2, 3, and 4, and the lower part of the slope of Fig. 5, the resistance to the action of the waves arises, almost altogether, from the weight of the stones, and therefore increases as the slope approaches the horizontal; but as the moving power, exercised by the particles of water, also increases, it is clear, that the stability of bulwarks so constructed depends altogether on the use of sufficiently large and heavy stones, such as those employed in Fig. 5. Hence, in Figs. 2, 3, and 4, the stones of the pitching not being sufficiently heavy, were partially displaced.

In Fig. 4, the destruction of the slope occasioned the fall of the wall, which rested on it; but in Figs. 2 and 3, where the pitching was not used to support the wall, but merely to protect the foundation, the wall suffered no injury in consequence of its removal.

In Fig. 2, where the pitching was laid on the natural level of the sand, the stones displaced, were deposited near their original site; but in Fig. 3, where the slope was comparatively steep, they rolled down with the receding oscillation.

The walls (Figs. 2 and 3) being vertical, or nearly so, approach the form of section which gives, at once, to the particles of water, the least amount of displacing power, and to the masonry the greatest amount of the resistance, arising from the pressure of the superincumbent materials, and the cohesion of cement and mortar; and they afford an illustration of the stability which may be attained with such a form of section, in a structure built of comparatively small stones.

Owing to the extremely small elevation of the wall (Fig. 2) above the surface of the water, it was necessary that the coping should be sufficiently massive to resist, by its weight alone, any force tending to displace it; but in Fig. 3 such a coping was not necessary, as the top of the wall was above the reach of the action of the waves.

The Author has endeavoured, in drawing general conclusions respecting the construction of sea walls, to avoid going beyond the limits warranted by the facts he has stated. His conclusions may be received with caution, or with dissent; but he trusts that the facts will be considered worth recording.

The Paper is illustrated by five diagrams, showing the section of the several sea walls described, and from which Plate 8 is compiled.

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Major-General Pasley referred to an opinion expressed by him at a meeting of the Institution in 1842,* when he stated, that from "his observations of the action of the sea upon various parts of the

* *Vide* Minutes of Proceedings, 1842, vol. ii., p. 130.

coast, he conceived, that a perpendicular wall, constructed of large ashlar work, well cemented, would assume the character of a rock, and all the prejudicial action of the receding wave would be avoided." The correctness of this opinion had been confirmed, in his mind, by the result of an examination he had made of a sea wall, built by Mr. Brunel, along a portion of the South Devon line, upon which he had reported, when he was Inspector-General of Railways. The wall to which he alluded was nearly vertical; it was so situated, that it was only exposed to any very violent action of the sea for about three days at a time, during spring tides, and then only when a heavy gale of wind blew at the same time. This however had once occurred, and it was then reported, that extensive damage had been done. He found, however, that although, at the part within the estuary of the Exe, a portion of the parapet had been destroyed, by a barge striking against it, the only serious damage which had occurred was to the earthwork withinside the wall, which had not been protected by masonry; the waves had been thrown over in such masses, as to plough up the earth and to wash it away. That portion of the sea wall which was constructed of ashlar work, was not injured at all; but a part which was constructed of dry stone masses, or boulders, of considerable weight, was entirely destroyed. The damage was soon repaired, by covering the earth slopes withinside the wall with stone pitching, and substituting good sound ashlar work for the dry-stone wall, and since that time no injury had been sustained. His previous opinion, in favour of vertical sea walls, was thus, he contended, fully confirmed.

Mr. Brunel confirmed General Pasley's account, of the extent of injury sustained by the sea walls on the South Devon line, on the occasion alluded to, and begged to renew his thanks for the assistance afforded him by the General, in refuting *ex parte* and unjust statements, which had been made at the time, and were calculated to produce prejudicial effects.

With respect to any comparison between vertical and sloping walls for sea defences, he must repeat his objections to drawing general conclusions from one class of evidence, or to laying down general rules to suit all cases. In this particular instance, upon the South Devon line, a nearly vertical wall was more applicable, from the position, the depth of the water, and the general circumstances. His intention had been to build the wall with a perfectly vertical face; a slight batter was however given to it; the coping, also, which projected from 2 feet to 2 feet 6 inches, was found effectually to turn the wave down again; the recess of 6 feet, or 8 feet, caused by setting back the parapet wall that distance from the face of the main wall, received the mass of the wave, and the high parapet finally prevented any considerable quantity of water from being projected over the wall. The principal injury had, therefore, been received by the slopes withinside the wall, and where no parapet was built, as within the estuary of the Exe, the waves had destroyed the slopes; but no other damage was done.

As it was always useful to give an account of even comparative failures, he would state, that with respect to that part of the work which was composed of dry-stone, it had been formed of blocks of a hard conglomerate, which were found in large quantities on the shore; the wall was about 25 feet high, by about 10 feet thick, and the blocks, when used, were only roughly shaped, so as to give them a kind of bed, that they might be laid together, without cement, like cyclopæan masonry. The whole had been destroyed, as General Pasley had described, while a wall built close beside it, of small ashlar masonry set in mortar, resisted perfectly the action of the same storm. Mr. Brunel ascribed the destruction of the dry-stone wall to the roughness of the surface, and the want of cement between the blocks, allowing the sea to enter and to dislocate and destroy the mass.

It was necessary to have pitching at the base of sea walls, in order to counteract the action of the receding waves, which was always powerful, where the water was only from 4 feet to 6 feet deep. On the southern coast he had constructed bulwarks in advance of the wall, to act as breakwaters, and as groynes, to collect the beach, in order to prevent the scour, which so frequently undermined and destroyed walls, whose foundations were even carried down to a considerable depth. A rock foundation would not always save them, for he had seen the surface completely rubbed away by the scour of the shingle, so as to render it necessary to underpin the wall, and to build an apron upon the rock, to prevent the recurrence of the same action.

Mr. Green said, that as a somewhat analogous instance, he might mention the Dymchurch wall, to which so much damage was done by the sea in the year 1803, that he was subsequently sent there, at the recommendation of the late Mr. Rennie, to carry out improvements in that extensive embankment, which protected from the sea a tract of not less than fifty thousand acres of marsh land, lying between the town of Hythe and the port of Rye. The wall, or embankment, was constructed entirely of earth; the face next the sea was defended by "Arming," which consisted of a facing of coppice wood, held down to the earthwork by oak stakes and laths, in a very ingenious manner; but the front of the embankment had been laid at slopes of different inclinations, and in very irregular longitudinal directions. In some parts, the front slope formed nearly an angle of 45° with the horizon, or at an inclination of one horizontal to one perpendicular, varying in other parts between that slope and three horizontal to one perpendicular. The top of the embankment was in many parts at least 30 feet wide, and 20 feet above the level of extraordinary spring tides, and a great portion of it formed the public road from Hythe to Dymchurch and New Romney. It was customary to make large depôts of brush and coppice wood, for the occasional repairs of the embankment, on the top of the more elevated and the widest parts of it; but occasionally, the force of the sea was so great, at those parts having the steepest slopes, that the waves broke over the top, and carried the large stacks, of two hundred waggon loads of coppice wood, from the top of the embankment down into the marshes behind it.

In executing the repairs and the reconstruction with which he was entrusted, Mr. Green's first object, was to make the line of the face of the embankment, as nearly as possible, that of the general line of the shore, and to remove all sudden projections into the sea; and secondly, to bring the front slope of the embankment to an uniform inclination of seven horizontal to one perpendicular, the top of the embankment being only 6 feet higher than the level of extraordinary spring tides. The general inclination of the beach on the shore, from high water downwards, was, in that part of the shore, about eight horizontal to one perpendicular; but the face of the slope was defended by the coppice-wood arming, as before, as the expense of facing it with stone would have been beyond the means of the proprietors of the lands.

The plan pursued was found to answer extremely well, as, in the greatest storms, the surge of the sea never reached the top of the embankment.

This and other experience, convinced him of the propriety of so forming sea embankments, as to offer the least possible resistance to the direct force of the sea. He had since successfully constructed many other sea embankments, on the same principle, and had been fully confirmed in his opinion.

Mr. Borthwick said, that in the year 1833, Mr. Walker reported upon the state of the Dymchurch wall, and recommended a general amendment of its condition, which, he believed, was partly carried into effect, by the construction of a sloping pitched bank, with a vertical wall at the top. Mr. Elliott's paper, which was read at the Institution in the session of 1847,* stated, that even that plan had been modified, and a general line had been adopted, with a pitched slope, at an average inclination of about eight horizontal to one perpendicular.

Mr. RENDEL knew the position where the walls described by Mr. Rankine were situated, as well as those on the coast of Devonshire, mentioned by General Pasley and Mr. Brunel. In his opinion there could be no comparison between the two cases. The former were situated in an estuary, sheltered by Inchkeith and the land of Fife, having, at the same time, a long shallow foreshore; whilst the latter were placed in exposed positions, with considerable depth of water, and heavy waves breaking upon them. A substantial wall, built of proper proportions, of good smooth-faced materials, with strong hydraulic lime, or cement, would stand well if it were nearly vertical, and a slope would also stand, if well packed with dry stones. The surface, however, must be such as to prevent the stones from offering such opposition to the waves, as to permit them to be loosened and torn up. In practice this was generally a question of relative cost, and in most cases a nearly vertical wall, well built in mortar, was found to be the cheapest.

The great difficulty was, to protect the toe of the wall, and to prevent it from being undermined; for even when the foundation was carried down to the rock, the beach, which had previously accumulated to a considerable depth, was not unfrequently carried away, and the surface of the rock was abraded to such an extent, by the travelling of the shingle, as to loosen the lower courses of the wall. In all such cases it was necessary, either to place a paved apron, or to construct groynes, for the purpose of collecting the shingle. The latter was perhaps the most effectual mode, if the litoral currents were well examined and taken advantage of, in settling the direction and position of the groynes. No conclusions, as to the best forms for breakwaters, could be deduced from examples of walls built like these, four-fifths up the shore. The cases were not in any degree similar, and it was necessary to be very careful not to assume any similarity of action, or of effect, between the long heavy deep waves, to which breakwaters were exposed, and the comparatively shallow and broken-up waves, to whose action the sea walls near Edinburgh were subjected.

Mr. SCOTT RUSSELL confirmed Mr. Rendel's view. The value of the arrangements shown in the sections, depended entirely upon the nature of the foreshore, the depth of the water, the length of

* *Vide* Minutes of Proceedings, 1847, vol. vi.

the reach for the sea to rise upon, and the direction of the exposure. It appeared to him, that the mass of masonry in the wall, (shown in Figs. 1 and 2, Plate 8) was so great, the depth of the water was so small, and it was comparatively so little exposed to the sea, that the form of the wall was of little importance, and the circumstance of its standing proved nothing. In the wall shown in Fig. 3, on the other hand, the perpendicular part was nothing more than a parapet, being protected by a sloping wall, up to the level of high water.

The thinness of the wall in Fig. 4, compared with that of Fig. 2, rendered any comparison uninstructive, as it was manifestly insufficient, and the foundation, which was only a loose rubble wall, was evidently inadequate; there was also a greater depth of water and more action of the waves, than in the case of the wall in Fig. 3.

The wall shown in Fig. 5 was precisely of the form to endanger the stability of the parapet; and it had given way, as might have been expected. It was similar to that on the Dublin and Kingstown Railway, of which a great part was thrown down by a storm, although it was built of large blocks of granite.

The general conclusions he was disposed to draw from the facts stated, and from similar instances which had come under his own observation, were, that a vertical wall, if it was composed of good masonry, united by strong hydraulic lime, or cement, not carried to a height exceeding 30 feet, and not exposed to the action of a heavy Atlantic swell; but protected by a long foreshore, or shallow water, would answer perfectly well, unless the foundation gave way. He might give as examples the quay walls of Liverpool, which were all built nearly vertical; they were also examples of excellent rubble work, which had resisted perfectly all the action to which they were subjected. In the case of exposure to a heavy breaching sea, or deep water, with large waves, it was necessary to begin to break the water as early as possible, and for this purpose a considerable slope would be found safer, and, eventually cheaper, especially with such materials as were, usually, most conveniently to be found for such purposes.

Mr. J. Thomson wished that Mr. Rendel had extended his observations, and had told them, for what positions he considered each kind of wall was best adapted; for although he thought, that the promulgation of any empirical rules must be prejudicial, yet there were conditions, under which certain forms of construction had been proved in practice to be bad, and it was very desirable to have such examples brought before the meetings.

Mr. Thomson thought, that the foundation, upon which the wall, or the slope, was to be placed, was a principal consideration; if it was hard and sound, a vertical wall would, under ordinary circumstances, and with proper precautions, most probably stand well; but if it was soft and liable to be washed away, a slope, with a long pitched foreshore, must be preferable.

The situation, also, must be considered. If a sea defence was required to be built on the beach, near low-water mark, where the half tide would set upon it, with all its destructive force, a vertical wall was not desirable, however well the same wall might succeed, if it were placed out of the direct influence of the half tide.

With respect to the material, Mr. Thomson had found, that coursed rubble formed an excellent durable vertical sea wall, if laid in strong hydraulic mortar, or any cement, so that a smooth face could be given to the masonry, affording no salient points for the power of the water to be exerted upon; and even in slopes, it was more desirable to attend to having close joints, and smooth-faced stones, than to selecting those of large dimensions.

Major-General Pasley thought, that the depth of the water against the foundation, should be considered, as, from the experience of the divers who operated, under his directions, upon the wreck of the Royal George, it appeared, that at certain depths, the water was comparatively still, when it was much agitated at the surface. It might be received as a rule, that the waves had little, or no force below the level of low water; and even at a depth of 6 feet below the tide level, he thought the force of the waves would be innocuous.

Mr. Rendel, V.P., said, it was well known, that at a depth of about 12 feet below low water-mark, there was no injurious action of the waves, however deep the action of the tidal current might be.

Mr. Bateman agreed, that the specific gravity of materials employed under water should be considered; yet he thought, that their structure and qualities were of more importance. Some stones became softened, others readily disintegrated, others were chipped away, or their surfaces were worn away, by the travelling over them of sand and shingle, and others again appeared to be worn down by the action of the water alone. These were all to be avoided for submarine constructions.

He had seen some sea walls built of basaltic rock, which possessed great strength and solidity, standing well at an inclination of three to one; but the most remarkable example he recollected, was that of the Loch Foyle embankment, the face of which was pitched with a clay slate stone. By the action of the waves, small laminated portions were carried off, and were forced, like wedges, into the interstices between the larger stones; the whole face by this means became so smooth, that not a crevice could be detected, and the waves rolled over the surface innocuously, having nothing to lay hold of in their passage. In fact, this material gave naturally, as perfect a surface as engineers endeavoured to obtain artificially, by laying large dressed blocks of stone, at a considerable expense.

Mr. MURRAY agreed with the preceding remarks, as to the abrasion of materials; it proceeded in some cases to such an extent, as to be a subject of serious consideration to the engineer. The faces of several glacis, or sea slopes, of four, or four-and-a-half to one, which he had constructed of hard limestone, had been so worn down and scooped out, by the action of the shingle when travelling over it, that constant repairs became necessary.

In the Harbour of Walker, there was a glacis faced with sandstone, full 3 feet in thickness. During the progress of the works, the small chippings of the stones formed a very sharp shingle, which being carried by the waves over the finished portion, wore it away, and injured it so extensively, that the sandstone pitching was obliged to be taken up and be replaced by whin-stone, and this, in spite of men being employed to clear the shingle from the surface of the glacis.

It was of the utmost importance to the duration of masonry, in such situations, that the action of the sand and shingle, under the influence of the tides and currents, should be carefully observed, as by the judicious erection of groynes, it was practicable to accumulate masses of sand, or shingle, which would act effectually as a protection for the works, or they might be made to deflect the travelling material into the deep water. This principle had been adopted with great success at the new harbour works at Sunderland, which he had mentioned on a previous occasion.*

The coasts of Holland exhibited many interesting examples of sea defences of various kinds. There the groynes were constructed of fascines, straw, and sand, and yet with these simple materials, which the Dutch Engineers had been compelled to use, from the absence, or great cost, of more durable substances, very effective structures were raised, which protected the coasts, and cost very little for repairs.†

Mr. RANKINE wished to explain, that he had not read Mr. Scott Russell's paper on Sea Walls,‡ before he had written the paper under

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* *Vide* Minutes of Proceedings, 1847, vol. vi.
† Ibid, ibid, vol. vi.
‡ Ibid, ibid, vol. vi.

discussion; if he had done so, he should have referred to some parts, which were confirmed by his observations on the walls described. He begged it to be understood, that in giving this description, he had not pretended to lay down universal rules for the construction of breakwaters in deep water, from effects that had been produced upon walls founded on the beach.

He concurred in the principle, that an engineer ought to be guided by circumstances, in designing works; but he conceived that cases sometimes occurred, where the locality permitted the engineer to create such circumstances as he required; for instance, at Cherbourg, the want of a natural beach, on which to found the vertical face of the seaward side of the breakwater, was supplied by the flat summit of a stone embankment; it however remained to be shown by experience, whether that artificial foreshore was sufficiently extensive for its purpose.

Mr. Rankine thought Mr. Scott Russell somewhat underrated the power of the waves against the vertical wall at Trinity (Fig. 3). The fact, that a fishing-boat had been thrown over, and had been lodged upon the road, which was 8 feet above the high-water level of spring tides, showed, that the waves had acted on it throughout its whole height, and the exposure had been still further increased at the points, where the pitching had been carried away. He also pointed out, that the vertical wall (Fig. 3) was not exposed to a less depth of water, than the curved wall (Fig. 4), but rather to a greater depth, and an increased action of the waves.

Mr. C. H. Smith said it appeared to him, that in almost all engineering works, the specific gravity, or weight of the stone, was of the utmost importance, especially for low buildings which were occasionally under sea water, and where there was, perhaps, a rapid current, or in other situations, subject to the influence of powerful waves; such circumstances would require a heavy quality of stone to be used, because the weight of all bodies, when submerged, was reduced by that of the bulk of water displaced. The lightest stone he had ever found, in masses sufficiently large for building purposes, weighed only 103 lbs. per cubic foot, and if this was used in sea water, its weight would be reduced about 66 lbs., which was the weight of a cubic foot of sea water, and therefore it would be like building on land, with a material weighing but 37 lbs. per cubic foot.

The heaviest building stones that he had met with, were the dark grey varieties of sandstone, from the vicinity of Swansea, from Abercarne, from the Forest of Dean, and from Dundee; some of these were even heavier than granite, weighing upwards of 170 lbs. per cubic foot, and in his opinion, they would be quite as durable.

There was also a remarkably heavy stone found in some of the western islands of Scotland, particularly in the island of Tiree; it was composed of carbonate of lime, with a large quantity of hornblende in small nodules. He conceived, that such stones were peculiarly adapted for the building of docks, harbours, breakwaters, sea embankments, and indeed for all purposes, where the violent action of water was to be contended against. In situations where the stone was constantly, or alternately under sea water, sandstone was preferable to limestone, because it was not so likely to be acted upon by the *Saxicava rugosa*, the *Pholas*, or any other boring molluscæ, which frequently pierced calcareous stones to the depth of several inches, thus changing a smooth face to an extremely rough one, and consequently, by increasing the friction, rendering the stones more likely to be disturbed by the action of the waves.

The sea walls, or embankments in the neighbourhood of Leith, were constructed with Craigleith stone, which was a very good material for many purposes; but he believed that some of the rocks in the neighbourhood of Dundee, would furnish a preferable kind of stone for such works, because the Dundee stone weighed from 25 lbs. to 30 lbs. per cubic foot, more than the Craigleith stone, and it could be procured in blocks of much greater size at the same cost.

Mr. J. R. M'Clean said, that the Barrow and Piel sea embankments, of the Furness Railway, which were each about one mile in length, were somewhat peculiar in construction. The situation was generally well sheltered; but during the equinoctial gales, the banks were exposed to a heavy sea. The embankments were formed of sand, faced with a thickness of 12 inches of clay puddle, into which a thickness of about 4 inches of broken stone was beaten, so as to form a clay concrete bed to receive the pitching, or stone facing, which was 12 inches in depth. The portion of the embankment, above the level of the equinoctial tides, was faced on each side with sods, 6 inches in thickness, cut from the "salting." The grass, although on a slope of one to one on the inner side, was very strong and luxuriant, and the parapet thus formed, afforded a complete shelter for the railway. The cost of the stone facing, including the puddle concrete, was 1*s*. 6*d*. per superficial yard, and that of the sodding was 3*d*. per superficial yard. This form of embankment was, in his opinion, better adapted to the situation, and was constructed at less cost than an upright wall would have been.

He agreed with the statement made by Mr. Green, that the greater the slope of the face of the embankment, the less would be the disturbance to the foreshore; and he thought, that the necessity for pitching, and putting down groynes to protect the foreshore, when an upright wall was built, proved, in a great degree, the correctness of this principle; more especially when the foreshore was composed of alluvial deposit, or other matter of a light description.

The Rev. the DEAN of WESTMINSTER directed the attention of Engineers, to the shape of the Cob Wall, which formed the extremity of the pier at Lyme Regis, Dorset. It was a nearly vertical wall, with a rounded end, built of Portland stone, and the stones were fastened together with oak dowels; it projected about a furlong into the sea, at a depth of 10 feet at low water, and was exposed to all the force of the Atlantic; but it was placed at such an angle to the run of the sea, that it appeared to divide the waves, deflecting one portion innocuously past, to expend itself, gradually, upon the beach, leaving still water within the port, and turning aside the other portion in such a manner, along the flank of the wall, that the body of water might interpose between the masonry and the succeeding wave, whose force was thus in a great degree expended before reaching the wall. Thus the greater the original wave, the greater was the resisting force of the mass of water, forming, as it were, a cushion for receiving the succeeding wave; and though the shingle beach had sometimes been driven in, during heavy gales, no injury had ever been done to the masonry of the wall.

There might be local, or engineering peculiarities in the construction of this pier, which had, perhaps, escaped the Reverend Dean; and he suggested, that it would form a good subject for a communication to the Institution.

Mr. WALKER agreed, in the impracticability of laying down abstract rules for the forms of construction of sea defences, suitable for all situations, when so much depended upon the local position, the force acting upon them, the direction of that force, and the quality and dimensions of the material of which the defences were constructed. The engineer must, in all cases, after considering the whole of the circumstances, combine his plan in accordance with scientific laws and practical experience, without attempting to fit an empirical formula to all cases, however dissimilar.

In many instances, nearly vertical walls cost less than long slopes, and this would be the case when the materials were expensive, from the distance they had to be conveyed. On the other hand, whenever the materials were close at hand, and so situated that an inexpensive kind of labour sufficed for placing them, long slopes would be least expensive.

Combinations of the two systems had frequently been proposed, as in the original design for the Plymouth Breakwater, which was, that it should be composed of rough hewn blocks, thrown down upon a base of 70 yards wide, in a depth of 5 fathoms, rising to a width of 10 yards on the top, at 10 feet above the level of low water of spring-tides, up to which point the materials were supposed to form a slope of about three to one, and above it a nearly vertical wall of hewn stone was to have been built. The action of the sea upon this work, in carrying a large quantity of the stones from the sea-ward slope, entirely over the breakwater, and lodging them on the beach, showed that the inclination should be increased; accordingly, slopes of three to one for the land-side, and of five to one for the sea-side, were adopted, and had been since adhered to in the subsequent works, a long foreshore being at the same time formed.

At the western extremity, a buttress of hewn stone, at a less inclination than the other parts, had been constructed, under the directions of Mr. Walker; great pains were taken with the construction, the whole being bonded vertically from the bottom to the top, as well as horizontally, by dovetailing the stones and crossing the joints in both directions, in order to render it nearly a monolythic mass. The result of this was, that it had perfectly resisted all the action of the sea for the last six, or seven, years, when considerable injury had been received by the other ports.

At Dover, the part of the works now executing for the commencement of the Harbour of Refuge, was a wall with an inclination of only one-third of a foot horizontal to one foot vertical, in order to enable vessels to load and unload alongside it, and the main body of the work would be only at a small slope.

At the Channel Islands, where fine materials were close at hand, but labour was expensive, a long slope was intended to be adopted, up to the level of low water, and then a nearly vertical wall.

At Harwich, all the defences were laid at a long slope, having respect to the cost of materials and labour.

Great discrepancy of opinion existed, as to the rising of seas against nearly vertical walls. From lengthened observation, Mr. Walker was induced to believe, that in very deep water, where the direction of the wall coincided with that of the prevailing wind, the waves would not rise high upon it; but when the face was at a right angle to the sea, it would strike heavily and rise high.

This subject had been recently treated very ably by Sir Howard Douglas,* and his arguments in favour of long slopes were based

* *Vide* Reports of the Commissioners on Harbours of Refuge, 1846.

upon sound scientific reasoning, and practical examples, which entitled them to much respect.

Mr. Walker must repeat, that in practice, engineers must not expect to apply, successfully, any general rules in all cases; but must act from the dictates of their own reason, and the experience of former works under similar circumstances.

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March 21, 1848.

JOSHUA FIELD, President, in the Chair.

No. 785.—"On Railway Junctions." By Arthur Beanlands, Assoc. Inst. C. E.

The present paper is intended to furnish an easy and correct method of setting out railway junctions.

The Author is not aware whether this subject has ever yet been reduced to any formal rule, or whether the following, which he has found, practically, to be an easy and correct method of setting out junction curves, &c., is altogether new. It is not, however, improbable that it may have presented itself to other persons, in the same light in which he now endeavours to exhibit it; if therefore, it is not new, he must beg to be acquitted of any intention of appropriating that credit which may be equally due to other parties.

Every one versed in railway engineering, is familiar with the ordinary system employed, to enable carriages to travel from one line of railway to another, on the same level, by means of points and crossings, with their appendages. It is unnecessary to enter into any description of these, farther than to remark that the switch rail, or point, is usually between 12 feet and 15 feet in length, and is separated from the main rail, at the fixed extremity, by an interval of about 2 inches, so as to allow the flanches of the wheels to pass in the cavity.

It is supposed that the main line of railway is straight; that the 'unction line is an uniform curve, *i.e.*, a portion of one and the same circle, inclusive of the points themselves, when applied to the main rail; that the switch rail is 14 feet long, $2\frac{1}{2}$ inches broad at the fixed extremity, and 2 inches apart from the main rail; also that the lead of the junction, or distance from the points to the furthest crossing, is previously fixed upon. If then, the radius of the curve be 260 feet, or about four chains, which corresponds to a lead of 90 feet on the narrow gauge, the offset from the tangent in 14 feet, is $4\frac{1}{2}$ inches, which is the same as that made by the switch rail, as