There are only two ways in which a perfect arch can be constructed, and these are the converse of each other; either the curve of the arch must be designed to correspond with the loading, or the loading must be placed to correspond with the curve adopted. This can always be done when only dead weight or a stationary load are in question. For example, in the case of uniform loading the catenary and the parabola are familiar as the forms required, according as the load is uniformly distributed along the curve itself or along a horizontal line; and a circular arch may also become equilibrated by a suitable distribution of the loading upon it. If these methods were adopted, the curve of pressure would coincide with the centre of the arch ring throughout, and the direction of the pressure would be perpendicular to the joints. There would be entire harmony between principle and practice, and the only condition of stability would be the absolute pressure admissible in accordance with the material used. When it is the loading that is prescribed, the form required for the arch is usually difficult of construction, owing to the continual change in the radius of curvature; but notwithstanding this, close approximations to the true forms have been adopted with economy on aqueducts and canals. Their advantages disappear however when a change in the position of the loading has to be allowed for; and for railway purposes semi-circular, elliptic and segmental arches are substituted. Although this is the case, a valuable improvement in the stability of the arch may be obtained by a suitable distribution of the dead weight. To simplify construction the ellipse is often replaced by circular arcs, and there are very elegant methods of describing these by means of a series of centres, (3) to which the name of "basket-handle arches" has been given.

When both the form of the arch and the loading are defined, the arch is subjected to conditions diverging from those required for perfect equilibrium. This is unfortunately the case we are called upon to consider in practice, and for which a theory has to be found. The curve of pressure no longer cuts the joints of the arch ring at the centre, and a weak point develops at the haunch known as the joint of rupture where the curve passes nearest to the intrados.

In considering a series of voussoirs in such an arch, we must first determine how the pressure on the surface of a joint will be distributed when the resultant of the external forces is known. We will suppose the resultant known in position and magnitude, and for simplicity we will take it perpendicular to the surface of the joint. We further take the surfaces at the joint to be in perfect contact, but without cohesion, so that only compression can be resisted and not tension. With regard to stone and brick we have also some evidence that we are dealing with a material that is elastic and therefore also compressible. As boys we learn that a marble will bounce on a paving stone; the amount that a brick chimney will oscillate in the wind cannot be attributed to the mortar alone; and we have further the corroborative evidence that stone expands with heat. (4) Co-efficients of elasticity have been determined for glass and also for slate; but not for the materials ordinarily used in construction and when under direct compression, so far as the writer is aware. It is the existence of elasticity and not its amount however, that affects the question; and it is doubtful whether any solids exist which are either absolutely incompressible or infinitely hard. Without going further into those physical properties of stone and brick for which the experimental data are so meagre, it is enough that we have the right to infer that they are elastic, and to apply to masonry the same Theory of Elasticity as to other materials. In accordance with this theory, the particles which are in a plane when the body has its natural shape will remain in a plane when the body becomes deformed under compression, the new plane being either parallel or inclined to its original position. Apart from this theory we have no means of determining the distribution of pressure at a joint; and although something might be inferred from the final conditions obtaining on the failure of the arch, we could have no knowledge of the internal strains at any other time. We find accordingly that all authors describe the pressure at the joints as being distributed in a lineal ratio to be determined by the position of the resultant; and in doing so, whether they give the explanation or not, they are assuming either that stone and brick are elastic or that they act as if they were; and not only so, but that they conform to the accepted Theory of Elasticity. (5)

With regard to the nature of the contact at the joint, the most accurate workmanship could not be depended on to make it perfect without the intervention of mortar. Nearly all authors agree in considering this the only function of the mortar, (6) and even in the case of cement the adhesion is not counted upon, but is left to form part of the margin of safety. Some few make an exception of brickwork built in cement, and consider both tension and compression as occurring at the joints. This amounts to transferring brickwork from the conditions of masonry to those of a metallic arch, and limiting masonry to stonework only; but there are few who make such a distinction between stone and brick. The only remaining action considered at the joint is friction, which renders an inclination of the resultant compatible with stability when within the limits of the angle of friction.

It follows then directly from the theory of elasticity that when the resultant passes through the centre of the joint, the pressure is uni-