Stresses in Buildings.

By Prof. E. G. COKER, F.R.S.

THE range and variety of the problems connected with the provision of safe and suitable buildings and structures have recently been brought to the attention of the British public in many ways, notably by a lack of housing accommodation, the insecurity of Waterloo Bridge, and the dangerous state of St. Paul's

FIG. 1.—Stress distribution and lines of principal stress at the base of a wall.

Cathedral. During the post-War period, the provision of new materials and improved methods of construction have also engaged the attention of eminent architects, engineers, and firms of constructors. Commercial buildings are in the main proceeding apace, where great capital interests are involved, as in Regent Street, London, or where private munificence is supplying the urgent needs of hospitals and educational institutions. New technical problems are in consequence arising, and will no doubt continue to present themselves under a condition of affairs in which methods of construction are rapidly changing and new materials are being pressed into service.

Some elementary problems of this kind presented themselves recently during the partial completion of the engineering wing of University College, London, upon foundations built thirty years ago. These difficulties were dealt with successfully as they arose, but the absence of definite data in existing literature led to an experimental investigation on transparent models,¹ in which stress is measured by the temporary double refraction produced by load. One of these primary problems is the stress at the junction of a main wall with an enlarged base spread out in the usual fashion shown by Fig. 1, *a*, to afford a safe load on the earth below it.

It is at once apparent that, at the first sudden enlargement in such a wall, the stress at the angles must be extremely great, as experiments show, but for experimental purposes it is necessary to avoid an excessive concentration of stress at such places in order to measure the distribution. All such angles were, therefore, completed by a small circular arc in this case of radius $b/24$, where b is the breadth of the

wall. With this modified arrangement, it was found that the stress at the horizontal cross section due to a mean vertical stress p_m rose to approximately $2.5 p_m$ at the junction with the wall, but is even greater at a point on the circular fillet just below this where it rose to $3.04 p_m$ (Fig. 1, *b*). The general vertical distribution p over this cross section is also accompanied by a variable cross stress q as indicated, while at *C*, well below the change of section, the tendency of the stress is to concentrate towards the centre, as my colleague, Prof. Filon, had already shown, mathematically, must be the case. It will also be noted from Fig. 1, *a*, that in the wall the tendency is exactly opposite. Monolithic walls are not usually constructed with stepped footings, but are connected to the base by sloping sides such as may be obtained when the projecting angles, Fig. 1, *a*, are removed, as in Fig. 1, *c*. This is found to result in a diminution of the maximum stress at the face of the wall to $2.79 p_m$.

Another problem of frequent occurrence is the stress effect due to a line of window openings, and represented here by two rectangular openings with rounded angles, Fig. 2, in a wall of limited width, such as might occur with some modifications and many more windows in a monolithic concrete wall of a building. The stress distribution here shows that at the cross section *AB*, the central part of the wall is under practically uniform stress, while the side walls are under nearly uniformly varying stress with maximum values at the window

FIG. 2.—Stress distribution and lines of principal stress due to window openings.

openings, accompanied by great local concentrations of stress at the rounded angles, and variable tension along the upper and lower boundaries of the window openings. This latter stress is unsuitable for masonry, brickwork, or concrete to bear, unless reinforced by steel, or, as in a high building, dealt with by a steel framework, which transmits the main load to the

¹ For a description of the experiments, see the issue of February 6 of the *Journal of the Royal Institute of British Architects*.

foundations, leaving the walls a mere protecting cover of no structural importance.

Structural weakness in a building may also be produced by an excess of material placed there from purely artistic considerations, and a good example of

FIG. 3.—Stress effect of a cornice.

this is an ornamental cornice, Fig. 3, such as may be found in, say, a Gothic cathedral structure. The effect of the projecting part is to cause a considerable change in the vertical directions of the lines of stress, as Fig. 3 indicates. Such lines are also found in the free pro-

jecting part and direct attention to the stress there. An examination of the stress across the horizontal joints shows that there is a great local increase of load at the face of the wall, which in this case causes an increase of stress of about 75 per cent. of the mean stress at this face, and is also approximately the same at the outermost point of the lower joint. It may happen, therefore, due to sinking of the foundations at one place, that a good deal of extra load may be thrown on another part of a wall, and the extra stress on a cornice may then rise to so great a value that the material at the face is crushed locally and cracks develop, which ultimately lead to the cornice falling down, as occasionally happens. The reason for this concentration of stress is not difficult to understand, if it is remembered that, in a simple rectangular block of masonry with plane joints and without projections, the compression stress is uniformly distributed, and the two horizontal faces approach one another by a small definite amount.

The effect of a projection such as a cornice is to resist alterations of the form of the block, more especially in its own neighbourhood, and in consequence the plane surfaces of the joints deform into slightly curved surfaces resulting in a higher stress developing at the ends and more especially at the face of the wall.

This example is one of many instances in construction where an addition of material causes increased stress, which must be taken into account where architectural or other requirements compel the use of excess of material in disadvantageous positions. Experiment in this case shows that some slight improvement in stress conditions is obtained when the cornice is itself of much less depth than the masonry block.

Obituary.

PROF. A. PEROT.

THE death of Prof. Alfred Perot on November 28, 1925, was a serious loss to French science. Perot was born at Nancy in 1863, and after completing his studies at the École Polytechnique at Paris, returned in 1884 to the University of his native town, where he undertook research upon the density of saturated vapours, obtaining experimental confirmation of the thermodynamic formulæ. In 1884 he commenced teaching at the University of Marseilles, where he also undertook investigations on the properties of dielectrics, and on Hertzian waves, and ultimately became associated with Charles Fabry in a series of researches on optical interference, particularly between plane parallel semi-silvered surfaces. The methods developed by Perot and Fabry have formed the basis for the precise determination of the values of the reference lines in the international system of wave-lengths now universally employed.

In 1901 Perot was entrusted with the task of organising a "Laboratoire d'Essais" in connexion with the Conservatoire des Arts et Métiers. While engaged on this task he continued his association with Fabry, and with the further collaboration of the late Dr. R. Benoit, then director of the Bureau International des Poids et Mesures, carried out by new methods a fundamental determination of the value of the metre in terms of the wave-length of the cadmium red line, the result of which confirmed with truly remarkable pre-

cision the earlier determination of Michelson and Benoit. This determination remains the recognised standard of departure for wave-length values to the present time.

In 1908 Perot left the Laboratoire d'Essais to become professor at the École Polytechnique, and physical astronomer of the Observatory of Meudon, resuming his spectroscopic studies, particularly with respect to very small displacements of lines in the solar spectrum due to various causes. He continued to occupy himself with questions of measures and units, and succeeded M. B. Violle as president of the Commission de Métrologie Usuelle, in connexion with the French weights and measures service. He also took an active part, as president of the Special Commission de Refonte des Règles, in the preparation of the new French law on the subject (1923) whereby the definitions of the metric system were extended and amplified (for example, by the introduction of a system of units based on the metre, tonne and second [M] [T] [S]), with the view of increasing their applicability to the ordinary transactions of commerce and industry.

Perot was not only a sound theoretician and skilled experimenter, but also an excellent mechanic, who was well able to construct with his own hands the very delicate apparatus used in some of his investigations. During the War his time was mainly devoted to confidential researches connected therewith.

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