Mr. ZERAH COLBURN thought the Paper gave a very complete account of the construction of American Timber Bridges, but it hardly contained sufficient information to lead to a correct judgment as to the relative merits of timber and of iron. Timber had been almost exclusively used in the States, for railway bridges, chiefly because iron was beyond the means of the Railway Companies, and partly, no doubt, because its application was not so well understood. American Engineers had perhaps made a virtue of necessity, but Mr. Colburn thought there were but very few among them who would not prefer iron, or stone to the best timber bridges ever built. Whatever form of truss was employed, timber bridges were very perishable, and they were always liable to destruction by fire. The Report, for 1857, of the chief Engineer of the Pennsylvania Central Railroad, contained the following remarks:—

“The bridges have all undergone a thorough examination, and many of them found to be much decayed. This examination leads to the conclusion, that about nine years is as much as can be calculated upon for the duration of an uncovered wooden superstructure; and when the liability to fire and the expense of watching are taken into consideration, shows most conclusively that economy, as well as safety, is in favour of iron structures.”

The following classification of bridges was given by Mr. Post, formerly chief Engineer of the New York and Erie Railroad, one of the most important lines in the States, in his Report on that line for 1857:—

“**A** represents bridges of the first class on this, or any other railroad. Their superstructures, composed principally of white pine, white oak, and iron, have been constructed in the most substantial manner from the best materials, and remain in every way sound and in perfect condition. When first put together, the joints were thoroughly inlaid with white lead and oil paint, and as soon afterwards as the timber became perfectly seasoned, their external surfaces were well painted, the season checks cemented, and other exposed points protected, so that the timber is almost completely secured from the effects of the weather and preserved from premature decay. If kept properly painted, these bridges will, unquestionably, with very little other repair, perform their offices well, and with perfect safety, for twenty years, or more. **B** represents bridges of the second class on this road. They were built of inferior timber, with little, or no mechanical skill, and are, generally, of too slight proportions to be of long duration. The greater number of them have been supported with ‘bents’ from the beds of the streams, &c., or strengthened by other expedients. They may probably be made to last, from the time they were built, about fifteen years. **C** represents bridges of the third class on this road. They are built of inferior timber, but are generally of good workmanship. Their most general defect is the weakness of their lower chords, which were not made up with strength enough to resist the tensile strain to which they have been subjected. With but a single exception, these bridges have failed, so as to require supports beneath, or to be strengthened by applying additional thickness of timber to the chords. There have been already expended, for repairs on these bridges, from five to six and a

half dollars per lineal foot, and many of them require renewal this year. The average wear will not probably exceed ten years. **E** represents bridges of the fourth class, or trestle bridges. They cost, aside from their foundation masonry, about eight dollars per lineal foot for single track, and will give about six years' service with small repairs—say at an average cost of twenty-five cents per foot per annum. Many of these have already been renewed. **D** represents bridges of the fifth class, or stringer bridges. They cost, independent of their masonry, about five dollars per lineal foot, and will last altogether about eight years. Many of them have been renewed."

Mr. Colburn stated that the New York and Erie Railroad Company was then expending £9,000 yearly in the repairs of timber bridges, exclusive of costly renewals. As an instance of what these renewals sometimes were, might be mentioned the Cascade Bridge, a timber arch of 276 feet clear span over a ravine 185 feet deep. This bridge was put up in 1848, and cost £9,000. In 1860, from fears of the failure of the bridge, the line was diverted so as to cross the stream higher up, and on an embankment over a stone culvert. The cost of this deviation was £21,000. The bridge was taken down immediately afterwards, and many of the timbers were found to be in a rotten state. Indeed timber bridges were always rotting. In 1858 a short bridge broke down under a passenger train on the New York Central Railroad, and nine passengers were killed. It was found that some of the timbers were so decayed that a walking-stick could be pushed through them. In 1860 a bridge broke down on the Albany Northern Railroad, and a number of passengers were killed. In this case, too, the timbers were much decayed. A bridge broke down about the same time on the Great Falls and Conway Railroad, in New Hampshire, and some time previously a large railroad bridge fell near Easton, Pennsylvania. One of the railway papers, the 'American Railway Times,' had a leading article, stating that there were great numbers of railway bridges just as unsound as the Great Falls Bridge and the Albany Northern Bridge. The article stated, that the editor could name ten bridges which were likely to fall in a fortnight, twenty bridges which might come down any time within six months, and forty bridges which were not safe for more than a year. Mr. Colburn could not say whether any of these bridges had yet broken down, but he had just received a copy of the 'American Railway Times,' from which he read the following extract:—

"On Monday, December 1st, the Howe Truss Bridge over the West Fork of White Lick Creek, gave way while a freight train was passing, and a portion of the train fell with it, killing a brakeman, Isaac Pratt, and a stranger, who was standing on the east abutment. The bridge had been well protected from the weather, and the timbers were all sound. Every precaution had been taken to guard against such an accident."

In very many cases American bridges were built of unseasoned

timber, and they were not always painted. There was sometimes a deficiency of skill in the distribution of the material. The top and bottom chords, and also the diagonals, were often of the same scantling all the way through, even for large spans. Besides the decay of the timbers, the joints worked loose after a time, and in this way timber bridges finally became very shaky. Mr. Colburn believed this was the case with the very best forms of truss, and the inferior kinds began to go very soon. There was a large lattice bridge of nineteen spans of 153 feet each, and nearly 100 feet high, over the James River, at Richmond, Virginia. This was erected about the year 1835, and when Mr. Colburn was living in Richmond, eleven years ago, it was considered to be very weak, even for light trains crossing at a slow speed. Mr. Colburn was connected with locomotive works there, and the Railway Company objected to their heavy engines being taken over the bridge when they were being sent southwards. It was a rule, on most American railways, to cross long timber bridges at a slow speed, and on highway bridges there was almost always a notice, that a fine of five dollars would be imposed for driving a horse over faster than a walking pace.

Fires were very frequent among timber bridges. Mr. Colburn could mention a dozen within his own recollection. The White River Bridge across the Connecticut River, about twelve years ago,—the Coosa River Bridge on the Alabama and Tennessee Railroad, about eight years ago,—the Mohawk Bridge on the New York Central Railroad,—the Orwigsburg Bridge on the Reading Railroad,—the Salmon Falls Bridge on the Boston and Maine Railroad,—the Valley Creek Bridge on the Philadelphia and Columbia Railroad (the first bridge was built here in 1837, and the third was now standing on the same site),—the Lackawaxen Bridge on the New York and Erie Railroad,—the Conewago Bridge on the Lancaster and Harrisburgh Railroad (the first bridge was built here in 1837, and the fourth was now standing), besides bridges on the Pittsburgh, Fort Wayne, and Chicago Railroad, the railway bridge over the Middlesex Canal at Lowell, and others. A roadway bridge over the Schuylkill River, at Philadelphia, a single span of 340 feet, and one of the best examples of this class of construction, was also burnt.

All long bridges required watchmen, generally day and night. The Baltimore and Ohio Railroad paid £1,600 yearly for watching bridges. Large tubs of water were kept on the bridges, the water being saturated with salt, to prevent its freezing in winter. There were cases of incendiary fires. Many attempts had been made to burn the great bridge across the Mississippi River at Rock Island. The Michigan Central Railroad had several bridges burnt at one time. Since the beginning of the present

war many bridges, of course, had been destroyed, and chiefly by fire.

Mr. Colburn then gave the cost of a number of American timber bridges, as follows:—The Bedford Bridge, on the Cleveland and Pittsburgh Railroad, a Howe bridge with an arch, had a clear span of 243 feet, was for a single line, and was 20 feet high: it cost 30 dollars per foot. A single line, Howe span of 230 feet, without an arch, and 24 feet high in the truss, erected, in 1853, on the Rochester and Lockport (now part of the New York Central) Railroad, cost 35 dollars per foot. A Howe bridge without an arch, of 250 feet clear span, on the Washington county road, in Texas, cost 60 dollars per foot. An arched Howe bridge over the Connecticut River at Bellows Falls, having two spans, each 250 feet in the clear and 23 feet high, cost 35 dollars per foot. The bridge over the Mississippi River at Rock Island had five spans of 250 feet each, and three spans of 150 feet. The wider spans cost 52 dollars per foot; the spans being Howe's truss, with arches, and the timbers all planed. The Miami Bridge on the Ohio and Mississippi Railroad had six spans of McCallum's truss, each 210 feet, and cost 33 dollars per foot for a single line. The Delaware Bridge on the New York and Erie Railroad had two of McCallum's spans of 262 feet each, and cost 42 dollars per foot. The Susquehanna Bridge on the same line, with 188 feet spans, cost 35 dollars per foot. The Clinton Bridge on the Galena and Chicago Railroad had seven McCallum spans of 200 feet, and cost 28 dollars per foot.

Mr. C. H. GREGORY, V. P., considered that the remarks of Mr. Colburn tended to confirm the prices given by Mr. Mosse for the constructions described in the Paper. Of course the cost would vary according to the character of the work, the locality, and the convenience of transport of the timber. Mr. Mosse's opinion of the durability of these bridges was not inconsistent with what had just been stated; for the Paper no doubt alluded to bridges which had been well and carefully constructed: but when roughly executed, of inferior materials, such bridges could not be expected to be durable. The Paper would be a valuable addition to the records of the Institution, as affording instances of the most approved forms of timber bridges, derived from the large experience which had been gained in those parts of America where timber was readily obtained, and where other circumstances had led to its extensive employment on public works. Of course English Engineers preferred, if possible, using the most permanent materials; but there might be circumstances where a limited amount of capital, or a high rate of interest for money, might render it more economical to put up a cheap and temporary structure, to be renewed in a certain number of years. Any English

[1862-63. N.S.]

Y

Engineer who had travelled in America, would agree with the remark, that many of the timber-trussed bridges were not put together in a way to answer the description which had been given of the well-executed structures referred to in the Paper, and he would observe that a cheap and rough description of work was not limited to timber bridges, but that it extended to the permanent way of railways, in which it was no uncommon circumstance to find ballast entirely omitted in the first construction: and although there might be rules for limiting the speed of the trains in passing timber bridges, his own experience was that the general custom was to travel without checking the speed, even over timber bridges of very doubtful security.

He agreed that one great fault in the timber bridges used in America was their liability to destruction by fire. Numerous instances of such destruction had come to his knowledge when travelling in Canada and the Northern States of America; and although he had not seen many watchmen in charge of timber bridges, he had noticed the evidence of contemplated risk in the frequent presence of water-tanks near the bridges. This risk of fire was perhaps in America the most serious objection to the use of these large timber bridges; and it was difficult to estimate the evils which might arise, either through loss of life consequent on the destruction of a bridge by fire, or the unavoidable and serious interruption of traffic, after a bridge had been so destroyed. In 1857 he had examined and reported on the Grand Trunk Railway of Canada, where the bridges executed by the Company were all of a character as permanent as those of an English railway, but on the line between the Atlantic and the St. Lawrence, which had come into the Company's possession, the numerous large river bridges were almost invariably of one, or other of the forms which had been described; and having reference to all the circumstances of the case, to the increased facility in the introduction of iron, and to the fact that a large number of these bridges, however good in design, had not been executed with that care which was essential to make them safe structures, and considering also the great risk of fire during the hot and dry summers of that country, he had thought it his duty to recommend, in every case, the substitution of wrought-iron girder bridges, at the earliest possible period.

At the same time he thought Engineers were too apt to look upon structures of wrought-iron as being of an absolutely permanent character. There was always a deteriorating action going on in them to a greater, or less extent; and where box girders were used, or any structure not of the simplest form, and perfectly accessible for repair, and for protecting all parts, by paint, from atmospheric influences, this deteriorating action might, in a few years, reduce to a most temporary character, and even to a dan-

gerous condition, some bridges which were considered as being necessarily durable, because they were made of iron: and whilst many wrought-iron bridges were undoubtedly monuments of genius, ability, and courage, he thought the time would come when, if wrought-iron bridges were not looked upon as being 'pro tanto' as temporary as wooden ones, they would not be adopted by English Engineers, in some of their present forms, so generally as was now the case.

Mr. A. S. ORMSBY stated, that he had been informed by the President of the Richmond and Petersburg Railway, that the expense of the insurance of the bridges on that line, which were all of wood, amounted to 15 per cent. upon the cost of each bridge.

Mr. COCKBURN CURTIS observed, that when employed upon railways in Spain he had some opportunity of witnessing the great expense, annoyance, inconvenience, and interruption to the traffic, which arose from the employment of timber bridges and viaducts. To effect a saving of first cost, many of the bridges of the lines, in the central portion of Spain, had been constructed of timber. But the subsequent outlay for repairs and renewals certainly could not have been less than that stated by Mr. Zerah Colburn in reference to the American lines. Another drawback to their employment in Spain was their liability to be burnt in the pronunciamientos and insurrections, to which that country, unhappily, seemed chronically liable. While Mr. Curtis was in Spain the large bridge across the River Turia, near Valencia, had been so destroyed, and owing to the cost and danger of using timber, the leading lessees and empresarios of the main lines, in the central portion of Spain, had determined upon substituting iron girders for the original timber structures.

Mr. SHEILDS thought some additional information was required as to the details of construction. Every one dealing with framing, whether of wood, or iron, knew that the method of joining the separate pieces, or parts together was the most critical point to be considered in the design. He had known failures occur from a bolt, passing through two timbers, tearing a piece of its own width out of the end of the wood, and from other causes, while the middle part of the timber was generally secure. Some details as to these points would therefore be valuable to those who had to use framings of timber, or of iron and timber in combination, and he was rather disappointed at not finding them fully given in the Paper. The whole of the structures which had been described, appeared to have been designed upon the principle of diminishing the strain upon the top and bottom, by using framings of very great depth; and this principle seemed to be carried to such an extent as to make them top heavy, and he thought it was alto-

gether a form of construction which Engineers in this country would scarcely venture upon. The only other point was as to the cost. The first cost per lineal foot appeared to be from one-half to two-thirds of the cost of wrought-iron bridges in this country: and there was no doubt, looking at it in a commercial point of view, and even irrespective of the danger from fire and other such circumstances, that the balance of economy would be much in favour of iron structures, owing to the want of durability in the timber bridges, and the heavy outlay required for their maintenance.

Mr. A. GILES said, there was one point which had not been touched upon, viz., the difficulty of repairing wooden bridges of large span, on single lines, without stopping the traffic. In case of fire the stoppage of the traffic was inevitable. This was one of the principal objections to wooden bridges: another was the expense of watching. He had examined and reported on a line in Canada which had nearly 4 miles of wooden bridges, and which cost for watching above £2,000 a-year; yet even that was not always effectual. He had recommended the large spans to be reduced, wherever it was practicable, so that in case of accident or decay, the renewal of the bridge could be more easily executed.

Captain MOORSOM said, that after what had fallen from the previous speakers relative to wooden bridges in America, the journey to Plymouth ought to be regarded as wilful seeking of danger, on account of the numerous timber structures on the line; yet he had to go very frequently over it, and he had done so in safety for many years past: and going further on into Cornwall, such structures were even more numerous than in Devonshire, over which many thousands of passengers had passed in safety. He therefore thought the experience of these structures in England was not so generally adverse to them as appeared to be the case in America.

He exhibited a sketch, by one of his assistants, of a lattice bridge of 90 feet, or 100 feet span, which had been built under his direction between 1837 and 1840. On the Birmingham and Gloucester Railway he had erected at least a dozen of those bridges. Having left that line, and not being interested in the maintenance of it, he took no trouble to inquire about these bridges till the year 1854, when they had been at least fourteen, or fifteen years in use. He then wrote to the Resident Engineer to know what had been the cost of repairs, and the answer was that the Company had been at no expense, except that of repainting them from time to time. The timber in all those bridges had however been subjected to some preservative process. So far, therefore, as he might quote that experience, these bridges might be used with advantage in certain cases. This description

of bridge had been erected by him usually on common roads, where economy was necessary, as the traffic was but small, and also in localities where they might be dispensed with hereafter at the fancy of the landowner. He thought in such cases the timber lattice bridge might be adopted with advantage. Mr. Mallet had erected for him a large lattice bridge in 1847 at Thomastown, over the River Nore,¹ and he believed it was still standing, without objection having been made against it. He would therefore express his decided conviction, contrary to the opinion of those who had spoken of the destructibility of the American bridges, that if timber bridges, and especially lattice bridges, were properly constructed, as they had been in this country, they might be adopted in many cases with perfect safety, and with great advantage in point of economy. Captain Moorsom added that he had found one great advantage of the lattice bridge to consist in the facility for repairs, and that he should have no difficulty in repairing a lattice bridge with a single track, while the trains were passing, provided it was of the ordinary character.

Mr. MALLET said the Paper did not give any information, as to the particular sort and quality of timber used in these structures in America. Practical men knew that there were three important elements which chiefly determined the durability of any timber bridge;—the quality of the timber, the way in which it was put together, especially the extent to which the joints were water tight, and the climate to which it was exposed. He was rather surprised at the very short life assigned to American timber bridges by Mr. Colburn, whose facts were nevertheless, he did not doubt, worthy of full acceptance in point of accuracy. It must, however, be borne in mind, that the climate of North America tried timber very severely; in addition to which he suspected, that the timber used was probably unseasoned, and not in all cases of the best quality. Upon these points, and whether due regard had been paid to the exclusion of moisture lodging between the opposing surfaces, he should deem it very desirable to have further information. The large annual expense for repairs and the short durability mentioned, did not quite coincide with European experience of wooden bridges. In the east of Germany, for example, it was well known that there were many wooden bridges, whose durability had been so great, that they were now actually objects of antiquity. The original bridge of Schaffhausen had stood, he believed, for more than forty years, before it was burnt by the French. The Germans and the Swiss, however, employed excellent timber, and they well understood how to put it together. In the case of the River Nore Viaduct, on the Waterford and Kil-

¹ *Vide Minutes of Proceedings Inst. C.E., vol. xi., pp. 426-434.*

kenny Railway, alluded to by Captain Moorsom, Mr. Mallet's firm had been the contractors for the erection of that structure; the timber used was of admirable quality, the wales being pitch pine and the lattice bars choice crown memel. That viaduct was still standing, and was, he believed, sound, after being in use for fifteen years. He had passed over it last year, and it appeared to stand well. He had heard, however, that since Captain Moorsom had ceased to have charge of the line, piles and struts had been put in, forming a centre pier, and dividing the original long span of 200 feet into two spans of 100 feet each nearly. This appeared to him to be perfectly unnecessary—though it was only another example of a case that too frequently occurred, in which advice given by a second Engineer subsequent to the completion of a work by his predecessor, was based upon an assertion of original insufficiency.