beams; *m′ m′*, the horizontal rods connecting with the main ties; *h′ h′*, &c., the horizontal braces; *n n n n*, the cheeks or frame of the wheels and machinery, with the two great bolts marked *n′ n′*, by which the frame was principally connected; these bolts being passed also through the interior ends of the balance and working beams.

Sir JOHN RENNIE, *President*, remembered the late Mr. Rennie and Mr. Logan stating, that the principal part of the mechanical arrangements used at the Bell Rock light-house, were carried out by Mr. Francis Watt.* It was therefore very probable that Mr. Stevenson had a right to the merit of first adopting its use at the Bell Rock light-house. The discussions at the meetings were peculiarly advantageous for bringing forward and establishing points of this kind, and it was desirable that the real inventor, or the introducer of any useful implements should be clearly ascertained.

Mr. WALKER said that the crane upon this principle, which had been used at Granton Pier, and of which a model had been presented to the Institution by Mr. Howkins (Assoc. Inst. C.E.), † had been found extremely useful, and for the kind of duty it was intended to perform, it was preferable to any other sort of crane.

Mr. FAREY said he did not consider this kind of crane to have been a new invention, at the time of the building of the Bell Rock light-house. It was a modification of the derrick, commonly used by seamen for unloading ships, by their own tackle, the mast of the ship serving for the upright post, with a guy rope extended from the head of the mast to the upper end of the inclined boom, from which the tackle for raising the weight was to be suspended. It was not unusual to employ a purchase tackle for a guy rope, which could then be taken in or let out, so as to give the boom less or more inclination from the vertical, and thereby adapt the derrick for lifting a weight nearer to or farther from the mast. A similar plan was commonly used at stone quarries: the upright mast being very tall and stayed by chain rods, extended from the upper end of the mast to convenient attachments at the sides of the quarry, so as to permit the derrick to swing partly or entirely round beneath those stays; such derricks being fitted with barrels and wheelwork, were called derrick cranes, and had been in use for many years.

The cranes described in the paper which had been read, had the advantage of convenience, in being so readily extended to a greater distance than ordinary cranes; but it must not be overlooked, that

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* Vide Dr. Jamieson's 'Mechanical Dictionary' and 'The Surveyor, Engineer and Architect,' 1840, p. 139 (conducted by R. Mudie), for an account of the moveable beam crane and of Francis Watt's connexion with it.

† Minutes of Proceedings, 1844, vol. iii. p. 213.

the tendency of the load to break the crane was very greatly increased when it was made to reach out, so that the boom became much inclined from the vertical. That tendency increased more rapidly as the crane was made to reach out farther, and in consequence it could not be considered a safe kind of crane for common use, in building operations. The paper seemed to speak of it as liable to accidents, and the improvements suggested were only palliatives; they would give more strength in one part which might hitherto have been the weakest, but the liability to accident must always continue, if the crane was used with its full latitude of extension. Such cranes ought not to be tolerated, except on condition that the guy chain was only of such length as not to let out the boom to any lower inclination than an angle of 45 degrees at the very utmost, and there to detain it by the ends of the chain being permanently attached, and put it wholly out of the power of the workmen to make the crane extend any farther. The convenience of reaching a little farther, and a little farther still, would otherwise tempt them to do so, and render accidents inevitable; the crane should be proved for three times the weight it was intended to lift at the utmost, when the whole of the guy chain was let out and the crane reaching to its very farthest span. Under such conditions they would be safe and useful cranes, but then they would not be so light and moveable as those used in Scotland, and consequently not so convenient for temporary use in building works. Convenience which was only obtainable with danger of breaking down was not desirable.

The distressing accident at the Yarmouth bridge* was attributable to want of strength to meet an unusual contingency; even if the weld which actually gave way, had been sound, that bridge was very weak, and all the suspension bridges which had been yet erected were in his opinion too weak. They could not be considered to be permanent structures, like bridges of stone and cast iron, but more like wooden bridges in regard to their probable durability and need of reparation in course of years. Several had actually fallen, and the Menai bridge, which was of stronger proportions than many others, had required repeated repairs and additions.

Allusion had on a former evening been made to the strength of iron work used in steam engines, compared with cases of suspension bridges; if time had then permitted, he would have troubled the meeting with a few general observations, but as those observations applied to cranes they would be applicable to the present discussion. The experience acquired in the construction and use of steam en-

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* Vide p. 296.

engines, had brought the knowledge of the strength of iron work to a great degree of certainty, and by trial of the working of engines with the indicator, the strain to which the parts were subjected in ordinary and habitual working was known with precision. Comparing those strains with the force which, according to well authenticated experiments, would actually break the iron work, it was found, that the dimensions of the iron work must be such as would require full fifteen times the ordinary and habitual force of working to break the iron. Experience showed, that when from a desire to make light engines, or by increasing the pressure of the steam beyond the original intention, the ordinary working force became as much as one-tenth of what would actually break the iron work, accidents would occur, sooner or later, in engines so worked, and that they were not safe with more than one-fifteenth. The axletrees of carriages which had been proportioned by experience alone, without any attempt at calculation, show very similar results. Yet in applying iron work in buildings, where it was only subjected to a quiescent pressure of weight, it was common to make it bear one-fifth of the weight which would break the iron, and timber was loaded nearly in the same proportion of its absolute strength. In ordinary buildings which were considered quite safe from serious accidents, the proportion of one-fourth was considered sufficient, and a proportion of only one-sixth or one-seventh was considered to be a strong building. Hence there were two totally distinct proportions of strength to be provided, in the constructions which engineers had to direct, and each had been established by long experience; one for cases of resisting quiescent force, or pressure of mere weight; the other for cases of moving force, which was necessarily subject to shocks and concussions. Cranes and suspension bridges were a sort of intermediate class between the two; the slow motion wherewith the load was raised by cranes approximated towards quiescent pressure of weight, and suspension bridges had been assumed to be of the same character; but more consideration would show that cranes and suspension bridges should be considered as approximating more to the condition of moving machines, and that a greater proportion of strength should be given to them than had been hitherto done. Cranes were commonly warranted for lifting some specified weight, but when they were so tried, the rate of motion in lifting the weight was necessarily very slow, so that they could get through the trial very well; but suspension bridges, as experience showed, were liable to be put in motion by storms, and by crowds of passengers, so as to be occasionally tried severely with shocks and concussions, and then they were put under the condition of the moving parts of engines, as regarded a trial of the strength of the materials used in their construction.

Mr. Cottam believed, that the limits assigned by Mr. Farey were frequently exceeded in practice, at the risk of imminent danger to the buildings, where cast iron beams of such insufficient proportions were adopted. The rule which was generally still followed, in determining the dimensions of beams, was that of Tredgold, which was derived from the limit of the elastic force rather than from the breaking point. This was taken upon the assumption that a permanent alteration of form was a partial fracture, and hence it was by the power of a beam to resume its original position, on the load being removed, that the proper limit of strength could be determined. This view, and the dimensions assumed from it, might perhaps have been correct when cold blast iron was employed, but since the introduction of hot blast iron, it could not be received safely.

In the casting of hollow columns to support given weights for buildings, there appeared to be even less attention to proper dimensions, as the object seemed to be to make the metal as thin as possible, without ever imagining that a cross strain might be brought upon the column by the partial sinking of the building.

Mr. Cottam was of opinion, that in order to insure greater security in the construction of modern buildings, wrought iron should be more extensively used.

June 10, 1845.

Sir JOHN RENNIE, President, in the Chair.

No. 727. "Description of Stirling's Improved Air Engine." By James Stirling, M. Inst. C. E.

The principle upon which the movements of the air-engine depend, is the well known one in pneumatics, that air has its bulk or pressure increased when its temperature is raised, and diminished when its temperature is lowered. The means by which this principle is brought into action will be easily understood by reference to Plate XXIV.

Two strong air-tight vessels are connected with the opposite ends of a cylinder, in which a piston works in the usual manner. About four-fifths of the interior space in these vessels, is occupied by two similar air-tight vessels or plungers, which are suspended to the opposite extremities of a beam, and capable of being alternately moved up and down to the extent of the remaining fifth. By the motion of these interior vessels, which are filled with non-conducting substances,