J H Barnes Esqr
with the Author's compliments

THE

GREAT BASSES LIGHTHOUSE, CEYLON.

BY

WILLIAM DOUGLASS, M. Inst. C.E.

WITH AN ABSTRACT OF THE DISCUSSION UPON THE PAPER.

EDITED BY

JAMES FORREST, Assoc. Inst. C.E.,
Secretary.

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THE INSTITUTION OF CIVIL ENGINEERS.

March 3, 1874.

THOMAS E. HARRISON, President,
In the Chair.

THE following candidates were balloted for and duly elected:—ALFRED WALTER BRIND, ARTHUR HARMAN M[c]DONALD, and JAMES ALKIN PASKIN, as Members; ROBERT BALLARD, OSWALD BROWN, Stud. Inst. C.E., THOMAS DUERDIN, Stud. Inst. C.E., MALCOLM GRAHAM, Stud. Inst. C.E., GEORGE GATTON MELHUISH HARDINGHAM, Stud. Inst. C.E., Lieut.-Col. CHARLES SCROPE HUTCHINSON, R.E., SAMUEL HUBBARD JAMES, HUGO LEUPOLD, MICHAEL LONGRIDGE, FRANCIS BLAYNEY MACLARAN, JOHN COOMBE SEARLE, Stud. Inst. C.E., CHARLES WOODLEY WHITAKER, and ARTHUR WOODS, as Associates.

It was announced that the Council, acting under the provisions of Sect. III., Cl. 7, of the Bye-Laws, had transferred JOSEPH GORDON and JOSEPH TOMLINSON, jun., from the Class of Associate to that of Member.

Also, that the following Candidates, having been duly recommended, had been admitted by the Council, under the provisions of Sect. IV. of the Bye-Laws, as Students of the Institution:—JOHN EDWARD CATTON, WILLIAM PATRICK CHURCHWARD, HAMPDEN HENRY HELY, WILLIAM HENRY JONES, WILLIAM GIBBS KERLE, JOSIAH EDWARD PAUL, and WILLIAM POLE, jun.

No. 1,394.—"The Great Basses Lighthouse, Ceylon." By WILLIAM DOUGLASS, M. Inst. C.E.

IN consequence of the vast increase in the shipping, especially steamers, passing the south-east coast of Ceylon, the subject of lighthouses, for marking its outlying dangers, received for many years the consideration of the colonial authorities. As early as November 1826 an examination was made of the south and east coasts of the island by the late Sir J. J. Gordon Bremer, when in command of Her Majesty's ship 'Tamar,' and the late Captain W. F. Dawson, of the Royal Engineers, for the purpose of ascertaining the most eligible positions for lighthouses or beacons.

The result was a recommendation that lighthouses should be erected on Dondra Head, and on Flagstaff Point, Trincomalie, and a beacon on the Great Basses; and that a light-vessel should be moored near the Little Basses. (Plate 19.)

In 1853 a survey was made of the Great and Little Basses by Rear-Admiral Sir W. H. Hall, K.C.B., who recommended the erection of a lighthouse on the Great Basses, and the mooring of a light-vessel near the Little Basses. Admiral Pellew, then Commander-in-Chief at Trincomalie, in a report to the Secretary of the Admiralty, dated May 16th, 1853, stated that "There are now about ten large steamers monthly touching at Galle, all of which have to pass the Basses, and mostly during the night; and if left unlighted, some serious accident may be expected to occur." These recommendations were afterwards confirmed by the late Admiral Sir Francis Beaufort (Hydrographer to the Admiralty), who suggested the immediate construction of the lighthouse on the Great Basses, but considered that the placing of a light-vessel, to mark the Little Basses, might be suspended, until the lighthouse on the Great Basses was in progress. The most eligible anchorage for such a vessel should then, he said, be carefully sought, and the extent and nature of the reef closely examined, as possibly it might be found to afford a spot sufficiently wide and stable to support a tower.

On the 16th of July, 1855, the late Mr. Alexander Gordon, M. Inst. C.E., was instructed by the Board of Trade to prepare and submit plans and estimates for a lighthouse on the Great Basses, and to consider the relative expense and advantages of stone and iron as materials for constructing the same. The design submitted and recommended by Mr. Gordon is shown on Plate 20. It was a cylindrical cast-iron tower, secured within an enlarged basement of masonry or brickwork. The basement was inclosed within an outer casing of cast iron 2 inches thick, and both the tower and the casing were sunk into the rock. The basement was to be 30 feet in height above the rock. The brickwork inside the cast-iron casing was to be set in bitumen, worked hot, and bonded to the outer shell. In order to prevent salt water remaining in contact with the cast-iron shell at its junction with the rock, it was proposed to provide an outer inclosing ring or plinth, about 2 feet high, leaving an annular space about 1 foot wide between the plinth and the casing of the basement, which space was to be filled with heated Trinidad pitch, mixed with sand and small gravel. As each course of plates of the basement and portion of tower within it was laid and bolted together, the interior was to be filled up to the same level by large Ceylon bricks, 12 inches by 6 inches by 4 inches, set and jointed solid in Trinidad pitch, mixed with an equal quantity of sharp sand, and applied hot. The inside and outside of the ironwork were to be well "paid" over with the same, and the space between the iron and the brickwork was to be carefully run-in at every course of bricks with the same hot bituminous mixture. Accommodation for the light-keepers was to be provided in and upon the basement, the plateau of which could be covered at pleasure by an awning. The cast-iron shaft, 12 feet in diameter, built of plates 1 inch thick, and lined with thin wrought iron, secured to the internal flanges, was to be surmounted by a lantern and apparatus for a revolving catoptric light at an elevation of 120 feet above high-water. The illuminating apparatus, consisting of eighteen paraboloidal 'Gordon' reflectors, each 21 inches in diameter, was arranged in six faces of three reflectors to each face, thus giving six beams of light to the circle. The total cost of the work, including the necessary station on shore, was estimated at £15,673 15*s.*, and it was considered that the work could be completed, and the light exhibited, in about eighteen months.

An alternative plan, with the basement constructed of pick-dressed granite, was ultimately determined on by the Board of Trade, which occasioned an increase of £4,000 in the estimate. Mr. Gordon thought that the work, thus modified, would be completed within six years. It was resolved to employ a steamer in lieu of sailing-vessels, as previously intended. A revised estimate, embodying these additions, and amounting to £33,946, was submitted and finally approved.

On the 20th of March, 1856, the late Mr. W. W. Poingdestre, Assoc. Inst. C.E., having been appointed Resident Engineer, left England for Ceylon, to carry on the operations. In the meantime the granite base, iron tower, lantern, and illuminating apparatus were prepared in England and despatched to Galle, where they were landed and stored. After three years only a few landings at the rock had been effected, and nothing had been accomplished beyond the erection of a beacon-mast, 60 feet high, surmounted by a ball, and the marking-out of the site of the proposed lighthouse. It was found, in fact, that the difficulties had not been fully appreciated before the work was commenced, and consequently the arrangements for meeting them proved insufficient. According to Parliamentary Paper No. 491, session 1863, page 138, about £40,000 had been expended, and it was estimated that £20,000 per annum for five years would still be required to complete the lighthouse. The authorities, unwilling to enter into so large an expenditure upon what seemed, from past experience, a doubtful chance of success, suffered the work to lie in abeyance.

Various schemes were subsequently submitted to the Board of Trade for the erection of a lighthouse on the Great Basses, of which one, apparently the most deserving of consideration, was from Colonel Fraser, R.E., C.B., who had previously erected the lighthouse on the Alguada Reef, in the Bay of Bengal, under circumstances of great difficulty. Colonel Fraser proposed to erect a granite structure, having a base $15\frac{1}{2}$ feet high, with its bottom course 33 feet in diameter, and on this base to place the granite pedestal of Mr. Gordon's lighthouse, which was in turn to be surmounted by a granite tower, $74\frac{1}{2}$ feet high. Colonel Fraser's estimate for the work, exclusive of the lantern, of the illuminating apparatus, and of the value of the materials already provided for the original structure, then lying at Galle, was £53,914.

In June 1867 the whole question as to the practicability, probable cost, and reasonable chance of success of the erection of a lighthouse on the Great Basses, together with the various proposals for its construction, was referred to the Elder Brethren of the Trinity House, and the result was the design by their Engineer, Mr. J. N. Douglass, M. Inst. C.E., shown on Plate 21.

This design was for a granite structure, in which the base of the 'Gordon' lighthouse, the only portion of the original work which could be made available, was proposed to be utilised, as previously suggested by Colonel Fraser. The plan further included a lantern and dioptric revolving apparatus of the first order, also a light-vessel, to be moored off the rock, for exhibiting a red revolving light regularly every night, from the commencement to the completion of the work, and to serve as a barrack for the executive engineer and staff. The total estimated cost of the work was £64,661.

A double advantage was anticipated from the barrack lightship: the working party would be accommodated, and the Government would be enabled at once to collect a toll for the light, instead of waiting for the completion of the tower. The Board of Trade, having approved the design, and having requested the Trinity House to undertake the execution of the work, the necessary funds were voted by Parliament, and the work was immediately proceeded with. The Author, who was then building the Wolf Rock lighthouse, was appointed Executive Engineer. Two iron twin-screw steam vessels, and the light-vessel, all specially designed for the work, together with the granite tower, internal fittings and lantern, and the dioptric illuminating apparatus, were put in hand, the contracts for the several works being taken by various firms as follows, viz.:— Iron steam vessels, Messrs. T. B. Seath and Co., Glasgow; light-vessel and floating barrack, Messrs. Fletcher, Son, and Fearnall, Limehouse; illuminating apparatus for this vessel, Messrs. Wilkins and Co., Long Acre; granite tower, Messrs. Shearer, Smith, and Co., Dalbeattie, Scotland; lantern and internal fittings of tower, Messrs. Deville and Co., London; dioptric illuminating apparatus, Messrs. Chance, Brothers, and Co., Birmingham. The present lighthouse consists of a cylindrical base, 30 feet in height and 32 feet in diameter, on which is placed a tower, 67 feet 5 inches in height, 23 feet in diameter at the base, and 17 feet in diameter at the springing of the curve of the cavetto. The thickness of the wall at the base of the tower is 5 feet, and at the top 2 feet. The accommodation within consists of six circular rooms, each 13 feet in diameter. There is also a room in the base 12 feet in diameter for coals and water, and a rain-water tank below 7 feet 6 inches in diameter. From the floor of the tank to the rock, a depth of 11 feet 6 inches, the building is solid. The tower contains 12,288 cubic feet of granite, and the cylindrical base 25,077 cubic feet, making a total of 37,365 cubic feet, weighing about 2,768 tons.

The stones forming the wall of the tower are dovetailed, both horizontally and vertically, in the same manner as was adopted at the Wolf Rock lighthouse. Each course of the base was at first only joggled horizontally with granite joggles, the courses having no bond with those either above or below them. Slate joggles, 6 inches longer than the granite joggles at first provided, have been substituted, and holes, 3 inches deep, have been cut in the courses above and below to receive the ends of each joggle, thereby obtaining a horizontal bond between each course of twice the total sectional area of the joggles. Bolting was not required, as the sea did not break over the rock during the working season with sufficient force to displace the stones when set.

Medina cement was used for the first and second courses, and Portland cement for the courses above. Salt water was employed for mixing the cement for the base, and fresh water for the cement above the base. The cement was mixed with an equal portion of clean, sharp, river sand for bedding the stones above the base; and the joints were filled with pure cement. The step ladders, for ascending from floor to floor, are of cast iron. The entrance door and storm shutters are of gun metal. The cylindrical 14-feet lantern of the Trinity House was adopted. The dioptric apparatus has eight panels of refractors, with upper and lower prisms, for emitting flashes of red light at intervals of forty-five seconds; the colour being produced at the glass chimney on the large central lamp, which chimney is ruby-coloured.

A 5-cwt. bell, for a signal during foggy weather, is fixed on the lantern gallery. It is struck three blows in quick succession, every fifteen seconds, by two hammers worked from machinery fixed in the pedestal of the dioptric apparatus.

The Great Basses reef is 80 miles to the eastward of Point de Galle, and 6 miles from the nearest land, viz., Kirinde. It is about $\frac{5}{8}$ mile long, $\frac{1}{4}$ mile broad, and is composed of hard red sandstone. Four rocks are above water, and two are just a-wash. The lighthouse is built on the east rock, which is 220 feet in length, 75 feet in breadth, and 6 feet above the mean sea level. The extreme range of tide is about 3 feet. The reef is exposed to both monsoons, therefore the days available for working on it are few. If 50 miles nearer Galle, or the same distance nearer Trincomalie, the number of days when work might be executed on it during a monsoon would be doubled. The only suitable season for working on the rock is during the north-east monsoon, which commences in November and terminates in April; and the best months of the monsoon are the first and the last two. During part of December, the whole of January, and part of February, the wind blows strongly from the N.E., especially about 2 P.M., when a short quick sea, on reaching the shallow water near the reef, breaks heavily on each side, rendering it dangerous to approach the rocks in a boat. During November, March, and April the wind is variable; light breezes prevail frequently off the shore in the morning, and on the shore in the evening, with a calm at mid-day. The current sets westward during the north-east monsoon, and eastward during the south-west monsoon; the speed is very irregular, sometimes varying from $\frac{1}{2}$ knot to 4 knots per hour during the same day. The usual direction of the current is parallel with the coast, and at the Great Basses it changes very little from this course. Towards the close of the monsoon the current is weak, and occasionally flows feebly in opposite directions during the same day. It attains the highest velocity to the westward in December, January, and the early part of February.

The coast for many miles on both sides of the Basses is almost continuously exposed to a heavy surf from S. or S.W. As it is very thinly populated, and without secure shelter for shipping, it was determined to form at Galle the depôt, from which the operations at the rock were to be carried on.

Two iron twin-screw steamers, one of which is shown on Plate 22, each capable of carrying 120 tons of cargo at a speed of 10 knots per hour, were used for conveying the materials from the workyard at Galle to the rock, and for attending upon the light-vessel and floating barrack, as well as the Little Basses light-vessel, during the progress of the work. For the purpose of landing and hoisting material rapidly at the rock with a minimum number of workmen, the steamers were each fitted with two steam double-barrel winches, by which the stones of the tower were hoisted on board, stowed below, hoisted again to the deck, and from thence to the rock. The Author is of opinion that this is the first instance of material being landed in a seaway from a vessel by means of her own steam-power, excepting where the load could be deposited by her own swinging derrick. The arrangement was very successful, and tended considerably to expedite the completion of the work. Although it was necessary, owing to the shallow water, to moor the steamers, when laden, at a distance of 30 fathoms from the rock, stones weighing on an average 2½ tons were hoisted out of the hold, landed, and deposited 28 feet above the rock, at the rate of ten per hour.

On the 8th of November, 1869, the Author left England, and on the 14th of the following month arrived at Galle. On the 27th of the same month he made an attempt to reach the Basses in a small sailing vessel, but, owing to head winds and an adverse current, only one-third of the distance was reached in eight days. He therefore returned to Galle to await the arrival from England of one of the steamers, the 'Arrow,' which, under the command of Captain Laing, of the Peninsular and Oriental Company, reached Galle on the 27th of February 1870, *viâ* the Suez Canal. Her cargo of plant and stores was immediately discharged, and her hold was fitted up to accommodate native workmen. On the 5th of March she left for the Great Basses; and on the 7th the Author landed on the rock, when he determined on the site for the lighthouse.

The excavation of the foundation for the previous work was scarcely visible. There was a timber beacon pole on the rock, surmounted by a small ball; the stays of coir rope, which had been attached to the mast and eye-bolts fixed in the rock, had parted; but the mast, being well stepped in the rock, remained upright. Chain-stays were at once fitted to the mast, and a long derrick was suspended from it, which derrick, with the aid of a small winch, served for landing cement and sand. To prevent the almost constant wash of the sea interfering with and delaying the cutting of the foundation for the tower, advantage was taken of every opportunity to build, in quick-setting Medina cement, a brick dam, 2 feet thick and 3 feet high, round the seaward side of the foundation. To this the rubble stone excavated from the foundation was added, until a continuous wall or dam was formed, 3 feet 6 inches thick and 4 feet 6 inches high, provided with holes for drainage. This dam afforded protection from the surf for the workmen while engaged trimming the foundation pit. It has since been faced with small ashlar and coped, and now forms a useful portion of the landing platform,—also constructed of rubble stone in cement, and faced and coped with granite ashlar. This platform contains 10,443 cubic feet of masonry, making, together with the tower and base, a total of 47,808 cubic feet, or about 3,541 tons. The foundation-pit was roughly excavated by means of small charges of powder, carefully applied, so as not to shake the rock; and the surface was afterwards finished with pick and point.

On the 17th of March, 1870, the light-vessel arrived at Galle from London, *viâ* the Cape. On the 30th of the same month, the vessel was moored $\frac{1}{3}$ mile E.N.E. of the reef, and the light was exhibited the same evening. The workmen were now quartered on board the light-vessel, and the 'Arrow' was available to obtain supplies from Galle without delaying the work.

The season ended on the 3rd of May, when thirty-six landings had been effected and two hundred and twenty hours worked on the rock. In this time the foundation-pit was prepared, the dam was completed around the foundation, and part of the landing platform had been built with the stone excavated.

Season of 1870—1871.

On the 19th of October, 1870, the 'Hercules,' under the command of Captain Laing, arrived at Galle from London, *viâ* the Suez Canal, to co-operate with the 'Arrow' in conveying material from Galle to the rock. The first landing for the season took place on the 28th of November, and the last on the 28th of April. Eighty-four landings were effected, and six hundred and fifty-one hours worked on the rock. The first stone was landed on the 28th of December, after which both vessels were used alternately in conveying stone from Galle to the rock. During the monsoon the foundation was completed, and sixteen stones of the twenty-first course were set. The dam around the foundation was also faced with ashlar, and coped.

SEASON OF 1871—1872.

The first landing took place on the 16th of November, and the last on the 2nd of May. During the season seventy-four landings were effected, and six hundred and seventy-nine hours worked on the rock. A hurricane-house was fixed on the gallery around the base of the tower, to afford extra accommodation for the workmen when remaining on the rock, and in it a steam winch, for hoisting the stones to the top of the work, was fixed. The remaining portion of the masonry of the tower from the twenty-first course was set, and the framing of the lantern erected.

The number of working days of ten hours, from the first landing on the rock to the end of this season, was one hundred and fifty-five days three hours; and from laying the first stone of the tower to setting the last stone of the gallery course, one hundred and ten days.

METHOD OF LANDING THE STONES OF THE TOWER.

(Plate 23.)

A strong spar, 45 feet long and 14 inches diameter, was stepped into the rock 3 feet. To this spar three $\frac{5}{8}$-inch chain-guys were fixed, and from it a derrick, 50 feet long and 14 inches diameter at the centre, was swung by a $\frac{3}{4}$-inch chain, 20 feet long. A chain-guy was fixed to the head of the derrick, the latter being worked by a small winch, controlled by one man. The leading block at the foot of the derrick was so placed as to allow the derrick to travel inwards freely, the winch being used to ease it to the proper position.

The steamer in attendance was moored, one anchor ahead and a 4-inch warp to the mooring buoy, for veering it into position; two 11-inch coir hawsers were abreast to the mooring buoys, and two 8-inch coir hawsers to the rock.

The holds of the steamboats were fitted with two tiers of rollers, on which the stones were placed, and by means of which they were brought speedily under the hatchways, where an iron cage, working in slides, was fitted for conveying them to the level of the deck. The vessels, as already mentioned, were each provided with two strong double-barrel steam winches, either barrel of each winch working separately if required. Between the hatchway and the gangway a frame, carrying rollers, was fixed, to facilitate the passage of the stones over the side. One barrel of the forward winch lifted the stone on deck and deposited it on the rollers, in readiness to go out of the gangway. The shore purchase consisted of three parts of ½-inch chain, one end of which chain was made fast to the head of the rock derrick; the other end, after passing through a block at the foot of the derrick, and thence on board to the end of the winch aft, was made fast to the stone. A $\frac{7}{16}$-inch guy-chain was also attached to the stone and No. 2 barrel of the forward winch, on which was a powerful break. The winch aft was put in motion, and, as the stone went over the side, the guy-chain was eased away until the stone entered the water. It was then gradually checked, and "paid" out at about the same speed as the winch aft worked the stone ashore, until it hung perpendicularly from the rock derrick. When the stone was high enough, the derrick was swung towards the tower to its proper position by means of the small winch on shore, and the stone was then lowered. After the stone was released, No. 2 barrel of the forward winch was put in motion, and the purchase hove-off for another stone.

For depositing the stones gently on the tower during rough weather a strong tackle, with a claw attached to the top, was fixed at the foot of the derrick, and when the stone was at its full height, the claw was slipped on to the chain of the lifting purchase; the winch was then promptly reversed, and the stone was afterwards lowered by means of the tackle. A second tackle was attached to the derrick mast, with a claw at the bottom, for the purpose of taking up sufficient slack chain after the stone was lowered, to allow the lifting purchase to be released. One man attended to both tackles.

TOTAL NUMBER OF HOURS WORKED ON THE ROCK.

	hours.	mins.		days of 10 hours.	hours.	mins.
First Season: March 7th to May 3rd, 1870—						
	222	42	=	22	2	42
Second Season: Nov. 28th, 1870, to April 28th, 1871—						
	651	39	=	65	1	39
Third Season: Nov. 16th, 1871, to May 2nd, 1872—						
	678	59	=	67	8	59
Total	1,553	20	=	155	3	20

The number of hours worked on the rock from the first time of landing (March 7th, 1870) to the date of setting the last stone (April 10th, 1872) was—

hours.	mins.		days.	hours.	mins.
1,422	17	=	142	2	17

The number of hours from the date of setting the first stone (Dec. 28th, 1870) to the date of setting the last stone (April 10th, 1872) was—

hours.	mins.		days.	hours.	mins.
1,100	55	=	110	0	55

The number of hours cutting out the foundation, building the dam, and rigging the gear was—

First Season: March 7th to May 3rd, 1870—

	hours.	mins.		days.	hours.	mins.
	222	42	=	22	2	42
Part of second season, Nov. 28th to Dec. 27th, 1870—						
	98	40	=	9	8	40
Total	321	22	=	32	1	22

The number of landings on the rock was—

First Season, 1870	36
Second Season, 1870 and 1871 .	84
Third Season, 1871 and 1872 . .	74
Total	194

The maximum and minimum number of hours worked on the rock—

	hours.	mins.
Maximum . . .	11	17
Minimum . . .	1	47

Description and Number of Persons employed at the Work.

1 executive engineer, 1 chief foreman of works, 1 accountant and storekeeper.

'*Arrow*,' *S.V.*—(Europeans) 1 master, 1 mate, 2 engineers, 1 stoker, 2 seamen; (natives) 1 serang, 6 lascars, 1 bandaddy, 3 firemen, 1 cook, 1 steward.

'*Hercules*,' *S.V.*—(Europeans) 1 master, 1 mate, 2 engineers, 2 stokers, 2 seamen, 1 boy; (natives) 1 serang, 6 lascars, 1 bandaddy, 2 firemen, 1 cook, 1 steward.

Light-Vessel.—(Europeans) 1 master, 1 mate; (natives) 1 serang, 6 lascars, 1 bandaddy, 1 cook, 3 lamp-trimmers.

During the working season at the rock the following were added, viz.: 1 lascar, 1 cook's mate, 1 steward.

Rock Working Party.—(Europeans) 1 millwright, 1 shipwright, 2 masons, 1 smith, 1 miner, 5 seamen, 1 winchman; (natives) 7 boatmen, 2 wall-masons, 2 quarrymen.

When the steamers were discharging stone, 2 seamen were on board as winchmen.

The light was exhibited on the 10th of March, 1873, and has since been continued with regularity every night, from sunset to sunrise. The illuminant adopted was Ceylon cocoa-nut oil, which is obtained at Galle, at a price of about 2*s.* 3*d.* per gallon. This oil is found, by experiments made at the Trinity House, to be equal in illuminating power, when employed in a properly-constructed lamp, to the best colza oil. This important work has been executed in a tropical climate by a few Europeans, aided by natives, and under exceptional difficulties, without loss of life or of limb to any person employed. The total cost of the undertaking, including all incidental expenses, was £62,039, being £2,622 below the original estimate for the work.

The success which has attended the execution of this work has induced the Board of Trade to order the erection of a similar lighthouse on the Little Basses reef, in accordance with a special design and estimate furnished by the Engineer of the Trinity House. This work is of even greater difficulty than that at the Great Basses, the reef being 20 miles farther from Galle, and a-wash only at low water. The Corporation of the Trinity House have undertaken the execution of this work also, and the Author is now employed in carrying it out, the vessels and plant from the works at Great Basses having been transferred and charged for that purpose.

The Author desires to record his sincere thanks for the kind assistance rendered by Sir Hercules Robinson, the late Governor of Ceylon, and to the Colonial officers, as well as to the Peninsular and Oriental Company, and their officers at Galle and Bombay.

As incidental to the history of the Great Basses lighthouse, it may be added that the chief portions of the 'Gordon' cast-iron tower, inclusive of the lantern and illuminating apparatus, are being utilised, from designs furnished by the Engineer of the Trinity House, in the construction of a lighthouse on the Bird Rock, Bahamas.

Mr. Harrison, President, said he was sure it would be the wish of the Meeting to accord to Mr. Douglass their thanks for his exceedingly interesting and valuable paper. Mr. Douglass's brother was present, and would no doubt reply to any questions that might be put, or observations made.

Mr. Michael Beazeley congratulated the Author on the ability displayed in carrying out a work attended by no slight difficulties, and on the success which had been attained. He had been for some years intimately connected with Mr. William Douglass in works of a similar character, and he was certain that whatever difficulties might have to be encountered, and they would be extremely formidable, in the erection of the Little Basses lighthouse, Mr. Douglass's courage and ability would enable him to grapple as successfully with them as with those met with on the Great Basses. He had been particularly struck by the small number of European hands employed on such a work. The total rock party of Europeans was only twelve, and the number on board the three vessels employed eighteen, making a total European party, excluding the engineer, of thirty. That was a very small force to accomplish such a work, including as it did only five skilled mechanics, because the difficulties in carrying it on were much greater in a tropical country than in a similar work at home. Here if anything was wanted it could be easily obtained; but no such facilities existed in a case like that of the Great Basses. The expense incurred, however, appeared to have been rather heavy, amounting to £62,039. The tower contained 37,365 cubic feet. The solid base, which contained 25,077 cubic feet, was there previously, and had no doubt been paid for. If that base had not existed its cost would have had to be added, and taking the contract price of 7*s.* 3*d.* per cubic foot delivered at Galle, the 25,077 cubic feet would have called for an outlay of £9,090, bringing the total up to £71,129, and that would come out at £1 18*s.* 1*d.* per cubic foot. He considered that rather high, because the Wolf Rock lighthouse, which was an exceptionally expensive one, cost only £1 8*s.* 2¼*d.* per cubic foot. He could not gather from the Paper if the cost of the vessels was charged to the work. If it were included, of course the high price would be at once accounted for. Towards the end of the Paper, however, where the Little Basses was spoken of, it was stated that the vessels and plant had been transferred and charged for that purpose. He wished to know if the ten stones per hour which were discharged was the maximum or the average. He had no note of the rate at the Wolf Rock, but at the Longships, where barges were used, five and a half stones per hour was the average. The barge was moored very close in, within 8 or 10 feet of the landing place in fine weather, yet the rate was only five and a half stones per hour. He therefore thought ten stones must mean the maximum at the Great Basses. The average number of hours worked on the rock was eight per day, which for one hundred and ninety-four landings would give fifteen hundred and fifty-two hours. Each steamer carried 120 tons of stone; each stone weighed 2½ tons; giving fifty stones per steamer, or 1,620 cubic feet. The 37,365 cubic feet in the tower were landed and set in eleven hundred hours, which would give 34 cubic feet of stone set per hour during the working season, from the laying of the first to the last stone. Now the 1,620 cubic feet, or fifty stones, in the steamer, at ten per hour, could be discharged in five hours. The fifty stones would require forty-eight hours in setting, or six days of eight hours each, so that the steamer could discharge her cargo, return to Galle, load and return again before the stones were set, and as there were two steamers employed, of course the work was conveniently done. He thought, however, that ten per hour would be found to be too high an average. Long trials had so perfected the knowledge of the proper construction of these towers, that it was difficult to suggest any improvement; but he thought it would be an advantage to diminish the number of windows in the service room. The vibration caused by the lantern during high winds was considerable, and as the rooms were increased in diameter the floor stones had a greater tendency to tip, and it was advisable to get as great a weight on them as possible to hold them down. If the number of windows in the service room were reduced from four to three it would, he thought, be an improvement. In a small way he had himself suffered from the Great Basses not being illuminated. When he was returning from Calcutta, although the east coast of Ceylon was kept in sight all the evening, the captain was so afraid of the Great Basses Rock, that directly it got dusk he kept the course of the vessel to the south-west, till at dawn of day they found themselves 60 miles to the south-west of Galle, quite out of sight of land. Comparisons were certainly invidious, and he might be supposed to be prejudiced in favour of the corporation with which he had been for so many years connected; but he could not help referring to the miserable failure which caused £40,000 to be spent in doing nothing whatever as compared with what was accomplished as soon as the work was handed over for execution to the Trinity House. When he was at Galle in 1859, he saw the stones lying on the glacis of the fort, and made inquiries why they had not been placed in position. The only explanation he could get was that there was great difficulty in laying the foundation. That was self-evident, as not a single stone has been put in position, but every difficulty vanished before the courage and ability of Mr. Douglass when he undertook the work.

Mr. REDMAN referred to the cost of some lighthouse towers nearer home. The Bell Rock lighthouse, of nearly the same height (117 feet) as that on the Great Basses, cost £61,331; the Skerryvore lighthouse, with an altitude of 158 feet, cost £83,126. No portion of the literature of Civil Engineering had met with greater attention than that relating to the construction of lighthouses; but it would be admitted that this Paper, following as it did that by Mr. J. N. Douglass describing the construction of the Wolf Rock lighthouse,[1] was no mean addition to that literature, which ranged from the well-known folio of the great master of the art, Smeaton, to the works of Stevenson on the Skerryvore and the Bell Rock lighthouses, and to the numerous Papers in the records of the Institution. It was in many cases fallacious to compare the cost of such works, for the conditions were extremely various. He thought the Author had scarcely sufficiently described the geological structure of the rock, and the material used in the construction of the tower. He also wished to have some further and more detailed explanation of the bonding of the courses.

Admiral COLLINSON expressed his admiration at the arrangements which had been made for landing under great difficulties. As a sailor he considered the way in which the vessels were moored was a perfect specimen of what ought to be done where a difficult surf had to be dealt with. He also highly approved of the construction of the vessels. He went on board one before she left England, and was greatly delighted with its wonderful adaptability to the exigencies of the case. On behalf of the Trinity Corporation, he wished to express their sense of the great obligations they were under to Mr. Douglass for the successful issue of the undertaking.

Mr. SHEARER said the granite used in the construction of the Great Basses lighthouse was supplied from his works at Dalbeattie, in Scotland. The mode of construction adopted by Mr. Douglass made the structure almost a solid mass of granite, which would in all probability be everlasting. It certainly would not be subject to any annual outlay for painting or repairs, as would have been the case if built of iron. The stones for such a structure could be

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxx., pp. 1–28.

despatched to any distance with the utmost regularity and safety. The first two or three cargoes were forwarded in sailing vessels, the rest in steamers *viâ* the Suez canal. The order for the working was put in hand on the 4th of January, 1870, and in October 1871 the last cargo was delivered at Galle. There were many advantages to be gained by using materials prepared in this country. Among others, the engineer, if resident in England, would have an opportunity of testing and examining them before they were sent away for distant foreign works. In this instance the tower was built in sections in the quarries under Mr. Douglass's inspection, and each block was marked for its particular place, so that little skill was necessary at the Great Basses in putting them together. Between nine hundred and one thousand blocks were used, and only one was damaged by accident at Galle; but as spare stones had been provided, capable of being worked into whatever shape was required, no inconvenience resulted from the accident.

Mr. J. N. DOUGLASS, replying to Mr. Beazeley's questions, said ten was the average number of stones landed per hour, twelve the maximum. If the stones had not been landed with such rapidity, many opportunities would have been lost, as it sometimes happened that the steamers could not ride near the rock for more than two or three hours during one day. He did not agree in the opinion that the cost of this work was heavy. It was true the cost of the granite base of the 'Gordon' light house was not included in the estimate of £64,661, or in the actual cost of £62,039. The cost of this base delivered at Galle was about £9,526, which would give a total for the structure of £71,565. Now, in this was included two steamers and a light-vessel, less their actual value on the completion of the work, at which value they were transferred to the works at the Little Basses lighthouse. The actual charge to the work for the light-vessel, and her maintenance during the time the work was in hand (about £8,004), should fairly be deducted, thus reducing the cost of the work to £63,561. It was well known that wages and the cost of materials had greatly risen of late years; yet this work had been executed in a tropical climate, and at a distance of nearly 7,000 miles from this country, at a cost which would compare favourably with that of similar works at home. The Bell Rock lighthouse, of 28,530 cubic feet, cost £1 19*s.* per cubic foot; the Edystone, of 13,341 cubic feet, cost £2 19*s.* 11½*d.* per foot; and the Great Basses, of 47,808 cubic feet, cost £1 6*s.* 7¼*d.* per foot. No really fair comparison could, however, be drawn in the case of such structures, because of the variety of circumstances, and the different conditions to be dealt with. But, on the whole, remembering that Smeaton's admirable work, executed under the personal superintendence of that able engineer, cost £2 19*s.* 11½*d.* per cubic foot, he did not think such a work as that now on the Great Basses, fitted with all the modern improvements in engineering and optical science, at £1 7*s.* per cubic foot, could be considered costly. The subject of the windows of the service-room had received careful consideration. The late Professor Faraday used to say that the lighthouse commenced at the floor of the service-room, and that the lantern should be ventilated from the service-room windows. As it frequently happened, in stormy weather, that only the lee window could be kept open, it followed that with four windows there was more certainty of a lee window, and consequently of proper ventilation of the lantern. Without proper ventilation condensation occurred on the internal surface of the glazing of the lantern, and the efficiency of the light was thus seriously impaired. The system of ventilation, as arranged by Professor Faraday, was as follows:—The air was admitted at the windows of the service-room (in which was a stove for heating in cold weather), ascended through a perforated grating surrounding the lantern-floor, over the internal surface of the glazing (thus preventing condensation) to the space between the roof and the ceiling, by an annular aperture surrounding the latter, whence it reached the cowl, the circulation being invigorated by the heat of the funnel of the large central lamp. He knew of no case where there had been any indications of weakness from the adoption of four ventilating windows in the service-room, therefore he preferred four to three. His brother had estimated, as a consequence of the erection of the Great Basses lighthouse, that the voyages of passing steamers had been so shortened that the saving in coal, irrespective of time and wages and interest on capital, had already exceeded the cost of the lighthouse. The tower, as stated in the Paper, was constructed of Dalbeattie granite, and the rock was a hard red sandstone. The granite base was from the Cornish quarries of Cheesewring and Penryn.
