thrust will usually prove sufficient to keep the curve within the arch ring; and this is a very moderate amount compared with the limiting angle of friction. The curve corresponding to such an inclined thrust is found to rise under the load, as would be expected. The joint of rupture tends to fall on the loaded side and to rise on the unloaded side; and if the arch is so constructed that the joint of rupture cannot take a lower position, the value of the thrust for any assumed inclination can be found after a few trials by equating the moments on the loaded side only. So far as the writer has been able to determine, the effects of such partial loading may be actually greater than with a complete load, especially as regards the abutments. Although we may infer the general opinion to be that the results would not differ largely from those already obtained for complete loading, the effects produced should not be left to the margin of safety in the structure; and this part of the subject therefore requires further investigation.

REFERENCES.

(1.) *Curve of Pressure.* Its properties were first discussed by Méry in 1827, though his work remained in manuscript till 1840. In the meantime Moseley's article appeared in 1833. (See No. 8.)

(2.) Culmann. "Die graphische Statik," Zurich, 1866.

Levy. "La Statique graphique," Paris, 1874.

(3.) *Basket-handle arch or false ellipse.* A summary of various methods proposed for drawing these is given by Morandière, "Traite de la Construction des Ponts et Viaducs," chap. 3, pages 168 to 181; Paris, 1874. For the methods proposed by Michal and Perronet, see also Claudel, "Aide-memoire des Ingénieurs," Art. 854. 9th Edition; Paris, 1877.

(4.) *Expansion of stone by heat.* Mentioned by Stoney as occurring in masonry arches; "Theory of Strains in Girders," &c., Ch. 19, Art. 414. Observed in an experimental arch of 148 feet span designed by Romany for the Pont du Louvre, Paris; "Annales des Ponts et Chaussées," 1866, 2e semestre, page 10. Also cited in Morandière's "Traite," page 217.

(5.) *Theory of Elasticity applied to Masonry.* Well explained by Collignon, "Résistance des Matériaux," Arts. 30 to 66, and Art. 228.

(6.) *The function of mortar.* See Moseley, "Engineering and Architecture," 2nd Edition, page 482. London, 1855.

(7.) *Limiting positions of the Curve of Pressure.* See pages 85 and 28 in "A practical Theory of Voussoir Arches," by Prof. Wm. Cain; Van Nostrand's Science Series, No. 12, 1874.

Principle of Least Resistance.

(8.) Originally published by Moseley in the "Philosophical Magazine" for October, 1833. See also his "Engineering and Architecture," Art. 332. The priority claimed for Coulomb cannot be established.

(9.) "Theorie der Gewölbe und Futtermauern," Schettler, 1857. Translated into French by Victor Fournié, "Théorie des Voûtes," Paris, 1864.

(10.) Schettler's theory compared with experiment, "Voussoir Arches," by Prof. Wm. Cain; Van Nostrand's Science Series No. 42, 1879.

(11.) Dupuit's Theory. Published originally in the "Annales des Ponts et Chaussées," 1858. In a separate form as "Traite de l'Équilibre des Voûtes;" Text and Plates. Paris, 1870.

(12.) Summary of Dupuit's work given in Claudel, "Aide-mémoire des Ingénieurs," sections 870 to 934. 9th Edition.

Theory of the Middle Third

(13.) Rankine, "Civil Engineering;" Arts. 123 to 141, and 276 to 298.

(14.) Rankine's chapters on the Arch amplified and explained by Prof. Wm. Allan, "Theory of Arches," Van Nostrand's Science Series No. 11, 1874.

(15.) "Encyclopedia Britannica," ninth Edition, 1876. Article "Bridges," by Prof. Fleeming Jenkin.

(16.) See foot note to Art. 178 in "Graphical Statics," by Prof. Dubois New York, 1885.

Thickness of the arch ring at the key.

(17.) The equation of the form $t = C\sqrt{r}$ was first proposed by J. F. Hurst, "Building News," Feb. 27, 1857; though the corresponding form was adopted independently on the Continent.

(18.) For the bridges on which these formulæ are based, see Rankine's "Civil Engineering," Art. 290; and Dupuit's "Traité," Chapter 7 and Plate 5.

(19.) *Graphical methods.* Change from vertical lamina to real joints, given by Prof. Clarke, "Graphic Statics," Art. 52. London, 1876.

(20.) Difference between curve of pressure and line of resistance. Illustrated by Dubois under the names "pressure line" and "support line" in his "Graphical Statics," Art. 176 and Fig. 102.

(21.) *Unsymmetrical loading.* See Collignon's general theorem, "Résistance des Matériaux," Art. 225.

Examples of Arches.

Morandière, "Traite de la Construction des Ponts et Viaducs." Masonry Bridges, pages 1 to 598; and plates 34 to 136, being 12 x 18 engravings. Paris, 1876.