

given further on, will enable our readers to form as accurate an opinion in regard to the disaster as present information will permit. The precise nature of its failure cannot, we believe, be yet traced, as many details, notably those in regard to the quality of the material used and the exact position of the train and the girders, together with the shape of the wreck of the latter, are not yet clearly revealed. The Tay Bridge crosses the Frith in a direction almost due north and south, and it may be well to state that it serves as a connection between Dundee, situated on the north side of the Tay and Edinburgh, which lies 35 miles to the south of the former city. The Tay Bridge was not, as many have appeared to believe, a link between Scotland and England, but afforded uninterrupted connection between Edinburgh and the north of Scotland, having superseded the ferry used until its completion between Broughty Ferry and Ferry Port, some miles east of the present site of the Tay Bridge. The train which was precipitated into the river on the 28th of December last had left Edinburgh on its way north at 4.15 p. m. It consisted of an engine and one first-class, one second-class and four third-class carriages and the brake van, and was precipitated into the Tay together with the thirteen large spans forming the centre portion of the bridge. Present developments leave no doubt that the structure did not succumb in consequence of a derailment of the train, but because the bridge was too weak to withstand the pressure of a high wind upon it and the train moving on it at the time. We may mention, in this connection, that a passenger on the train which had been the last to pass the bridge in safety, testified that he experienced a strange feeling of oscillation, which goes to show that even then the bridge was in danger, and that possibly it may have been weakened by the fracture of some portions even at that time. It appears from the record kept by Prof. Grant, at the University of Glasgow, that at the latter city the storm reached a velocity of 72 miles at or about the time when the disaster occurred, and the inference is that the storm blowing at Dundee had at least attained that velocity. Its direction was W. S. W., and therefore struck the bridge almost broadside. The death of every person on the train, and the lack of facts in the possession of those who saw the "shower of sparks," reduce the account of the accident to little more than nothing. On the days following the disaster parties of divers attempted to examine the wreck, but as their working hours were limited to the short period between two tides, and as the muddy nature of the water left them in utter darkness, the result of their groping is unsatisfactory. Their evidence is conflicting on many important points, and their explorations have not yet been sufficiently complete to enable a clear picture to be drawn of the present location and condition of the fallen structure. They have, however, succeeded in finding a portion of the train. The engine lies about 50 feet south of the fifth broken pier, counting from the south, a method of designating the various fallen piers which, we may add, is generally accepted in this case, and which we will follow in the following particulars. It is believed that the position of the three cars behind the engine is approximately known, while little more than traces of the others and the brake van have been found. How far east of the centre line they lie is not known, but present developments plainly prove that the bridge collapsed after the train had safely passed three piers, had partially gone by the fourth, and was approaching the fifth. It is a very significant fact that at this fifth pier was the junction of two groups of girders, and we shall have occasion in the following to refer again to this subject.

We may now pause to consider the condition of the wreck of the piers, an admirable description of which was published in a recent issue of *Engineering*. There seems to have been no connection between the portion of the bridge carried away and that standing except the rails and a gas-pipe hand-rail. The ends of the large girders rested on a kind of shelf on the ends of the shore span girders, and the former appears to have slipped off, partially injuring the shelf in falling. The guard rails at this north end project 9 feet, the end being curved toward the east, and a similar fact was noted at the south end. From the damage done to the standing pier at the north end it is evident that the diagonal bracing was that portion of the structure which first yielded to the strain, all but one of those in tension, by reason of the wind pressure from the west, being detached between the two 15-inch columns on the north face by the breaking of the cast-iron snugs to which their lower ends were attached. The fact that those between two adjacent 15-inch pillars were strained most, proves clearly that the two groups of three on each side of the centre line were strained in a different manner during the overturning of the structure. The three columns lying to the east of the centre line, on the lee side, were cracked and broken at the lower flange, and the

direction of the cracks abundantly shows the working of the columns. The west column on the windward side has not cracked, but the stones to which the base is bolted have been moving. The condition of the piers which carried the fallen spans is highly suggestive, but we are unable to follow our contemporary in its accurate description of each, and will confine ourselves to giving the details of some of the more important ones of the series. We may state that in general only a few stumps of the columns remain, and that everything points to the strong movement of the bridge to the eastern lee side. Pier No. 4, counting from the south, upon which, it will be remembered, at least a portion of the train was when it fell, is all right as regards the foundation plates, but it makes an exception, as portions of the six columns hang over to the west or windward side, thus indicating that this pier failed at some height above the masonry, the lower lengths of the columns being pushed over in the opposite direction to that in which the chief mass fell. Pier No. 5 is of much interest, as above was the juncture of two groups of spans, and it is significant that this, as well as No. 9, another pier upon which a juncture took place, is exceptionally injured. While in most of the piers the stonework and the foundation plates are still in place, the two stones are moved that were at the west or windward corner, being lifted and still attached to the column base, while all the other stones are still in place. This is more pronounced yet in the case of No. 9, where the western and south-western columns are lying canted over, with their bases and two upper courses of stones attached, so that the latter lie on their edges. The stonework of No. 11 pier has also suffered very considerable damage, the entire foundation plates of the western and the two south-western columns, together with the two upper courses of stone, having disappeared entirely.

The facts just presented throw sufficient light on the subject to make the choice between the various modes of failure suggested an easy matter. These are (1) that the train should have been partially overturned or caused to leave the rails by the force of the wind, and that in so doing it should have so injured the lee girders as to cause the destruction of the bridge; (2) that the girders should have failed laterally; (3) that the girders should have been canted over on their piers and in falling have destroyed the latter; and (4) that the failure should have been due to the insufficient resistance of the piers to lateral strain, the piers first giving way and the superstructure then going over bodily. All the evidence points to the latter as the probable mode in which the structure failed, and we shall, therefore, following *Engineering*, briefly point out the three principal ways in which a pier constructed as those of the Tay Bridge could fail under lateral pressure. These are (1) that it should turn over bodily on the base of one of the outer columns; (2) that the outer column on the lee side should yield by bending or crushing, thus enabling the pier to turn over on the bases of the adjoining pair of columns, and (3) that the bracing should fail, thus allowing the pier to turn on the bases of all the columns. These three modes of failure might of course be also partially combined, or the columns, instead of giving way at their bases, might fail at some point above that level. *Engineering* calculates that, depending solely upon the weight resting on the pieces in order to secure stability of the structure, then 33 lbs. of wind pressure per square foot would suffice to upset the bridge, taking the weight of the columns and bracing at 90 tons, that of a pair of girders at 190 tons, and that of the engine and such portion of the train as could be carried on the length of one span at 120 tons. Assuming that each of the columns was so bolted down that it could not be lifted without carrying with it 5 tons of stonework, then the wind pressure required to overbalance the stability would be 35 lbs. per square foot. The compressive strain upon the lee columns, assuming the second to be the mode of failure, and taking into account the masonry fastenings, would be 2.39 per square inch of each of the three columns, while they would probably give way under any wind pressure exceeding 23.5 pounds per square foot. In the most favorable case, therefore, 35.5 lbs. per square foot would overturn the bridge, and, as it did not succumb in the way assumed in reaching that figure, there is little doubt that the pressure must have been less. We know, from an examination of the wreck, that there is evidence of at least a partial failure of the bracing, but it is impossible to ascertain, in the absence of figures on the subject, just at what pressure it was liable to give way. The maximum which it was able to resist was 35 lbs., and it may be of interest to note what were the estimates of those connected with the building of the bridge. In 1872, Mr. Edgar Gilkes, in a paper read before the Cleveland Institution of Engineers, made the following statement:

"A consideration of the action of the wind on this bridge will dissipate the oft-advanced theory that at some period it will be