

Mr. PARKES said, that in order to reduce the time occupied in the reading of the Paper, it had been necessary to omit several matters of detail. It would be seen that in these designs some unusual features had been introduced, to meet the conditions to be fulfilled. The lighthouses, therefore, were not intended as examples applicable to other situations; at the same time, he thought no other existing system of lighthouse construction would have been suitable in these places. In reply to an inquiry, Mr. Parkes stated, that the cost of the lanterns was included in the sums mentioned in the Paper.

Mr. ALEXANDER GORDON was much gratified with the Paper, and with the recognition given to the services of the late Mr. C. W. Scott. Mr. Gordon had had the advantage of Mr. Scott's co-operation in some difficult undertakings, and he had always found him a man of first-rate ability, of great endurance, and of wonderful decision of character. Mr. Scott had previously experienced in the Bahamas, difficulties analogous to those met with in the Red Sea, and he was therefore well prepared to encounter them.

The essential and peculiar feature of the Red Sea Lighthouses was the foundation. How far dependence could be placed upon concrete made with Portland cement and sea water, it was difficult to say; and he might, probably, be excused for expressing a doubt as to the foundations of the Ushuffee and the Dædalus Lighthouses, by references to facts well known to Engineers in India, with respect to the parts of wooden structures between wind and water. The wooden piles must be closely looked to, for, judging from the experience gained in the East Indies, they would be liable to fail at the places where they came out from above the concrete. The superstructure of wrought-iron framing, reminded him of some features in the work of Mr. J. W. P. Lewis, at Cay West, on the Florida Reef. Having to contend with the same doubtful foundation, Mr. Lewis did not have recourse to timber, but he used iron screw-piles, and screwed them deeply into the débris of the coral rock. Upon that he built his structure in cast iron, diagonally braced with wrought iron, perfectly rigid and good, to even a greater height than 144 feet. All the upper work of the Ushuffee and the Dædalus was sound, and would be durable, no doubt, if kept well painted; but the uncertainty was, whether the wooden piles would stand. If some of them once got adrift, he should fear they would act upon the others, and eventually knock down the whole.

A comparison had been made between the vibration of the structure at the Ushuffee and the lighthouses upon which Mr. Scott was engaged in the Bahamas, under Mr. Gordon's directions. The Ushuffee Lighthouse was 144 feet high; but it should be borne in

mind, that the Lobos Cay Lighthouse, in the Old Bahama Channel, built upon a foundation of disintegrated, or broken coral rock, was higher. If the statement were correct (which he doubted) as to the relative vibration of the two lighthouses, that was in some measure to be accounted for, by the greater altitude of the Lobos Cay Lighthouse, and the hurricane climate in which it was placed. Again, the whole of the island of Lobos Cay was probably far less solid than the ground on which the Ushruffee Light stood; the former, consisting of only half an acre to an acre in extent, was continually shaken by the action of the sea, and every blow of the pile-driving machine in laying the foundation, vibrated over the entire island.

The cost of the two lighthouses was stated in the Paper to be £55,200; the total cost of that on Lobos Cay, which was 160 feet high instead of 144 feet, and was also lighted, like the former, by a fixed apparatus of the first order of Fresnel, was only £22,419; there was thus a considerable difference in favour of the Bahama structure in point of cost.

The cost for the illuminating and optical apparatus of the three Red Sea Lighthouses was about £6,000. Now about the same time that the Red Sea Lights were in progress, Mr. Gordon had sent out from this country an apparatus of the first order, to be put up, under the directions of Colonel Collyer, in the Malacca Channel, the cost of which was only £1,500.

It had been stated in the Paper, that the revolving cowls for the purposes of ventilation, had sometimes failed; but this could be accounted for. In many, indeed in most cases, the Trinity House allowance for the escape of heated and foul air at the top, was, for the first order of lights, only 70 square inches. Mr. Gordon, however, had never used less than 153 square inches, and the sponges were never required to wipe the dew from the interior of the glass; the atmosphere was always pleasant and good. He had put up these cowls in his lighthouses, which were mostly situated in tropical and hurricane climates, and he had never found any inconvenience from them. There had been cases of other cowls standing still, which had been caused by the neglect of the workmen, but no cowl with such a large passage as he used, had stood still in any gale of wind.

There was one other point to which he would refer. The illuminating apparatus, manufactured by Messrs Chance, was very exact and beautiful, but there was a much cheaper mode; instead of using cut plate-glass, which was necessarily thick and costly, to press up from steel moulds flint glass, or crystal. In this way there was a thinner substance for the light to pass through, and therefore, a clearer light, was obtained; as also a perfectly accurate beam, or an accurate azimuthal light, if such

was required. Colonel Collyer had informed him, that a light of that sort, which Mr. Gordon had sent out to Rachadah, in the Malacca Channel, had been perfectly successful. It was seen as far as, and he believed farther than, any of the Fresnel lights. He gave, however, full credit to M. Fresnel for cutting up the bull's-eye into steps, as Buffon and Brewster had proposed, in order to lessen the thickness of glass which obstructed the light; and in this new process, M. Degrand, of the Ponts et Chaussées, when assistant to M. Renaud, the head of the Lighthouse Department of France, had merely followed out the views of M. Fresnel. M. Degrand had perfectly succeeded in that arrangement; and Mr. Gordon thought that Lighthouse Engineers would, by adopting it, get refracted light at a much cheaper cost than hitherto.

A compliment had been paid by the Author of the Paper, to the "official energy" of the Government in the instance of the Red Sea Lights. So far as the statement of accounts went, the Board of Trade was perfect; but he could not give them the same credit for their interference in the matter of Lighthouse Engineering.

Mr. VIGNOLES inquired what description of wood was used for the piles. He was not sufficiently acquainted with the locality, to know how the action of the wind in a gale would affect the structure, or whether the worms would get to the wood: and he was desirous of having some explanation of the reason why wood had been preferred to iron.

Mr. PARKES replied that the piles were of the best Malabar teak, and in the position in which they were placed, they could not be affected by the worm, as they were above the level of high water. If the piles had not been of wood, the alternative would have been cast or wrought iron. The former was of doubtful duration when exposed to sea water. If there had been any real advantage in the use of cast iron, there would have been no fear in employing it; but there was a practical advantage in the use of timber. In the first place, the piles were cheaper, and there was greater facility in adjusting them to an exact level, because timber could be cut, where iron could only be chipped; moreover, from the buoyancy of timber, it was easier to get the piles from the ship to the spot where they were to be erected. He thought the only feature to be set against these advantages was the question of duration. Teak was, however, a very durable material, perhaps not so much so as cast iron, but even that was not perfectly durable. Another advantage was, that any one of the piles could, if necessary, be withdrawn, and another substituted for it without disturbing the superstructure.

In reply to a question, Mr. Parkes said, that the concrete which formed the base was made with salt water.

Mr. VIGNOLES suggested whether, granting the explanation to be satisfactory with regard to cast iron, a succession of wrought iron cylinders connected by flanges, would not have offered all the advantages the Author had assumed with respect to lightness and facility of transport, and have avoided the inconvenience of cast iron. He did not make these observations in a captious spirit, but as he was about to engage in similar erections himself, he was anxious to know the reasons which had induced the Author to carry out this particular plan.

Captain ARROW observed, that the building of these lighthouses was more an engineering subject than one coming under his own immediate knowledge, but he felt great interest in the Paper, and he thought that the difficulties of carrying on any work in such a climate were so great, that the element of cost could not be so closely considered as it might be in England. With regard to the lighting apparatus, it had been brought forward as an element in favour of the moulded lenses of M. Degrand, and the accuracy that was obtained from them, that they were more economical than the apparatus made in the usual way. But cheapness was not an element which could be admitted in optical science, for the best instrument more than repaid the additional money that was expended upon it. He had seen several of these lenses, and he had yet to learn that any kind of glass could be made which could bear comparison with the beautiful instruments manufactured by Messrs. Chance, Brothers. It was a credit to this country, that the manufacture of these instruments had been brought to such perfection, and that the monopoly should have been taken out of the hands of the French manufacturers. The optical skill, and the great energy displayed by Messrs. Chance, were beyond all praise; and the mathematical accuracy obtained was such as could only be properly appreciated by those who were intimately acquainted with the subject. He had had the pleasure of meeting M. Degrand as well as M. Renaud, the French Ingénieur-en-Chef, but he was not aware that either in France, or in this country, the moulded glass apparatus had been tried, except in lights of the smaller orders. The errors in those lights were not cured. The smaller the lights, the less would be the errors; but when the system was applied to one of the large lights, the errors, which were trifling in a small light, would then be exaggerated and become serious. Mr. Gordon, in speaking of the bull's-eye of a lantern as analogous, had hardly done justice to the subject. It certainly was a transmission of light through a thick surface, but instead of merely cutting steps in that surface, the refractors were a work of great mechanical skill, and produced a result which he believed the moulded system could never accurately attain. The attempt on the part of M. Degrand to

introduce economy was undoubtedly praiseworthy, but although he might be comparatively successful in minor lenses, Captain Arrow doubted whether his plan would fulfil the objects of the Trinity House, or compete with the perfect system now in use.

Mr. GORDON observed, that Degrand's system had not been exclusively confined to the smaller order of lights. The one at Rachadah, in the Malacca Channel, was a first-order light.

Mr. E. A. COWPER said, many years ago, his father had made some observations in a discussion upon the Maplin Sand Lighthouse, which was described as being liable to a reciprocating rotatory motion at the top of the tower, and he exhibited a small model, in which the diagonals could be introduced, or withdrawn. Those diagonals, which were not from the outside to the centre, but round the outside, were introduced into the lighthouse, and they at once made it rigid and firm. The Mucking Sand Lighthouse and that at Sea Reach were originally constructed without diagonals, but at his suggestion they were employed, as it was found that the top of the lighthouses would not resist a force tending to produce torsion, or rotation. It was a curious feature in the Ushuffee Lighthouse, that it had diagonal iron ties in every floor except the bottom one, where there were, certainly, two slanting struts of timber, but one only of these could fully come into action at once, and would then cause a side motion in the lighthouse. The Bishop Rock Lighthouse was constructed in the same manner, and it unfortunately gave way at the point where the diagonals were wanting. This had caused it to be assumed that iron was bad for the purpose, and a stone structure had been substituted at about double the cost. For his own part, he considered the introduction of a complete system of iron diagonals indispensable in all iron lighthouses constructed of pipes, or piles. In cast-iron lighthouses every plate formed a diagonal, and he believed that when they were of a reasonable thickness, and were well bolted together, they were far stronger than stone; and if the iron was occasionally payed over with tar, it would last a long time. The principle of iron lighthouses was the proper one for this country to adopt. There were many places where, it was well known, a lighthouse was urgently required, and had not been erected solely on account of the cost; now the expense of iron lighthouses was less than one-half that of stone; he hoped, therefore, that the Trinity House would order the erection, in that material, of more of these safeguards of navigation.

Mr. BOWER, of the firm of G. Forrester and Co., the manufacturers of the Red Sea Lighthouses, said, that as the Author of the Paper was frequently present during the operation of erection on their premises, he was quite capable of replying to any inquiries. So far as the diagonals were concerned, they were specially con-

sidered with reference to the twisting motion, and he believed the system was carefully carried out from the top to the bottom, with that special view.

Admiral Sir EDWARD BELCHER remarked, with reference to the teredo, that it had been assumed it only worked under and at the surface of the water; but every one who had been in Africa, and other tropical climates, where mangrove was cut for firewood, knew that the attacks of the teredo extended as much as 9 feet up the trunk of the tree. On the River Guyaquil, the worm passed through the banks to the surface of the soil which was traversed by salt water only during high tide. But wooden piles were also subject to the ravages of the white ant, or termites, which had often been found on off-lying islands in the South Eastern Archipelago, but especially in Africa. In the year 1831, he had witnessed the sudden fall of a 32-pounder gun at a fort on the Barra side, opposite the town of Gambia. On entering the battery the carriage seemed to be perfect; it was newly painted, and was apparently firm. He had occasion to stand on the hinder truck to obtain a clear view, when the whole carriage crumbled, leaving just about the proportional remains of wood as would agree with the cellular divisions of the honeycomb, and he was unable to find any portion which would afford a clue to the nature of the wood of which it had been constructed. The Governor informed him that it was of iron-wood, which was harder than African oak. Between, therefore, the termites and the teredo navalis, he much feared that the wooden piles of the Red Sea Lighthouses would not endure long. It was desirable to be informed whether, before deccoration, they had been injected by any of the mercurial, zinc, or other preparations.

Mr. DOUGLASS inquired the height of the waves in the Red Sea, observing that at the Bishop Rock he had seen waves of 40 feet go over the platform.

Mr. FLEEMING JENKIN inquired, what was the mean temperature in the lighthouses, and how far the arrangements for keeping down the temperature had answered.

Mr. J. H. PORTER said, the Author had explained the facility with which a defective pile might be unshipped, but to his mind it was not satisfactory that the superstructure should stand within, instead of upon, the piles. There might be sufficient resistance to the shearing strain upon the supports of the bottom frame, but he thought the general aspect of the structure was, in this respect, hardly satisfactory. With regard to the diagonal bracing constituting its main support, he was not sure that Mr. Cowper's remarks had been quite understood. The diagram exhibited did not show clearly what diagonals were carried round the exterior of the structure. He recollected a discussion at the Institution of Me-

chanical Engineers¹ on the subject of lighthouses of a similar character to these, in the course of which allusion was made to a lighthouse 150 feet in height, which he had constructed for the Spanish Government; and on that occasion, Mr. Cowper made some interesting remarks upon the importance of diagonals round the structure. It was, in his opinion, an important element in resisting any tendency to torsion.

Mr. PARKES said, that the waves at some distance within the edges of the reefs were completely broken. Close to the lighthouses they were trifling, and there was nothing more than a little wash over the platform. The depth of water over the reefs at high tide did not exceed 4 feet for 100 yards from the lighthouses, in any direction. There was no comparison, as regarded the force of the sea, between these structures and those erected by Mr. Douglass on the English coast.

Mr. G. W. HEMANS remarked that the Paper gave an interesting account of an engineering work of considerable difficulty, which had been surmounted with great ingenuity. The work being at a distance, and as he had never seen the ground, or any similar locality, he felt some hesitation in offering criticism upon it. Still he could not but regret, that a work of so permanent a character as the iron structure should have been established upon a foundation which was obviously of a temporary and perishable character; nor had he as yet heard any adequate explanation of the reasons for putting an iron structure of that importance upon wooden legs. In the meantime, it seemed to him that a simple remedy might be suggested for what appeared an incomplete arrangement. He thought that having regard to the slots for wedges in the tops of the wooden piles, which allowed the entrance of water, the attachments of the iron framework to the pile heads, particularly where they were subject to alternations of heat and to the spray of the waves, ought to have caps to protect them from rain water, and that instead of shearing pins, the collar should be secured by through bolts. He would further suggest, as it was certain that sooner, or later, the wooden piles, though of teak, must decay, it would be easy to encircle them with boiler plates riveted and built in cylinders round the piles. If these were $\frac{1}{4}$ th of an inch thick and 4 feet diameter, they might be built to the top of the piles. Then the space between the pile and the plates might be made up with concrete of the best description and carried up flush to the frame of iron-work above, and the whole surmounted by an iron cap. He believed that the whole of the work for each pile would not cost more than about £60. The structure would then stand upon eighteen solid columns of concrete equal to rock, sur-

¹ Institution of Mechanical Engineers. Proceedings, 1861, pp. 15-29.

rounded with a casing of wrought iron, and an inside bearing of teak. By this means the external appearance of the structure would not be damaged, whilst it would be greatly improved as to durability. He was not aware whether it was generally known, that the new Westminster Bridge rested upon foundations similar in character. The solid stone piers which carried the iron arches, rested upon the tops of wooden piles which stood a considerable height above the bed of the river. Those piles were within cases composed of cast iron and granite slabs, and around the piles and filling up the sides of the casing, there was a solid bed of concrete as good as rock. Fault had been found with that construction during its progress, but he believed that mode was perfectly satisfactory, and that in future, the same plan would most probably be carried out, under similar circumstances, for works in the bed of a river at low water. The Red Sea Lighthouses might be made satisfactory in all respects by the adoption of a similar expedient.

Mr. J. G. COCKBURN CURTIS said, it was now so many years since he was in a vessel navigating the Red Sea, and the Paper seemed to him so clearly drawn up, that he should not have done more than have expressed his thanks to the Author, as an old sailor glad to see lighthouses established wherever danger existed, and as a Member of the Institution, glad that an able and minute record had been given of the execution of works under peculiarly difficult circumstances. But some remarks were made in the course of the discussion which, it appeared to him, must have arisen from a misappreciation of the peculiar circumstances of the sites upon which these lighthouses were erected; and as it might be possible that the nautical difficulties of the undertaking and the different local characteristics of the Red Sea coral reefs might not have been delineated with sufficient clearness, he would offer a few observations on those points.

This appeared to be a case in which the nautical difficulties of the undertaking were peculiar. He would pass over the lighthouse on Zafarana Point, which did not present any nautical difficulties, and come to that on the Ushruffee Reef. This reef, as the Author had correctly described, was situated on the western side of the navigable channel of the Straits of Jubal, 150 miles from Suez. It formed a portion of a series of reefs, and was possibly the most dangerous part of the navigation. The Ushruffee was a coral reef of which the sides sloped irregularly, from the level of a few inches under low water to a depth of from 8 fathoms to 10 fathoms, no part being above the water, and there being very little sand, even in the cavities of the coral. To this he must add, that there was indifferent anchorage, and that the north-west swell broke with great violence on the reef. There was a range of tide of about 5 feet, and at times a rapid current, and the channels

were so dangerous and intricate that, in the year 1831, the Indian ship 'Samarang,' while passing to the southward, was wrecked in one of them, even with a fair wind.

The next reef was the *Dædalus*. This was correctly stated as being situated in the middle of the Red Sea, 350 miles from Suez, and 180 miles from the entrance to the Gulf of Suez. It was 45 miles from the western shore, 55 miles from the eastern shore, and 45 miles from the nearest soundings: therefore it was quite impossible for any vessel to obtain anchorage near that reef. Soundings had been taken to the depth of 260 fathoms alongside it without reaching the bottom. The sand bank in the centre, according to the best authenticated statements, was periodically washed away when the sea rose and the wind blew strong. There were no harbours and no towns along the coast, and fresh water could only be obtained by distillation. If an ordinary sailing vessel were to hook on to the reef, she would be in great danger of getting foul of it, if the wind changed, or grew light. It would be a difficult matter even for a steamer to hook on to it, and when standing off and on, so soon as the light was low, the vessel would be under the necessity of regaining the reef by the compass bearing, which was, to say the least of it, a very nice operation in a locality where there were uncertain currents of as much as 1, or $1\frac{1}{2}$ knot per hour. Looking at the peculiar difficulties of the case, he thought the Author had good reason to speak in terms of the highest praise of the manner in which what might be termed the nautical part of the undertaking, had been carried out by Captain Kirton.

With regard to the objections which had been urged, as to the mode of obtaining the foundation for the superstructures, few persons who had not had an opportunity of minutely examining coral reefs, could understand the difficulty which was presented to the view of an Engineer by the peculiarly brittle structure of a coral reef;—a structure which varied in the case of almost every individual reef, the slightest force being sometimes sufficient to crush down, or break off a piece of the coral. In looking at all the circumstances, the course pursued by the Author, that of building the structures on the surface of the reef and not sinking into it, he considered to have been the wisest; as also that of keeping the weight of the superstructure as light as possible. As regarded the employment of concrete, he saw no objections to its use; and structures which he had seen on coral reefs gave no reason to suppose, that the plan adopted would be unsuccessful. Two alternatives had been suggested in the course of the discussion, those of wrought iron and cast iron. He should be sorry to attempt to put down screw piles into the coral reefs of the Red Sea, for fear that they might give way during the process of sinking,

or at the still more dangerous time when the superstructure was erected. The known liability of wrought iron to oxidation, when exposed to the action of salt water, was a serious objection. He would much rather have a pile where it was exposed, and where he could see the deficiency, than have wrought iron beneath a coral reef where he could not discover the defects. As regarded cast iron, he thought there was not sufficient experience to warrant the use of it in such a situation. It must be remembered, that cast iron there came into contact with the salt water, though it was covered over with concrete; when placed upon the tongue, there was a perceptible saline taste in the specimens of concrete exhibited upon the table; so that the question to his mind was, whether it was advisable to have a pile lasting certainly for ten years, or whether an uncertain material should be used, which, possibly, might last for twenty years. It should not be forgotten, that if there was any damage in this case, it was all in sight and could be at once seen, and be easily repaired and remedied. A valuable suggestion had been made, that the pile-work might be built in solid, or a ring of iron placed round it, if any deficiency occurred; he thought, however, that for at least ten years, no deficiency would occur. An objection had been taken to the want of diagonal bracings, and it was stated that the Bishop Rock Lighthouse failed from a similar deficiency. But that objection only afforded another illustration of the necessity in all engineering matters and comparisons of attending to the locus in quo. The Bishop Rock Lighthouse was exposed to the full force of the Atlantic waves, whereas the lighthouses now under consideration, had half a mile of reef extending from the lighthouse in the direction of the prevailing strongest wind, and the force of the sea was completely broken at some distance within the edge of the reef. In the case of the Bishop Rock Lighthouse, there was a rise and fall of tide of 12 feet; but what was the condition of this lighthouse with regard to the effect of the waves? The strong wind was from the north-west; there was half a mile of coral reef interposed between this lighthouse and the force of the waves; yet it had been argued that this structure was in danger of being knocked down by them. It would be at once seen, that the cases of the Bishop Rock and the Ushrufee and the Dædalus were widely different.

Another point involving the nautical question was that of the cost, and he ventured to offer a few remarks upon that in deference to the observations of Mr. Gordon, who was, undoubtedly, a great authority on lighthouses. A comparison had been made of the relative cost of the Lobos Cay Lighthouse and those erected by the Author; but there seemed to him to be but little analogy between the two cases. The Lobos Cay Light was only 160 miles from Nassau, the basis of operations for building that lighthouse, where

[1863-64. N.S.]

a sailing-vessel,—not a steamer,—could have been chartered to bring the materials to the Cay at the cheapest rate. The Cay being 3 feet above the level of high water, and the rise and fall of the tide only 3 feet with 4 fathoms close alongside, there was every facility for landing the materials, and making the Cay itself available for storing materials; whereas, in the present case, from the strong winds and currents, a sailing-vessel could not have been used, and no steamer could have been chartered nearer than Bombay; and when the steamer, which was evidently too small for the purpose, was employed, it must be remembered that in the case of the Ushruffee Lighthouse, the basis of operations was an island, $1\frac{1}{2}$ mile from the site, and that boating operations were necessary, involving at least a loss of a quarter of a day on each day's work. He thought that it was very desirable to have a correct comparison of the circumstances under which these lighthouses were built, and of the cost, and for that purpose he suggested, that the Author and Mr. Gordon should give the actual engineering cost of each construction, separately from that of carrying the materials.

Colonel COLLYER said, that two years ago, he had put up in the Straits Settlement on Cape Rachadah, a light which had been designed by Mr. Gordon, and that the cost of the lighting apparatus and lantern was only £1,500. It was a first-class great sea light, with four concentric wicks, and the refracting portions of the glass were made by M. Fresnel. He received a report a short time since from the Governor of the Straits Settlement, which stated, that it showed a clear, steady light at 28 nautical miles, the height being 374 feet above the sea. If it showed a light 28 miles in one direction, it would do so in another; and for £6,000, the cost of the three Red Sea Lights, four lights might be obtained, illuminating 224 miles, instead of three lights at the same elevation illuminating only 170 miles. He thought, therefore, so far as the lighting apparatus was concerned, that the light which Mr. Gordon had constructed was cheaper than those put up in the Red Sea.

Colonel SMITH remarked, that he was well acquainted with the circumstances of the contract just alluded to, and was therefore able to confirm the statements which had been made by Colonel Collyer.

Captain MAURY said, with reference to the efficiency of the lights, that he apprehended it was in some measure dependent upon meteorological conditions. He imagined a good light ought to be seen as far as the tangent of the earth's surface would allow, and the intensity of the light required to be seen at that distance varied in different latitudes; so that although a light which had been described as being sent through a particular

kind of pressed glass, might answer very well in tropical, or in other latitudes where the atmosphere was seldom thick, or muggy, yet in other parts of the world where the state of the atmosphere was different, he thought lights of greater intensity, such as Fresnel's best, would be required.

With regard to the Dædalus Lighthouse, it was stated to be situated in the centre of a shoal, which suddenly rose up from the bottom of the Red Sea to the surface, and upon which the sea broke before reaching the structure. Now any one who had cruised among the coral islands of the Pacific, must have been struck with the effect of those so called natural breakwaters, the coral reefs. In illustration of this, he might mention the Society Islands,—Tahiti, for instance,—which was surrounded by a coral reef not quite reaching to the surface, but always a little below ; and it was marvellous to see the rough sea foaming and tossing outside the reef with nothing visible to make the smooth water inside. He had been in parts of that ocean in rough weather, and he had on one occasion, in order to obtain shelter, found it necessary to place the boat on the top of a wave, and so let her jump from a stormy sea into perfectly smooth water. There could not be a better protection to a foundation than was afforded by these reefs forming, as they did, the most perfect breakwater.

Mr. H. GRISSELL disapproved entirely of the design for these lighthouses. He had constructed many lighthouses, and if he had been consulted in regard to those for the Red Sea, he should not have placed them upon wooden legs.

As regarded the difficulty of transport, he did not see that it was greater in this case, than in many others. He was engaged at the present time in constructing a lighthouse upon the Calf Rock, in the Atlantic, off Bantry Bay, 6 miles distant from any land that could be made use of. The stormy character of the Atlantic was well known, and such was the nature of the water round the rock, that there were only about two months in the course of the year, when materials could be safely landed ; yet he had recently constructed upon that rock a lighthouse, 80 feet high, in one month. Very frequently no boat could live near the rock, and several times it became necessary to convey food by means of indiarubber bags to the men who had remained upon the site. The men were now taken off every night, however fine the weather might be, as it was quite uncertain when the opportunity might again occur ; indeed, for weeks together it was not possible for a boat to approach the rock nearer than a quarter of a mile ; but by perseverance, and taking advantage of each opportunity, the work was effected this year, for one month's continued tolerable weather had been sufficient to erect a tower upon Mr. Gordon's system. With regard to cost, he thought he should have

been glad to have contracted with the Government at two-thirds the cost of these, and to have supplied the light for less than £1,300; the whole work ought, in his opinion, not to have cost, for a cast-iron tower, more than £10,000 or £12,000. He also thought it would have been better to have carried up a granite base for about 10 feet, in order to keep the iron work well out of the water; the cast-iron superstructure would then have stood perfectly well. The lighthouse upon the Calf Rock, to which he had referred, had stood through all the late gales, though it was only in an incomplete state. The rock was 70 feet above water, and the focal plane of the light was 150 feet above the level of the sea, yet the sea went over it, and his men had stated that sometimes they could not see the rock for an hour together. That might perhaps be a little exaggeration, but he was quite sure that, in very heavy gales, it was often not seen for a quarter of an hour at a time.

Mr. VIGNOLES said, with regard to the foundations of these lighthouses, he did not approve of wooden supports, but perhaps the Author might be able to give sufficient reasons for their adoption in preference to any other mode, for there might possibly have been many difficult circumstances to contend with. He was desirous of knowing, in the first place, why iron was not employed; and next, if there were reasons for rejecting cast iron, why wrought iron was not used. If the substratum was as good as had been represented, was it not practicable to carry up the structure to the height of 15 or 20 feet, in stone or granite? It was entirely in the province of the Engineer to appreciate the circumstances under which it would be most advisable to employ either iron, wood, or stone. It was not, in his opinion, of much consequence whether one lighthouse was 20 feet or 30 feet higher than another, the great expense being in the foundations. Although the cost of these works appeared to be high, it must be remembered that they were executed in a tropical climate, and that in all such cases the expense was double or treble what it would be in England. He doubted whether a comparison could be fairly made with, even the west coast of, Ireland, because in the one case all the necessary appliances and assistance were at hand, while in the other they could only be obtained with difficulty and delay.

Mr. GORDON was desirous of learning what amount of the labour employed in the Red Sea was the forced or slave labour of Egypt. As to the floating of the piles, from his experience he could state, that nearly one half of the teak piles he had used, when shod, would not float. He believed that hollow iron piles might have been employed which would have floated.

Mr. PARKES, in reply, said that a doubt had been expressed as to the durability of Portland cement concrete; but for his

own part, he thought experience was in favour of its being not only a durable, but a constantly-improving material. It was well known that, generally speaking, Portland cement concrete, made fifteen or twenty years ago, was now as good as, or even better than, when it was first put down; and he saw no reason why the concrete employed in these works should not stand equally well. Of the two specimens of concrete on the table, the inferior piece was from the *Dædalus*; and the other, which must be admitted to be of excellent quality, was from the *Ushruffee*. He had stated in his Paper, that he was disappointed in the result of the concrete at the *Dædalus* Lighthouse, and that he could not account for the partial failure of it. Until that lighthouse was visited, twelve months after the concrete was deposited, he had some expectation that it would be necessary to put some protection to it; but it was then found, that although where a piece was cut out of the interior, it was not as solid as it should be, yet there was a hard external crust formed upon it, sufficient to resist the little wash of the waves; he had every hope, therefore, that it was a sound structure so far as the concrete was concerned.

The specimen before alluded to showed how a block of concrete might be hard on the outside and yet be imperfect in the interior; in this particular case, however, the hard crust was a sufficient protection. It was to be observed that, from the form of the block of concrete, which was of little height and of large area, it would be easy to renew any portions that might prove to be imperfect. The concrete was formed of three and a half measures of triturated coral to one measure of cement. The coral sand was found on the reef. The specimen from the *Ushruffee* was, he believed, as good concrete as could be made under the circumstances; though, if he had had the facilities for mixing it in the most approved manner afforded in ordinary situations, it would, no doubt, have been better. The materials themselves were good, but the mixture was not so complete as if it had been made in a pug mill. The proportions were six measures of gravel, including pebbles and sand, to one measure of cement, turned over with shovels by sailors and native labourers, who had never done that kind of work before.

His reasons for adopting wooden piles were given in the Paper, with many other matters of detail. In making use of timber, he did not do so on the ground that iron was entirely inapplicable. He thought iron might have been used, but in balancing the advantages of the two materials, he decided upon wood. He might mention that the original design of these lighthouses was submitted to Linant Bey, an Engineer of great experience in Egypt, and the Director of the Government Department of Public Works. His first remark was "Why do you use

wooden piles?" Mr. Parkes explained his views generally, and little more was said at that time on the subject. After his return to England, Mr. Parkes received a letter from the Consul-General in Egypt, stating that Linant Bey had again spoken about the wooden piles. Linant Bey had not then the drawings before him, and might not have borne in mind the way in which the wood was to be applied. Mr. Parkes wrote to the Consul-General explaining his reasons for the employment of wood, and the letter was translated and sent to his Excellency, who entirely agreed with the Author. Mr. Parkes could not but think, that some of the Members who had in the discussion expressed what he must admit were natural *primâ facie* objections to the use of timber would, like Linant Bey, find them disappear on more mature consideration of the exceptional circumstances of the case.

The reasons which induced him to use wooden piles were mainly these:—Cast iron was liable to deterioration in salt water. That deterioration might take place very slowly, but he questioned whether the cause of the deterioration could be clearly explained, or how it could be prevented. He believed, that the iron was chemically extracted by the salt from the body of the casting, and the plumbago was left behind; that seemed the ultimate result. There were several structures which had stood for many years in salt water and were likely to stand many years more, yet there were others which had failed. At the best, cast iron was therefore a doubtful material. An objection had been taken to the employment of wood on a ground which had, on the contrary, always afforded him a strong argument in its favour; that wooden piles would decay between wind and water, at the point where they came out of the concrete. Now he looked upon that fact as an element of safety in timber. So long as a pile remained sound at that point, it was certain that the buried part was sound. If it showed symptoms of decay at that point, it then became a question whether it should be replaced by a new wooden pile, whether it should be replaced by iron, or whether the whole system of piles should be abandoned altogether, and a circular wall built up all round so as to make a solid base. But if cast iron was used, there would be no such certainty that the first decay would take place in an accessible part. That point which was the critical point in timber might be perfectly sound in iron, while the buried part might be rotten. The teak piles would remain sound for many years; they made a very firm substratum; he could not detect the slightest vibration in them, when a high wind was blowing; and they did not seem to have the slightest tendency to loosen themselves in the concrete.

In answer to a question from Mr. Vignoles, Mr. Parkes replied,

that there were about 10 feet clear between the concrete and the under side of the collars.

In an earlier part of the discussion he had brought forward in favour of timber, the argument of its buoyancy. He did not say that was in itself a sufficient reason, but it was a greater reason in this particular locality than it would be in almost any other. It was a fact, that at the time the piles of the Dædalus Lighthouse were in course of erection, every pair of hands employed on the operation was costing upwards of £4 per day. A fully-equipped steamer, which was costing about £1,200 a month, had to be maintained, and the greatest number of men that could be employed on the work at a time, was twelve. When men were costing at the rate of £4 per day each, it was some reason for working them to the greatest possible advantage; it would be easily understood how great was the advantage in discharging the materials from the ship, when she was rolling heavily; if the most bulky parts could be thrown overboard and towed on shore, instead of waiting hours, or perhaps days, till the sea was quiet enough to admit of their being lowered by slow-acting tackle into a small lighter alongside. If he had to renew the foundation by putting in fresh piles of wood, or of iron, or by building in masonry, or by casing the piles upon some such system as Mr. Hemans had suggested, the workmen would be quartered in the lighthouse itself, at a cost of from 10 shillings to 15 shillings per day instead of £4; so that even if the wooden piles were looked upon as a merely temporary expedient, there would be good reason for employing them. But he could not look upon the employment of teak as a merely temporary expedient, for it was acknowledged to be a most durable material,—in such a situation almost imperishable. In India teak ships, two hundred years old, were afloat, and the timbers in them were as sound as when they were first put in. In constructions in that country, if protected from the peculiar influences of the white ant on land and the worm at sea, teak would last an incalculable time. He hoped these piles would last for a considerable time; cast iron might perhaps last longer, but it was not of a nature sufficiently durable to justify its being used in place of teak, which had such other strong arguments in its favour. With regard to wrought iron, he did not think pipes of $\frac{1}{2}$ an inch thick, looking at the effect of salt water upon them, would be more durable than the wooden piles. That was his reason for at once rejecting wrought iron; he did not think it could last longer than teak, and unless made very thick, it was quite as objectionable as cast iron, from its liability to corrosion. Some interesting information had been given relative to the habits of the *teredo navalis* and of the white ant. These facts deserved the attention of Engineers, but he could not conceive that they afforded any ground for the fear, that those

insects could establish themselves to an injurious extent in the piles of either of the lighthouses in question.

With respect to the diagonal bracing, he had felt great anxiety about the possible motion to which attention had been directed. Many structures had stood for a great number of years without any precaution being taken against that twisting motion, and it was difficult to see how it could arise. In the case of the Maplin Sand Lighthouse there was a good reason for it, from the fact of there being a ladder on one side and none on the other side, and when the sea struck that ladder, a twisting motion was necessarily established. In a structure like the Ushruffee, he thought there was danger of a rotatory motion, simply from the imperfection of the workmanship. If one side of the lighthouse was not as strong as the other, it would yield more to the wind, and set up a rotatory motion, which if it once started, would tend to increase rather than diminish; and he had no doubt, acting as it would upon the weakest joints, it would, in time, destroy the whole structure. In order to guard against that, he had introduced, in each alternate side of the polygon, some diagonal braces, and he expected that would be sufficient to check the first attempt of the structure to rotate. That it was sufficient for the purpose, he thought he could give some proof. When the structure was being put up at Messrs. Forrester's yard, at Liverpool, and was raised five tiers high,—it was not placed upon the piles, but the ironwork rested directly upon the ground,—Messrs. Forrester wrote to him to state that it was so shaky that the men refused to go upon it, its want of rigidity being attributed to its not being riveted. The contractors suggested that it should be put up in two heights, but to this the Author objected, being desirous to test its steadiness when standing at its full height, as he was quite sure if it was not steady in the yard, it would not be so on the reef. Up to this time the diagonal braces, though part of the design, had not been put in. They were afterwards put in and bolted up, and the next report he received from the contractors a week later was, that the lighthouse had been raised four tiers higher, and was very steady. That satisfied him that there was then no fear of rotating. After it was raised to the full height, and the diagonals were in place, though the joints were merely bolted, there was, under a strong breeze, a sensible trembling at the top, but nothing approaching to a rotatory motion. The only way in which such a motion could be detected was when a man was drilling holes in the iron at the top; that motion caused it to twist to a slight extent; but only in the top tier in which the corrugated iron was not filled in. It had been remarked, that the diagonals were carried throughout the ironwork, but that in the tier of timber piles there were only two, of which only one could act at a time. He conceived it was a matter of indifference whether six diagonals were put in six

separate sides of the polygon, or whether one, six times as strong, was put on one side of the polygon. All that was wanted was sufficient resistance, at any point in any side of the polygon in the direction of that side. The direction of the diagonals was so arranged, that they would act as struts against the direct pressure of the wind, when in the quarter from which it blew most strongly. The failure of the first lighthouse erected on the Bishop Rock had been alluded to, and that failure had been attributed to the want of diagonals. He believed that there was no evidence whatever to justify any such conclusion as a matter of fact; it was mere supposition, probable or improbable; still he quite agreed as to the necessity of guarding against a tendency to twisting, and he believed he had done so sufficiently in the case of the Ushruffee.

A remark had been made, that the line of the support was not continuous from the ironwork to the piles, and it was suggested that it seemed as though there would be a shearing action between the one and the other. He could not himself see how the structure could yield by that shearing action, because there was immense strength in the collars, and he thought it impossible in a structure like this, to have brought the bearing of the ironwork directly upon the head of the pile. It might have been capped as had been suggested, but it was impossible to bring the bearing upon the top of the pile, because some allowance must be made for the adjustment of the level of the piles, and in some places there was as much as 6 inches difference of level in the surface of the reef at the feet of two piles, and it was necessary to have the means of adjustment to that extent. That was done by the collar on the head of the pile being moved up, or down, and then secured by wedges and screws.

He had been asked whether the arrangements for mitigating the great heat in the structure had been successful. He was sorry to say his reply to that question must be an indirect one, but he thought not the less satisfactory. He wrote to Captain Kirton some time ago with the view of getting information on this subject to lay before the Institution: he was able to state, that the European lighthouse keepers who went to Suez for relief expressed themselves satisfied in that respect; and if Europeans in so hot a climate had thus expressed themselves with regard to iron lighthouses, he thought the arrangements made for protecting them from heat must have been, on the whole, successful.¹

¹ By subsequent information it appears that the *Dædalus* is a very favourite station with the men. During the summer of 1863 there was not a day's illness amongst the three, and they were not inconvenienced by the heat. Thermometrical observations were kept, but they have not been received from the Egyptian Government.—W. P.

With regard to the cost of the lighthouses, he observed that, owing to their peculiar position, and to Suez being the nearest base of operations, it was necessary to employ a steamer at great expense, and he might add, that the control of the steamer was not in his own hands ; consequently, although he was sure that the Peninsular and Oriental Company did all they could to forward the work, and to do it economically, yet every one knew that the way to have work done economically, was not to allow a portion to be independent of the control of the Engineer. Under those circumstances he believed the steamer cost more than it otherwise would, if it had been entirely under his own orders. He had little control over the nautical arrangements, and he had none whatever over the accounts. He could not enter into particulars, but he might say that nearly one half the amount charged for the steamer was in no way productive to the undertaking. He therefore thought the fair way of treating this matter would be, to deduct from the gross charge of the undertaking the cost of the Peninsular and Oriental Company's steamer, and of some Egyptian Government steamers, which made a few casual voyages. The total expense so incurred, which was due to the remote and peculiar position of these lighthouses, was about £23,000, and if this was deducted from the total sum of £55,000, there would be left for the structures, as engineering works, £32,000 : that was to say, £32,000 would have been the cost, supposing that, instead of the materials having to be carried 150 miles and 350 miles from Suez respectively, and the work attended upon by a steamer, it had been possible to have erected them upon reefs, at the same distance from the mainland of Suez that the reefs were from the island of Ushruffee in the one case, and from the ship in the other. It was impossible to separate the two lighthouses, but as nearly as he could state, he thought the cost of the Ushruffee might have been £22,000, and that of the *Dædalus* £10,000. It was only just to the undertaking to remark, that the Ushruffee was the first of the kind that had been erected, and there were undoubtedly many little extravagances which on another occasion he should be able to correct. No doubt £22,000 was a large sum for it, and he thought the same kind of work might hereafter be executed in a similar place for £2,000 or £3,000 less.

He begged to repeat that he had not brought forward this communication with any intention of making comparisons between his works and those of others. He claimed no superiority for his own, and distinctly repudiated the idea that the principle of construction he had adopted was applicable to situations with which he was not acquainted. A comparison in the matter of cost had, however, been made between the Ushruffee and the Lobos Cay Lighthouses, and a conclusion had been drawn favourable to the

latter. He thought the following view of the comparison would be fairer:—There were several points of similarity between the two structures. Each was constructed in England, each erected in an utterly desert unproductive region which had to be attended by a specially-employed vessel. The arrangements for each were connected with those for another lighthouse, the *Dædalus* in the Red Sea, the *Great Isaacs* in the Bahamas. Their heights were not very different, the *Lobos Cay* being 150 feet above ground, the *Ushruffee* 140 feet above water; the difference between the respective extreme heights 158 feet above the heads of the piles and 144 feet, arising from the fact, that the foundation of the one was deep, of the other broad, two ways of obtaining the same end on ground somewhat similar in general character but requiring different treatment. Moreover, both structures were erected under the same Resident Engineer. Now for the points of difference:—The *Lobos Cay* materials were despatched direct to the island on which they were to be erected, and were put up on dry land within a few yards of the workmen's quarters. The *Ushruffee* materials were sent to Alexandria, about the same distance from England as *Lobos Cay*, they had then to be transported 240 miles by railway to Suez, then reshipped for the island on which the working establishment was formed, then taken piecemeal by boat one mile and a half across a stormy channel to a detached and submerged reef, and there erected in the water. Both working establishments had to be attended by ship, but special and unfavourable circumstances made this a very expensive requirement in the Red Sea; in the Bahamas it was comparatively trifling. The official return gave £24,000¹ as the total cost of the *Lobos Cay*, out of which half of £2,400, or £1,200, was for the attendant sailing-vessel, leaving £22,800 as the net cost of the structure, including all expenses except sea attendance, while the cost of the *Ushruffee*, with the same exception, was £22,000, or rather less than that of the *Lobos Cay*. If to the difference due to building in the water on an isolated reef $1\frac{1}{2}$ mile from shore instead of on dry land, be added the fact that the *Ushruffee* was the first of its class, the *Lobos Cay* an example of a stereotyped design, he thought he might claim the *Ushruffee* as the more economical work of the two. Still he was not prepared to say that he would have advised such a structure on the *Lobos Cay Reef*. He believed each structure was well adapted for its own position, and the difference of cost, so far as it depended on the constructive features, and on whichever side the small advantage might remain, was not a material item in the question.

¹ Mr. Gordon gives £22,419 as the total cost, but this does not include engineering charges, which are included in the returned cost of the Red Sea Lighthouses.—W. P.

It had been asked what proportion of the work was done by slave labour? None, so far as it was under his own control. The Egyptian workmen employed were furnished by the Government, and were paid by the Resident Engineer at rates varying from 1s. 6d. to 2s. per day. At first they were impressed into the service in the ordinary manner of the country, but latterly volunteers were engaged.
