APPARATUS FOR ASCERTAINING THE MINUTE STRAINS WHICH OCCUR IN MATERIALS WHEN STRESSED WITHIN THE ELASTIC LIMIT.

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[Read before the Royal Society of N. S. Wales, July 7, 1897.]

The coefficient of elasticity is usually defined as the ratio of the stress to the strain which it produces. It is necessary to know the coefficient of elasticity whenever it is desired to calculate the deformation or strain produced by a given load or stress, or to calculate the stress from an observed deformation. Such calculations are of frequent occurrence in connection with the design of structures and machinery.

The deformations produced by the stresses under normal working conditions are exceedingly minute, and require very delicate instruments to measure them accurately. This remark is especially true in connection with the determination of the elastic constants for stone, concrete, and cements, where a stress of one ton per square inch may produce a compression of only one hundred thousandth part of an inch ($\frac{1}{100000}$) per inch, in which case the coefficient of elasticity would be expressed as 100000, the units of stress being tons per square inch. In the case of a certain kind of sandstone, for example, Prof. Bauschinger obtained a coefficient of 240,000 with the same units in compression. So that a stress of one ton per square inch on this sandstone would produce a compressive strain of one two hundred and forty thousandth of an inch.

In the case of metals the deformations produced by stresses are much larger, and the elastic coefficients correspondingly smaller, so that their accurate determination is more easily accomplished. But even in this case it is necessary to be able to measure strains
as small as one ten thousandth of an inch, and for the determination of the true elastic limit the error in the measurements must not exceed one hundred thousandth of an inch.

The apparatus which has been hitherto in use in the Engineering Laboratory for the measurement of small strains consists of various arrangements of levers or micrometers. The most delicate of these are, a, the Lever Extensometer designed by Prof. Kennedy; b, the Richle-Yale Extensometer.

Prof. Kennedy’s Extensometer consists of a light frame attached to the test piece, and carrying a light lever multiplying the strain a hundred times, and giving the mean strain produced on each side of the test piece. The scale is divided into tenths of an inch, but it is possible to record one-tenth of these divisions, in which case the readings are taken to one ten thousandth part of an inch.

The Richle-Yale Extensometer consists of a light frame attached to the test piece, and carrying two screw-micrometers which measure the extension or compression of the bar on each side to one ten thousandth part of an inch. An electric battery and bell are attached to enable contacts to be made with the micrometers, with greater accuracy.

Professor Martens’ Mirror Apparatus is far more delicate than either of the foregoing, and has recently been made for the Engineering Laboratory by Mr. Edward Böhme, instrument maker to the Royal Mechanical Technical Experimental Station Charlottenburg, Berlin. It is represented in the accompanying sketches, Fig. 1–4, and consists of two small prisms \( kk \) which are held in firm contact with the test piece and the distance pieces \( dd \) by means of a steel wire spring, the action of which is indicated by the arrows \( ss \). Each prism is provided with a stem \( a \), which carries a small mirror \( m \) held in the frame \( ff \) rotating freely about the stem, and is held in position by means of a spring \( e \). At \( b \) is a capstan screw for the adjustment of the mirror which is held against its point by a small spring not shown in the sketch. At a definite distance from the test piece are two stands side by
side, each carrying a telescope \( t \) with adjusting appliances and a scale \( i \) which is divided into millimeters. The scale is seen clearly in the telescope reflected by the mirror, and as the mirror rotates slowly in consequence of the elongation of the test pieces, the image of the scale moves in the focus of the telescope and defines the tangents of the double angle through which the prisms, and consequently the mirror, has revolved. The proportion between the elongation of the specimen and the reading of the scales is determined as follows:

Let \( r \) denote the width of the prisms, and \( R \) the distance between the scales and the mirror. Then if \( U \) be the elongation we have approximately

\[
U = \frac{r}{2R}
\]

The mean width of the prisms in the apparatus shown is 4.5402 millimeters, and \( R \) is made 1135 millimeters

\[
\cdots U = \frac{1}{500}
\]

Now since differences of \( \frac{1}{10} \) of a millimeter can be easily defined on the scale, the extension corresponding with this reading is \( \frac{1}{1000} \) of a millimeter, and the total of both readings with \( \frac{1}{10000} \) of a millimeter, so that this apparatus is capable of showing elongations.
as small as one two hundred and fifty thousandth of an inch. It has the advantage also of not being influenced by the temperature of the body of the observer to anything approaching the same extent as with micrometer readings, and is probably the most accurate apparatus yet designed for measuring the small deformations which occur within the elastic limit of materials.

The apparatus is illustrated in Figs. 2, 3, and 4, which show its application to the testing of a mild steel bar, and a cube of concrete.

The following table gives a series of readings taken with the apparatus for a round specimen of mild steel:

<table>
<thead>
<tr>
<th>Diameter of test piece in millimeters</th>
<th>Load in tons</th>
<th>Readings of Scale</th>
<th>Mean Readings 1000 mm.</th>
<th>Differences</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Left 1/5000 mm.</td>
<td>Right 1/5000 mm.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.25</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>80</td>
<td>88</td>
<td>168</td>
<td>168</td>
</tr>
<tr>
<td></td>
<td>2.00</td>
<td>120</td>
<td>200</td>
<td>306</td>
<td>228</td>
</tr>
<tr>
<td></td>
<td>3.00</td>
<td>299</td>
<td>323</td>
<td>622</td>
<td>266</td>
</tr>
<tr>
<td></td>
<td>4.00</td>
<td>411</td>
<td>441</td>
<td>852</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td>5.00</td>
<td>530</td>
<td>551</td>
<td>1081</td>
<td>229</td>
</tr>
<tr>
<td></td>
<td>6.00</td>
<td>649</td>
<td>660</td>
<td>1309</td>
<td>228</td>
</tr>
<tr>
<td></td>
<td>7.00</td>
<td>758</td>
<td>779</td>
<td>1537</td>
<td>228</td>
</tr>
<tr>
<td></td>
<td>8.00</td>
<td>872</td>
<td>894</td>
<td>1766</td>
<td>229</td>
</tr>
</tbody>
</table>

Limite of elasticity.

Mr. Böhme has also made a pair of Roller Extensometers for the Engineering Laboratory, which will be used for ascertaining the deflections of beams, and compression of columns. This extensometer consists of a dial divided into five hundred parts and a rotating index, which has an angular displacement proportional to the deformation of the test piece. One revolution corresponds with one centimeter deformation, so that readings are taken to (1/50 mm.) one-fiftieth part of a millimeter, or one thousand two

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1 The letters in these figures refer to Mr. G. H. Knibbs' paper on the same subject, following on.
hundred and fiftieth part of an inch; there is no difficulty in subdividing the divisions on the dial if desired, in order to read in \(\frac{1}{1,00,000}\) mm. The writer has just used one of the instruments in determining the elastic deflections of some rails for Western Australia, and he proposes to use it in connection with a series of tests of brickwork and concrete columns.

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**THE THEORY OF THE REFLECTING EXTENSOMETER**

**OF Prof. MARTENS.**

By G. H. KNIBBS, F.R.A.S.,

Lecturer in Surveying, University of Sydney.

[Read before the Royal Society of N. S. Wales, August 4, 1897.]

1. Approximate theory sometimes inadequate.
2. Description of the extensometer.
3. Relation between extension and scale-reading.
4. Construction of tables of corrections to scale-reading.
5. Application of scale-reading correction.
6. Adjustment of prism perpendicular to test-piece.
7. Examination of the pivot axis of the mirror.
8. Parallelism of the rotation axis of the mirror with the knife-edges of the prism.
9. Error due to longitudinal movement of the test-piece.
10. Error from rotational movement of the test-piece.
11. Disposition of the apparatus in testing, and general.

1. *Approximate theory sometimes inadequate.*—The theory of the measurement of very small extensions by means of Professor Martens' reflecting extensometer, which was exhibited and described by Professor Warren at the last meeting of the Royal Society, leaves little to be desired, when the extensions do not exceed the limits contemplated in that description, that is, when they are extremely small as compared with the distances between the knife-edges of the rotated prism carrying the mirror. And

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