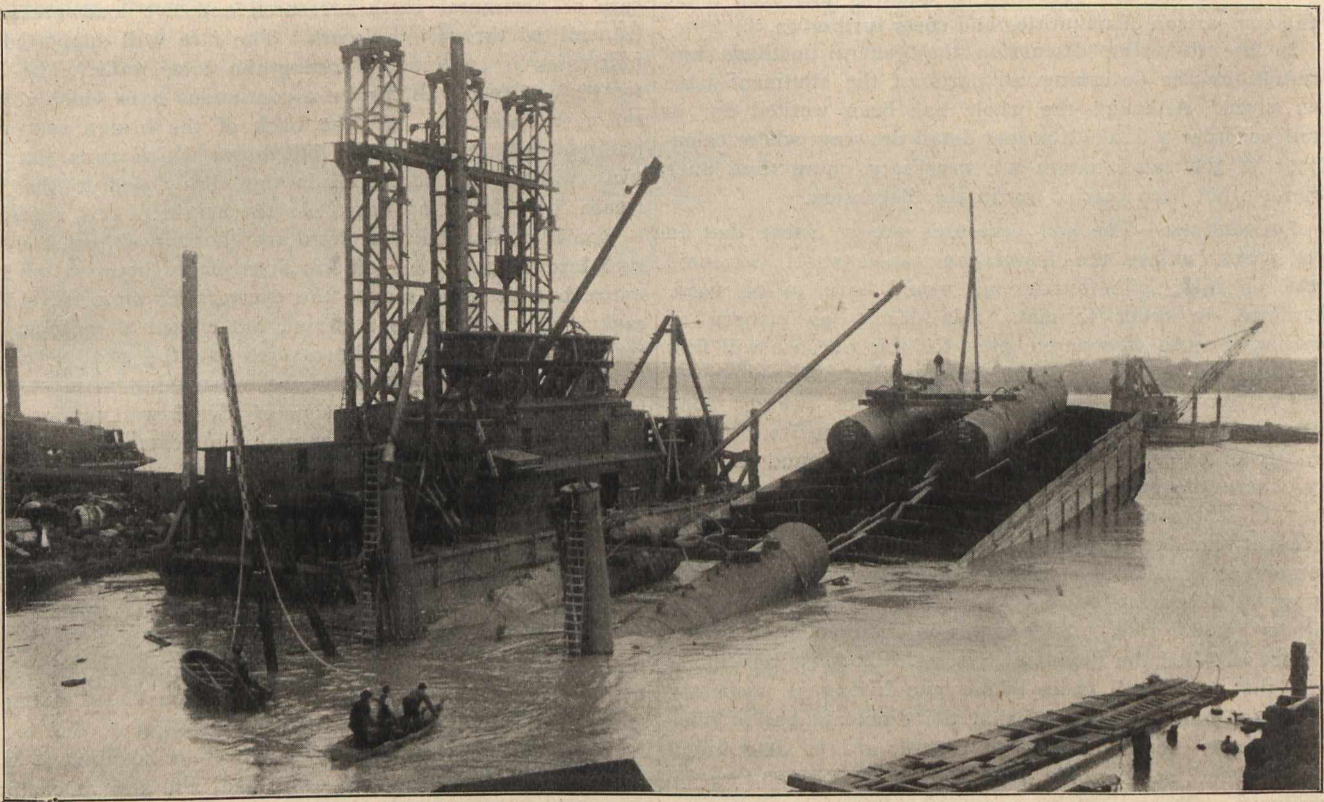
only, it is unquestionably destroyed; if the bond is a mechanical one, there remains, of course, much resistance, to slipping, but the beam is seriously weakened. The best description of the condition of a test beam at this point has been given by Professor A. H. Talbot, of the University of Illinois, in his bulletin of September, 1904, discussing results of tests carried on under his supervision at the engineering station of the University. Professor Talbot says in discussing beams reinforced with sufficient steel to take all tensile stresses: "The maximum load averaged about 6 per cent. more than the load at the yield point of the metal. It would seem then that for beams not having an excess of metal, the maximum load is nearly reached when the steel is stressed up to its yield point, and that the load at the yield point of the metal may be properly taken as the ultimate strength of the beam. It seems also true that the load which will stress the steel to its elastic limit, may be calculated by using the elastic limit of the naked steel for the tensile stress in the beam, and neglecting tension in the concrete."

What probably does occur in a beam when the elastic limit of the steel is reached is that, owing to the rapid extension of the steel, the neutral axis rises and the beam fails by compression of the extreme fibres of the concrete. For the above reasons, a formula in this discussion has been adopted which represents the ultimate strength of a beam at the point where the steel reaches its elastic limit.

A great deal of work has been designed, using steel which has an ultimate strength of say 64,000 lbs. per square inch, and using a working stress of 16,000 lbs., the designer thinking he has a factor of safety of 4. The real factor of safety accepting the foregoing conclusions is only 2, as the elastic limit of the above steel would average 32,000 lbs. That these conclusions are correct, is pretty well conceded by all authorities in the United States at present, yet a great deal of work, designed as above stated, is still being done. This, of course, can only be to the detriment of reinforced concrete, and be the cause of unnecessary failures. It stands to reason that as the ultimate strength of the beam depends on the elastic limit of the steel, the higher this elastic limit is, the more economical it will be. To the use of high carbon or high elastic limit steel the objections may be made that it is not reliable, and that its full value may not be developed owing to insufficient adhesion. Several years ago it was thought that economy could be effected by employing high carbon steel for bridge work. It was found, however, that owing to punching and the irregular stresses produced in plates and structural shapes, high carbon steel was unreliable. For this reason some engineers condemn its use for reinforced concrete. It should be remembered, though, that in this class of work there is no punching of the steel necessary. The stresses in the steel are nearly all tensile, and the ability of the steel to safely withstand them has been proven many times over. Shearing stresses need never be considered either, as they are always far within the shearing strength of the steel.

The objection that adhesion may not be sufficient to develop the full strength necessary of high elastic limit steel, is easily overcome by furnishing a suitable mechanical bond. An intimate union or bond between concrete and steel is of first importance, especially as failure of bond or lack of it may often have disastrous effects. Plain round or square bars depend on adhesion for the union of steel and concrete. This adhesion is partly due to friction, but chiefly to a mechanical bond, formed by the grout of the concrete entering into the irregularities on the surface of the bar. There are three influences affecting the adhesion and making a mechanical bond advisable: first, water percolating through the concrete (no concrete is perfectly watertight) has been proven to reduce the bond between ½ and ⅔; second, reinforcing bars when stressed, even within their elastic limit, must have their cross-section slightly reduced, and any shrinkage of the cross-section of the metal, however slight, is sufficient to materially affect the adhesion, inasmuch as the adhesion consists principally in the entering of the cement particles into the pores on the surface of the metal. If the metal has a working stress of 15,000 lbs. per square inch, then the proportionate elongation is .0005 per unit of length, with a decrease in diameter of practically one-half or .00025, by no means a negligible quantity.

Finally vibrations and shocks have also been proven to affect the adhesion. The last would alone warrant the adoption of mechanical bond reinforcement for railroad structures. To the above reasons may be added the many chances of bars being disturbed in partially set concrete during construction. From the foregoing it would seem wise to adopt a style of reinforcement with a suitable mechanical bond.



Lowering the First Section for the Detroit River Tunnel.

General Dimensions.—The general dimensions for the described design were taken from the set of Standard Abutments of the National Transcontinental Railway Commission, which