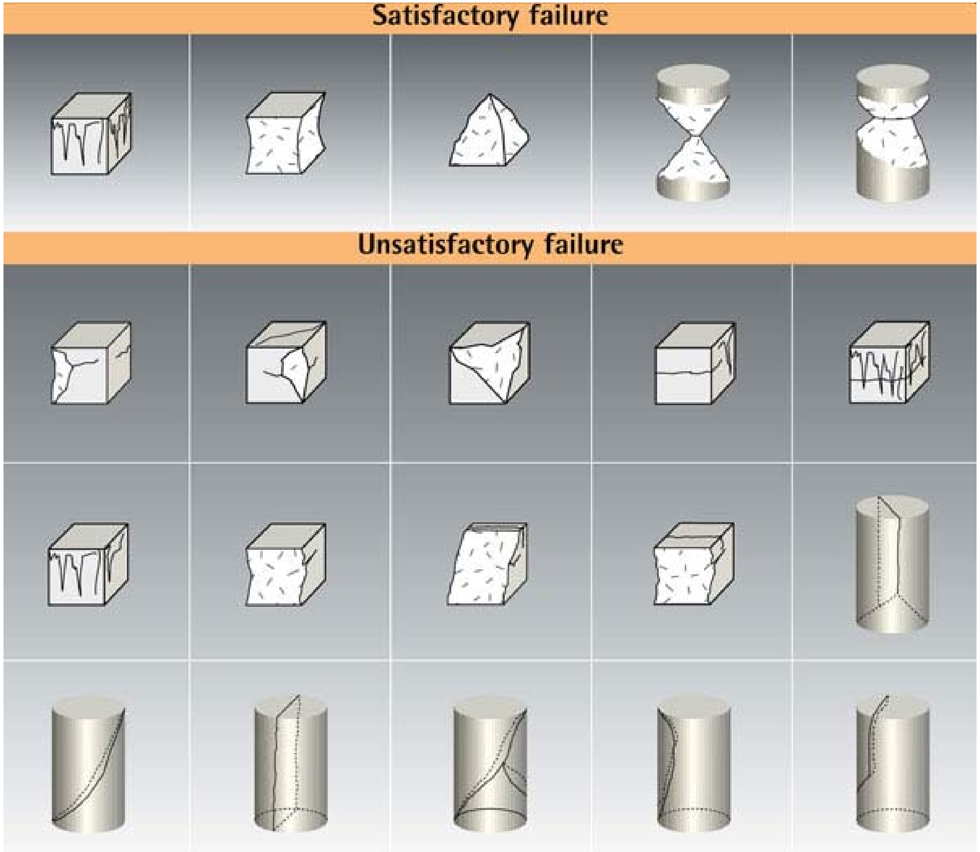
Introduction



Introduction

SAVETY CONCRETE CONSTRUCTION

↓

TESTS OF CONCRETE SPECIMENS USING COMPRESSION MACHINE

↓

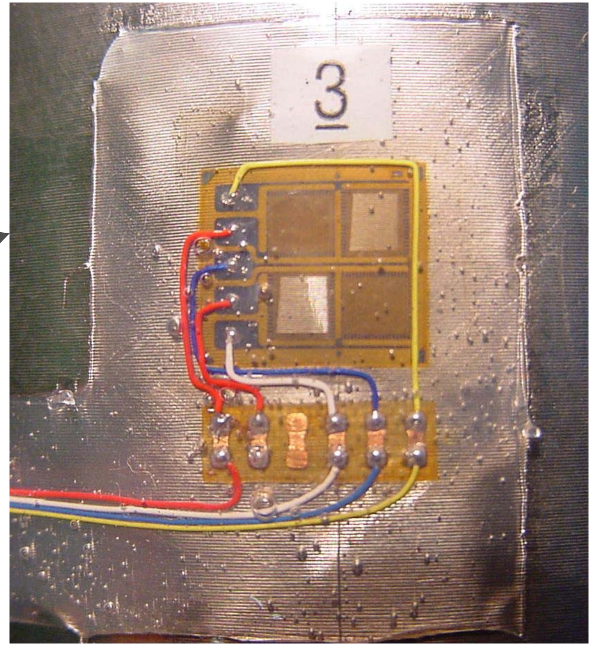
VERIFICATION OF TESTING MACHINES : EN 12390-4

ACCURACY OF FORCE INDICATION ← The same importance → UNIFORMITY FORCE DISTRIBUTION

FORCE MEASURING DEVICE | STRAIN CYLINDERS

ISO 376 ← Calibration → ???

Strain cylinder characteristics



$$\bar{e} = \frac{1}{4}\sum_{n=1}^{4} e_n$$

$$r_n = \frac{e_n - \bar{e}}{\bar{e}}$$

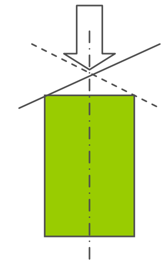
r_n = Strain ratio

e_n = bridge output N° n

Strain cylinder operating process : EN 12390

Self-alignment of the upper platen

$$200\ \text{kN} : \Delta r_n \leq 0.1$$

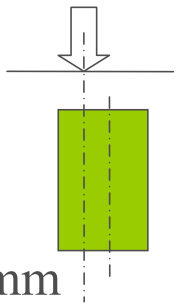


Alignment of the component parts of the machine

$$\overline{r_n} = 0.0 \pm 0.1$$

$$\rightarrow \varepsilon_1 = 1.22\varepsilon_2$$

Restraint on movement of the upper platen



± 6 mm

$$\overline{r_n} \leq 0.24 \text{ under } 2000\ \text{kN}$$

$$\overline{r_n} \leq 0.36 \text{ under } 200\ \text{kN}$$

$$\rightarrow \varepsilon_1 \approx 2\varepsilon_2$$

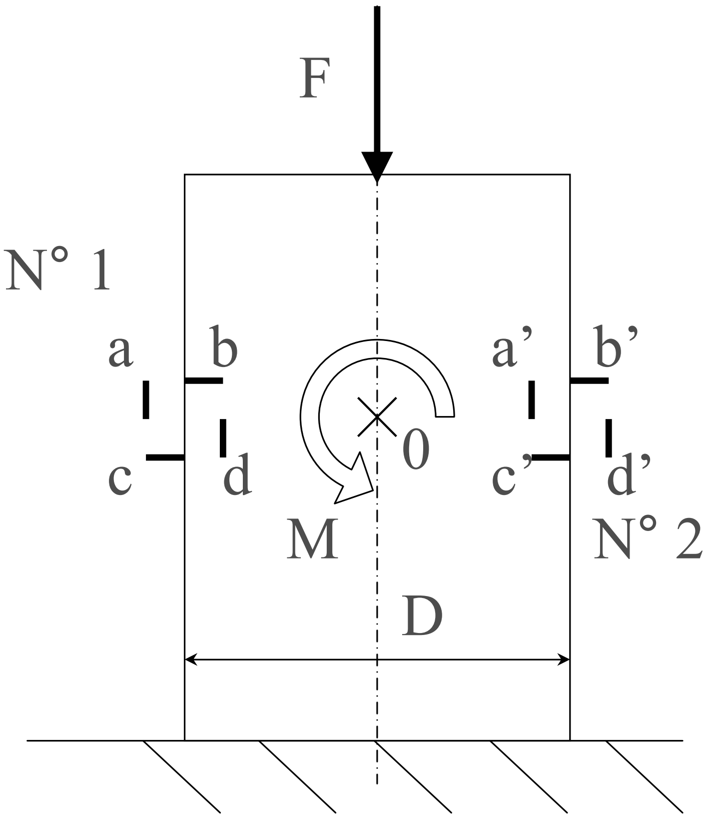
Cylinder calibration : 2 years

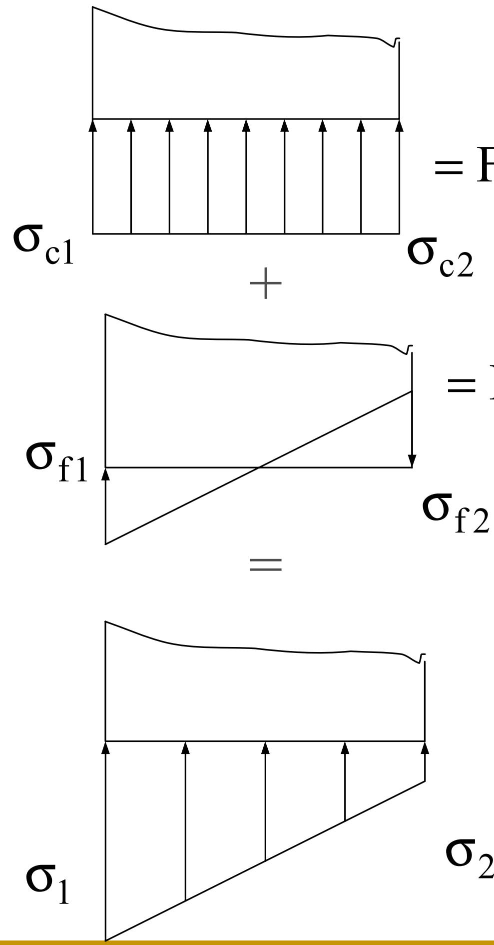
LNE calibration procedure

Apply a standard ratio and record the corresponding ratio indicated by the cylinder.

We generate standard ratios by applying on the cylinder a **centred standard axial force associated with a standard bending moment.**

Standard ratio





$= F / S = 4\,F / (\Pi\,D^2)$

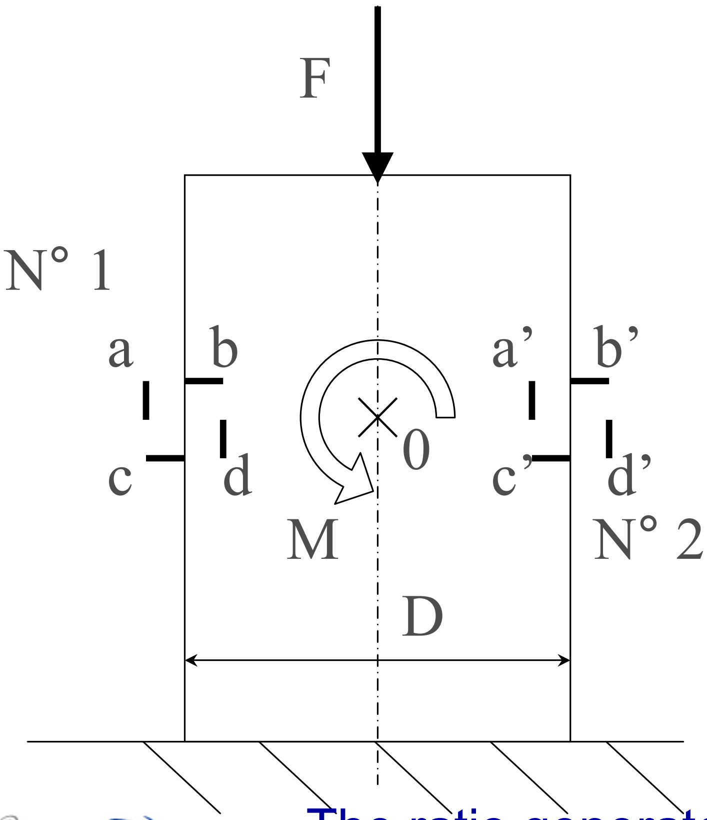
$v = \pm D / 2$

$= Mv / I$

$I = \Pi\,D^4 / 64$

$$= \frac{4}{\pi\,D^2}\left(F \pm \frac{8\,M}{D}\right)$$

Standard ratio



$$e = (\varepsilon_a + \varepsilon_d - \varepsilon_b - \varepsilon_c)\, k/4$$

$$\varepsilon_a = \varepsilon_d = \sigma / E \qquad \varepsilon_b = \varepsilon_c = -\nu\, \varepsilon_a$$

$$e = (1 + \nu)\, \sigma\, k / (2 E)$$

$$e = \frac{2k(1+\nu)}{\pi D^2 E}\left(F \pm \frac{8M}{D}\right)$$

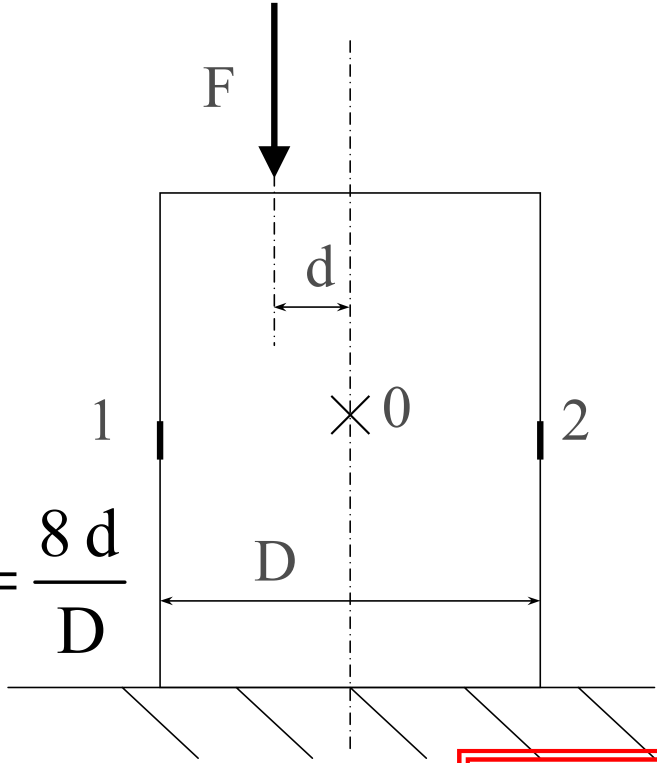
$$\bar{e} = \frac{2k(1+\nu)F}{\pi D^2 E}$$

$$r = \frac{e - \bar{e}}{\bar{e}}$$

$$r = \frac{8M}{DF}$$

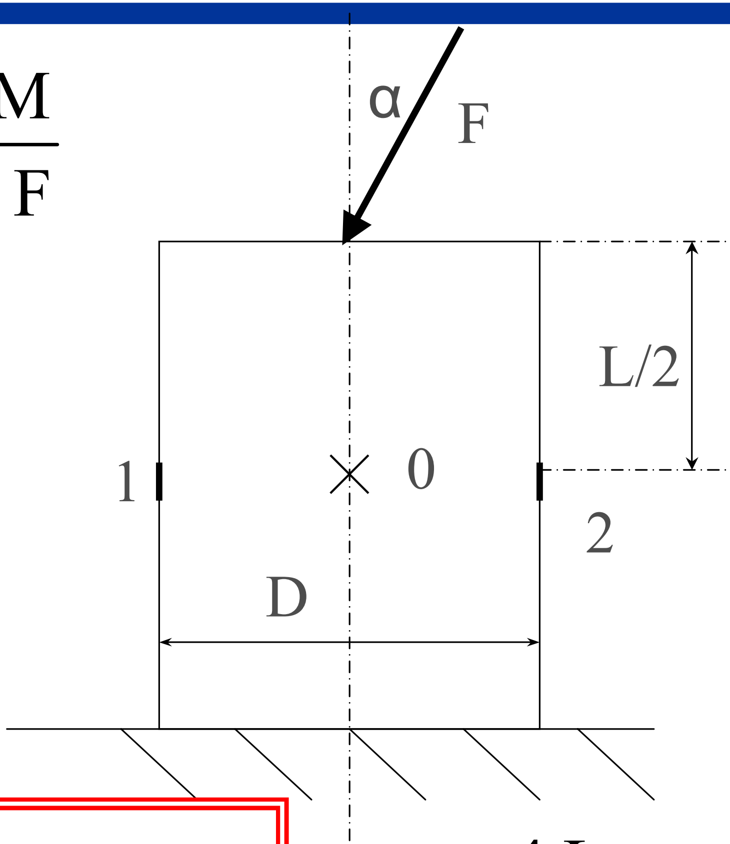
The ratio generated on a cylinder can be determined from the applied force and moment

Standard ratio



$$r = \frac{8\,d}{D}$$

$$r = \frac{8\,M}{D\,F}$$



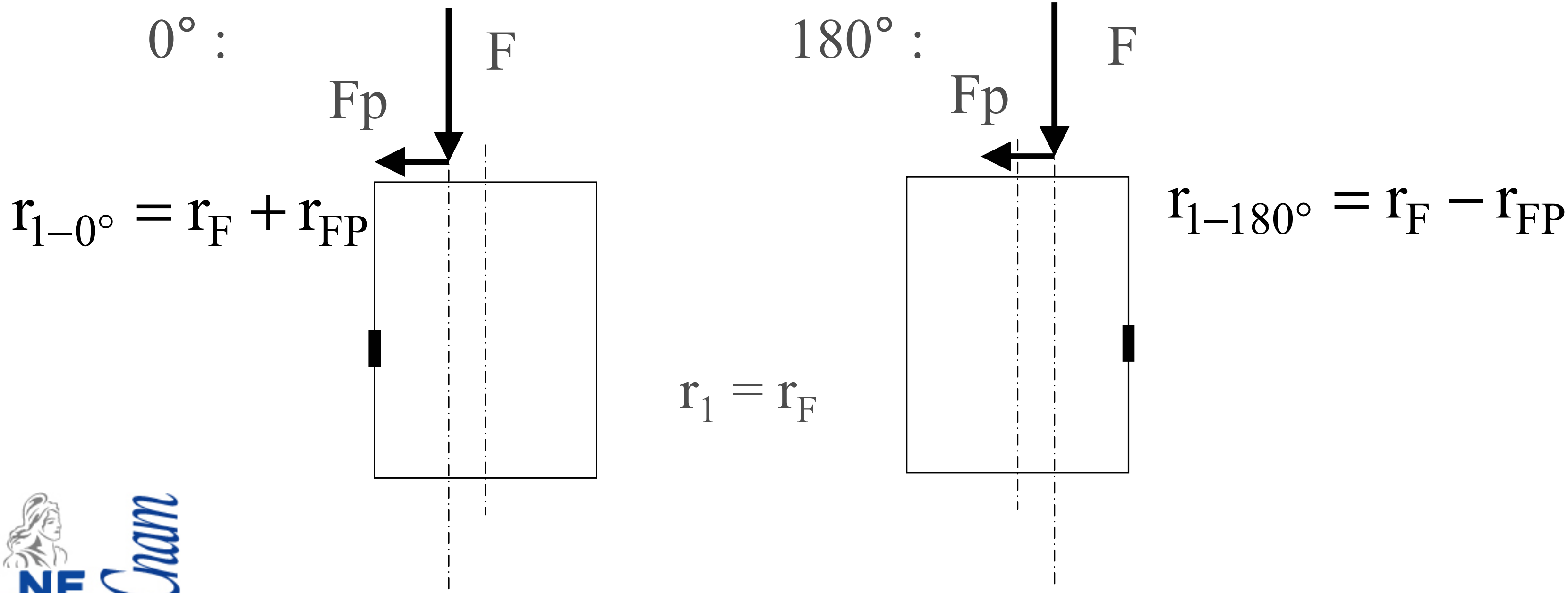
$$r = \frac{4}{D}\left[\,L\,tg(\alpha) + 2\,d\,\right]$$

$$r = \frac{4\,L}{D}\,tg(\alpha)$$

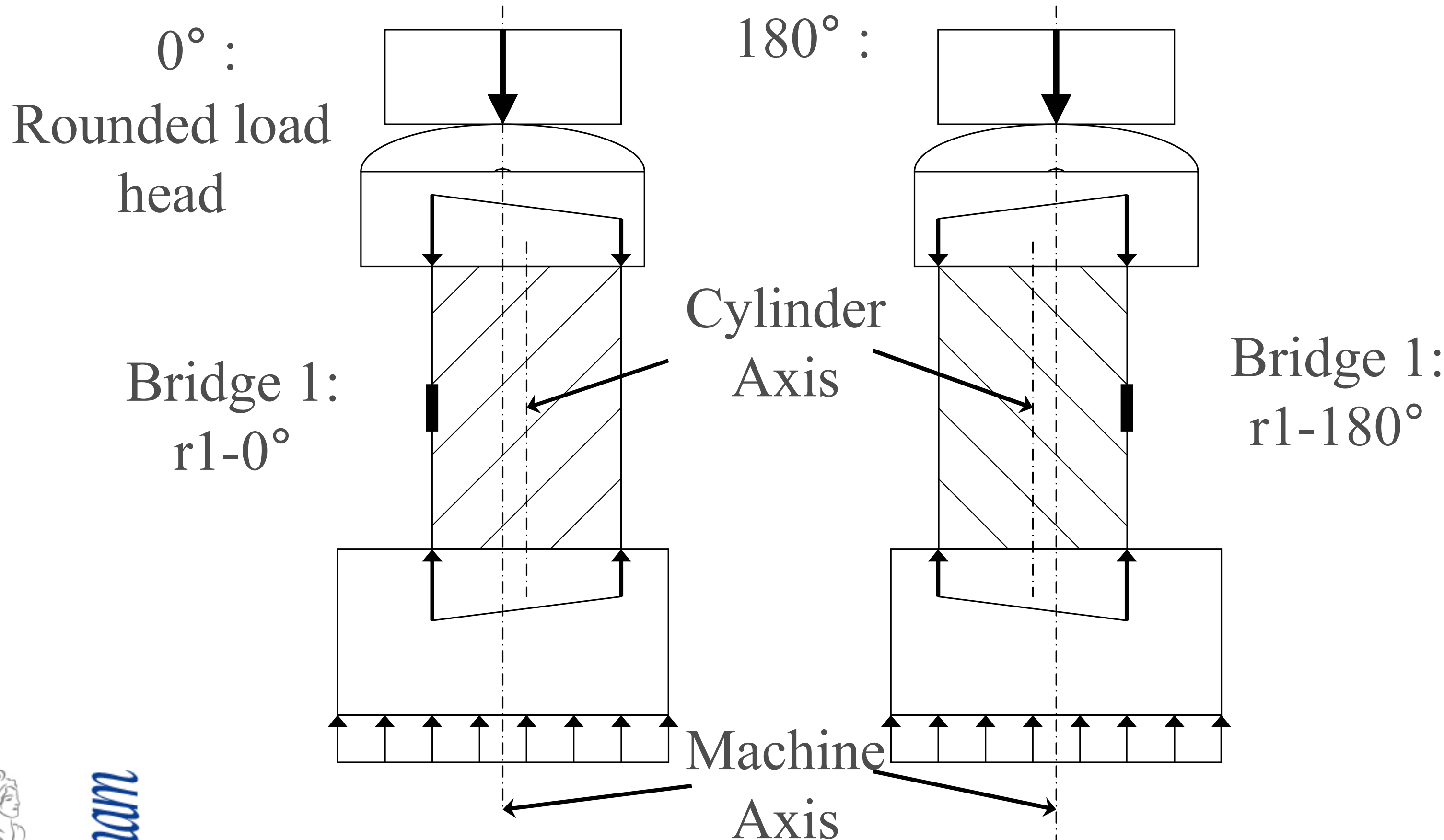
Standard ratio

The axis of the load introduction system will remain centred on the reference machine axis. Only the cylinder will be eccentred.

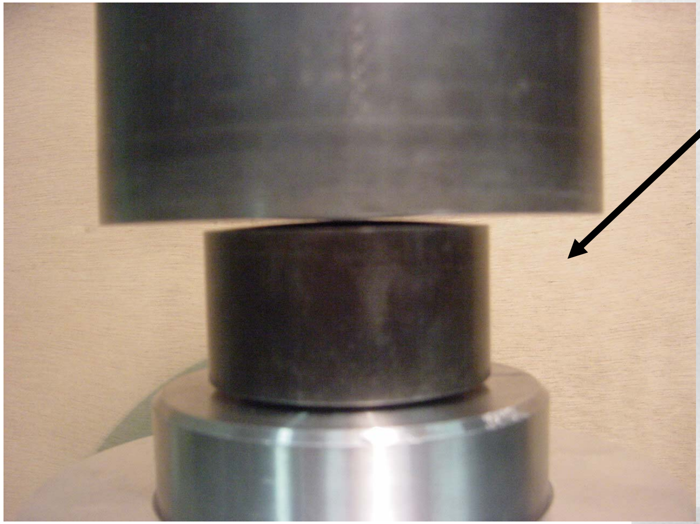
The cylinder should rotate during calibration around the force.

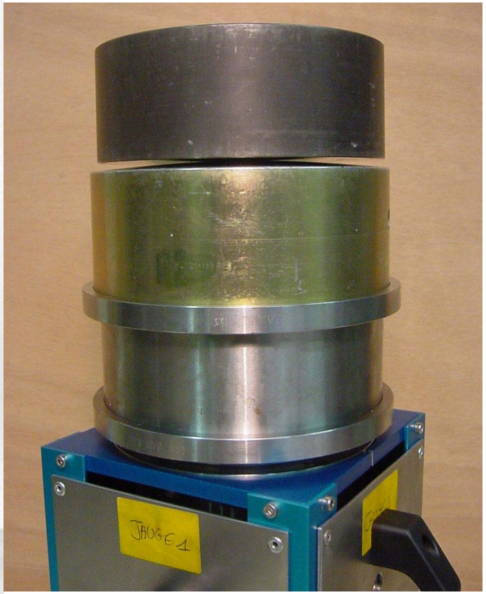


Mechanical interface

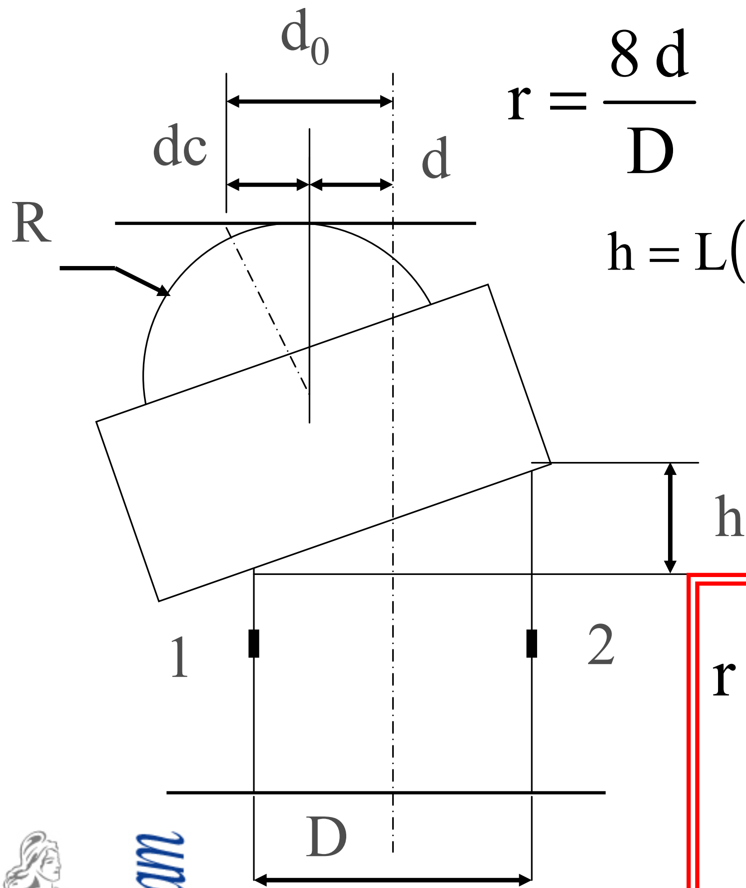


Mechanical interface





Mechanical interface



$$r = \frac{8\,d}{D} \qquad d = d_0 - d_c \qquad \frac{d_c}{R} = \frac{h}{D} \qquad d = d_0 - \frac{R\,h}{D}$$

$$h = L(\sigma_1 - \sigma_2)/E \qquad \sigma_1 - \sigma_2 = \frac{64\,M}{\pi\,D^3}$$

$$d = d_o - \frac{64\,L\,R\,F\,d}{\pi\,D^4\,E}$$

$$r = \frac{8\,d_o}{D\left(1 + \frac{64\,L\,R\,F}{\pi\,D^4\,E}\right)}$$

~~$$r = \frac{8\,d_0}{D}$$~~

24%

Uncertainty

$$r = \frac{4}{D}\left[L\,tg(\alpha) + 2\,d \right] \quad ; \quad u^2(r) = \left[\frac{\partial r}{\partial d}\right]^2 u^2(d) + \left[\frac{\partial r}{\partial \alpha}\right]^2 u^2(\alpha)$$

$$u^2(r) = \left[\frac{8}{D}\right]^2 u^2(d) + \left[\frac{4\,L}{D}\right]^2 u^2(\alpha)$$

$$d = \frac{d_o}{1 + \dfrac{64\,L\,R\,F}{\pi\,D^4\,E}} \quad ; \quad u^2(d) = \left(\frac{1}{1 + \dfrac{64\,L\,R\,F}{\pi\,D^4\,E}}\right)^2 u^2(d_o) + \left(\frac{d}{d_o}\right)^2 (d_o - d)^2 \left(\frac{u^2(R)}{R^2} + \frac{u^2(F)}{F^2}\right)$$

$$u^2(r) < 0{,}08^2\,u^2(d_o) + 0{,}14^2\,u^2(\alpha) + 0{,}05^2 \left(\frac{u^2(R)}{R^2} + \frac{u^2(F)}{F^2}\right)$$

r ± 0.01 => do ± 0.1 mm & α ± 0.1 mm/100mm & R ± 3% & F ± 1%

Conclusion

LNE strain cylinder calibration method : application of a force and a moment simultaneoulsy. The moment is applied using a defined eccentricity of the applied force.

This method is really a calibration : measurand, standard value, uncertainty have been determined.

It's not a theorical calibration method : it have been applied since 2003 for a lot of cylinders and results confirm the capability of this method. Calibration certificates are made under Cofrac accreditation.

Discussion

NPL method : comparison with a reference cylinder using a reference testing machine.

PTB method : calibration on force standard machine without additional moment

LNE calibration cover the range of using, not only with ratio near zero. This is not the case with an individual calibration bridges or a test on a very good machine.

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