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MADRAS RECORD OFFICE

Government of Madras

Public Works DEPARTMENT

G.O. No.	987	(w)	Press
~~B.P. No.~~			~~Mis.~~
Dated	20-4-	1876	

Not to be folded or roughly handled

No. 260. Read the following letter from JAMES MAY, Esq., Superintendent, Madras Harbour Works, to Major-General G. W. WALKER, R.E., Secretary to Government, Public Works Department, dated Madras, 11th March 1876, No. 46 W. :—

I HAVE the honor to report that having been requested on several occasions last year by Mr. William Parkes, of Westminster, to visit the works at Kurrachee, and having been authorized by the G. O., No. 67, dated 13th January last, to undertake this journey, I left Madras, *via* Bombay, on the evening of 17th January, arriving at Kurrachee on the morning of 24th January.

2. The reasons for this were two: *first*, the Manora Breakwater resembles in its construction the proposed Piers at Madras; *second*, there was a quantity of plant at Kurrachee available for Madras, and it became necessary to select the plant for shipment to this port.

3. I passed five days, 24th to 28th January inclusive, at Kurrachee, and Mr. W. H. Price, the Superintendent, placed at my disposal the means of seeing the works, particularly the Breakwater or Pier at Manora, in which I was specially interested. I returned here on 2nd ultime.

4. The Manora Pier is one of a series of works for the improvement of Kurrachee Harbour projected by the late Mr. James Walker, whose Reports of 8th September 1856 to the Secretary to the East India Company, and of 28th October 1858 to the Under Secretary of State for India, describe very nearly the existing state of things. A successful result has been attained:—a good harbour exists where a bad harbour existed twenty years ago, and a straight entrance channel has been made to a minimum depth of 20 feet below low water, being 6 feet deeper than the old tortuous channel. This, as stated by Mr. Price, the Superintendent, “trebles the former capabilities of the entrance during the south-west monsoon, and doubles them in the fair season; renders the harbour accessible to vessels of the largest class; greatly saves the use of Steam Tugs, and allows of the regular arrival and departure of the Mail Steamers. The breakwater also enables native craft to use the port at all seasons.” The breakwater cost rather less than £100,000, and a gross sum of about £150,000 has been expended on the harbour improvements.

5. On 9th November last a paper by Mr. Price on the Manora Breakwater was read at the Institution of Civil Engineers of London, and a discussion followed the reading of the paper, in which various opinions were advanced, some in favor of, and others against, the Manora work. Mr. Price's carefully prepared drawings have appeared in the printed Proceedings of the Institution.

6. The headland of Manpra projects into the sea in a south-easterly direction, terminating by a nearly perpendicular bluff about 90 feet above sea level, falling towards the north-west until it meets, within a short distance, a low reef of several miles in length connecting with the main land. Manora Point consists of conglomerate on the top, underlaid by a bed of stiff clay. Before the construction of the breakwater,

*Proceedings of the Madras Government, Public Works Department,
20th April 1876.*

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Manora Point formed the west side of the entrance to Kurrachee Harbour. It appears that the sea in the lapse of ages has undermined the clay at the foot of the cliff (this process is still going on), and the rock at the top has "fallen in great masses, which for about 700 feet from the shore, in a depth of water of from $1\frac{1}{2}$ to 4 fathoms, crop up thickly from the sandy bottom in irregular forms. For the remainder of the length of the breakwater, in a depth of water of 4 or 5 fathoms, a few boulders rise here and there through the sand. Clay occurs at a depth of from 8 to 14 feet below the surface of the sand." (Mr. Price's Paper, Inst. C. E., 9th November 1875).

7. The sand through which the great masses of conglomerate crop up, for about 700 feet from the shore, is described elsewhere as "quick sand," and than this there could not be a worse foundation. The sand below the outward half was less unfavorable for receiving the work.

8. The Breakwater or Pier springs from the shore at the foot of the cliff, and it is built for a length of 501 yards in a direction south by east $\frac{1}{4}$ east nearly. The depth of the original bottom in the line of the pier increased, as stated, from the shore to about 5 fathoms at the head.

9. The work is open to "the south-west monsoon, which brings a very heavy sea, lasting with full force for about three months, from the middle of June to the middle of September ***. Though called the south-west monsoon, the wind is generally west; but the run of the wave is more southerly than the wind, so that it meets the breakwater at an angle of 70° ." (Mr. Price's paper). It is further stated that "storms are unknown at Kurrachee, which is north of the limit of cyclones." None of them have occurred since the commencement of the works.

10. The mode of construction adopted at the Manora Breakwater is peculiar to itself. A base or foundation of rubble stone ("pierres perdues"), about 100 feet in width at the top with natural slopes on both sides, was dropped on the sea bottom, and afterwards brought by helmet-divers to a uniform level of 15 feet below low water. Nearer the shore, where the original depth was less than 15 feet, the rubble stone deposits were levelled to 10 feet below low water. Disregarding the shallow water section next the shore, a wall built solid of concrete blocks, 24 feet in thickness by as many in height, on the top of the rubble stone embankment forms the superstructure of the Kurrachee Breakwater. No mortar of any kind, except in cases of repairs, was used for the beds and joints of the blocks. Every block measured 12 feet by 8 feet, by $4\frac{1}{2}$ feet, weighing about 27 tons each, and they were placed in the work, not on their flat beds, but on their edges. The lower beds or heels of the foundation course blocks were bevelled 3 inches in the foot, and the effect of this is that every block in the work, instead of being placed vertically on its edge, is inclined towards the shore at an angle of about 14° to the perpendicular. No bond is applied on the cross section of the pier, of which an end view shows six blocks, two rows of three blocks in height, one row being placed alongside of the other row. The superstructure may be described as two walls, each 24 feet high by 12 feet thick, placed back to back, and there is a centre joint along the top from end to end of the work. This system has been called "the leaning block system of Kurrachee."

11. For a distance of 108 feet from the shore, the top of the pier is about 4 feet above high water level. Thence the top gradually descends to about high water level in a length of 468 feet. This last level was originally proposed for the remainder of the pier; but, in consequence of subsidence, the outermost 900 feet in length of the work are now 2 to 3 feet below high water level.

12. The base of rubble stone was thrown in chiefly by hand from boats, and afterwards levelled on the top to the required height by divers. The work of depositing the base was commenced on 17th March 1869. Pecuniary difficulties interfered for a time, but block-making on the shore commenced in August 1870, and on 1st November of that year the first 27-ton block was placed in the sea. The blocks were lifted on the block ground and loaded on to trucks by a powerful steam travelling crane ("Goliath,") with a span of 50 feet, worked by an 8-horse power engine. The trucks, each carrying one block, were run to the work by a Tank Locomotive Engine, and the blocks were placed in position by a travelling steam crane with a horizontal overhanging jib, specially contrived for the purpose of setting blocks in advance of itself. This crane has been called a "Titan," and it was the first machine of its kind. The Goliath, the Block Trucks, and the Titan are now being shipped at Kurrachee for the work at Madras.

13. The first working season at the pier walls extended from 1st November 1870 to 4th March 1871, by which date the end of the superstructure reached a point 270 feet from the shore.

14. The work of building was resumed on 28th October 1871, and it was continued until 23rd February 1872, the result of the second season having been 523 feet in length of pier walls, bringing the outer end to a point 793 feet from the shore.

15. The third and last season commenced on 1st November 1872, and closed on 22nd February 1873. The amount of work done in this case was greater than in either of the previous seasons, namely, 710 feet in less than four months, and completing the pier walls to their present extent of 1,503 feet from the shore.

16. The Breakwater walls had thus been under construction for twenty-eight months, of which a period of less than twelve months was occupied in setting blocks. It is stated that the full power of the Titan was never applied, because delays occurred either by the inadequate supply of blocks manufactured on the shore, or by the progress of the base.

17. Sea damages during progress appear to have been inconsiderable, and in this the Pier at Kurrachee will compare favorably with Harbour Works elsewhere. The heaviest blow occurred when the pier walls were 793 feet in length, shortly after the bursting of the monsoon in 1872, on which occasion eighteen blocks were washed off the top course on the harbour side, in one length of 86 feet, the middle of which was

622 feet from the shore. The second course on the harbour side was also partly thrown off, and the two upper courses on the sea side at the same place were driven inwards more or less, the maximum of which motion was 12 inches. This damage is well shown by a plan and cross sections at A and B in Plate No. 2 accompanying Mr. Price's paper. It was repaired in the following spring by dressing off the partially displaced second course to low water level, filling the opening in the interior with rubble, and substituting new blocks for the top course on the harbour side. The sea-side blocks in this case remain as displaced by the sea; and, as a rule, blocks once moved by the sea have not been reset in their original places at Kurrachee. Other sea damages of less importance occurred from year to year. They were limited for the most part to single blocks displaced at intervals from the top course, and these gaps were chiefly repaired by hand with rubble and concrete.

18. Another effect of sea action first developed itself after the bursting of the monsoon in 1871, when the pier walls were advanced to 270 feet from the shore.

Opening of Centre Joint.

In places where boulders had cropped up through the sand on the original sea bottom, the sea-side blocks moved or twisted seawards on the top, causing the sea side to overhang on the face, and opening a crevice along the centre joint. This opening has been called a "Rift," and it will be afterwards referred to. The overhanging of the sea side is shown by Mr. Price's cross sections at 210 feet, at 450 feet, at 850 feet, and at 1,400 feet from the shore, Plate 2.

19. The sinking of the pier walls into the rubble bank below them, added to the sinking of the bank itself into the original sea bottom, have together produced a considerable result at Kurrachee, drawn on Plate 4 accompanying Mr. Price's paper. The sea side of the pier walls in shallow water at 200 feet from the shore is now 24 inches below the level to which it was originally built, and the sea side of the pier walls in 5 fathom water near the head is 36 inches below the level to which it was originally built.

Subsidence.

SUBSIDENCE OF WALLS BUILT ON EMBANKMENTS OF RUBBLE STONE.

20. This is such an important point in every structure of the nature described, and, as it must soon develop itself on a considerable scale in the Piers at Madras, I beg you will excuse my dealing with it a little more particularly by quoting two or three paragraphs from a report of mine to the English Admiralty on a work at which I passed several years in the Channel Islands. I venture to do this, because at the work referred to all the elements of sea difficulties were concerned, and each of them existed to an extent unknown elsewhere. In this case there was no leaning system: the beds of every stone in the work were horizontal and the joints were vertical:—

"Alderney Pier.—The depth of the original sea bottom under the pier increased from the shore to 130 feet below low water of the lowest tides at the head. The

Depths of water.

depth of water in which the outermost 600 lineal yards of the pier were constructed was 105 feet below the lowest tide level on the average; and the original depth under the outermost 300 lineal yards of the work averaged 125 feet.

"The pier is exposed to the whole force of the Atlantic, the wildest winds of which strike it at right angles, and the destructive power of the sea is greatly

"Winds and Tides.

increased by the rapid tides surrounding this island. The current of the tides sets westerly against the storm for nine hours out of the twelve, with a velocity second only (if it is second), on the coast of Europe, to that of the streams of the Pentland Firth. The rise of tide at ordinary springs is 17 feet, and at extraordinary springs 25 feet.

"This stormy sea, rapid tides, and excessive depth of water have caused great difficulty in executing the work, and still more in maintaining it. The sea, the

"Difficulty of work.

rapid streams, and the deep water may be found elsewhere, but the pier, a mile in length, built out to meet them can be seen at Alderney alone.

"The Alderney Pier consists of an artificial base of loose rubble stone of various sizes, 52 yards in width at the top, dropped on the bottom from hopper-

"Construction.

barges, towed by steam tug boats to the work, and on the top of the base a superstructure of masonry founded 16 feet below low water level. The submarine courses of the superstructure were placed by helmet-divers, and above them a solid wall was built of Cyclopean strength and dimensions, set water-tight throughout with Medina cement from the Isle of Wight.

"The pier walls were built in short lengths of from 30 to 60 feet each fortnight, or rather each successive spring-tides, in the summer months, the measure of such lengths above low water depending on the weather and on the extent of submarine walls brought up to low water by the helmet-divers in the previous fortnight. The work of building walls was suspended in the winter months, from October to April, and the annual rate of progress was 400 or 500 lineal feet.

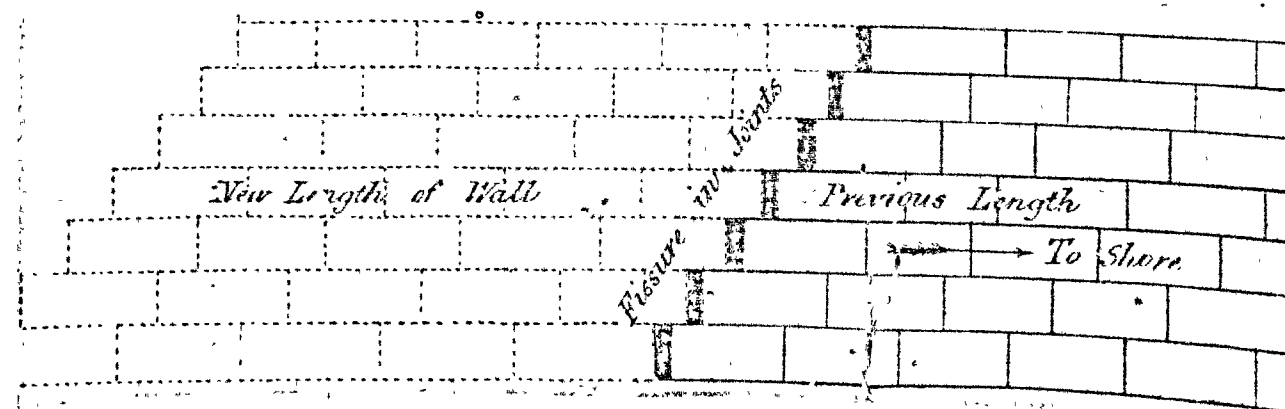
"Pier Walls built in lengths.

"Subsidence was the inevitable result of setting even a single course on the top of this great embankment. The walls by their weight compressed like a sponge

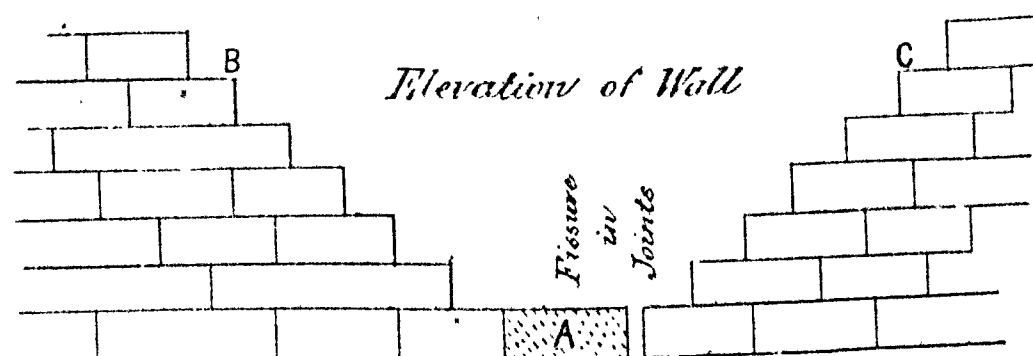
"Subsidence of Walls.

the mass of loose stone below them. Subsidence continues to go on for several years after the walls are built, until it finally amounts here to one-seventeenth part (about 6 per cent.) of the depth of the bank; but the greatest part of it takes place within the first month or two, and the consequence is that a crack, or fissure, or opening of the joints, exists at each division or junction between walls of different dates, as if the newer work had drawn away from the older work longitudinally, shown by the sketch below:—

"Elevation of Wall.



"Various expedients were tried for the repair of these fissures, which measured from 3 to 12 inches in length, such as removing the facing stones from time to time and substituting longer stones, but the masonry was dislocated at the fissures, and they must always remain so many weak points. The subjoined sketch shows the difficulty of getting out the stone A in a bonded wall for the purpose of introducing a larger stone in the fissure at that point. In order to remove the stone A from the wall, a formidable opening must be made in the courses above it, A. B. C."

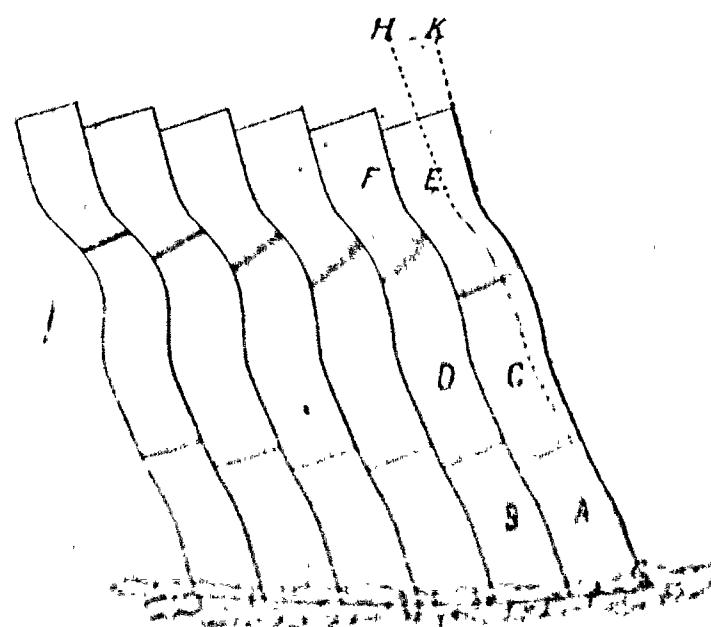


21. If I remember rightly, it was the dislocation of masonry and the difficulty of repairs in the case to which the above quotation refers, which first induced Mr. Parkes to adopt the system of blocks leaning on their edges, and with it, the abandonment of bond in the Kurrachee Cross Section. If, by a law of nature, the new lengths of walls must sink into the loose stone below them, less damage might accrue by the absence of bond. Each length would sink, so to speak, by itself, without disturbing the previous length. The question is full of difficulty.

22. It has been claimed for the Kurrachee system that it "enabled each block to fall into place easily, and helped to obviate distortion from slight errors or subsidence of the foundation. The inclination also secured the upper blocks against displacement by lifting, and proved of great service by causing the tiers to tighten together under the action of the sea." (Mr. Price's paper).

Kurrachee Blocks.

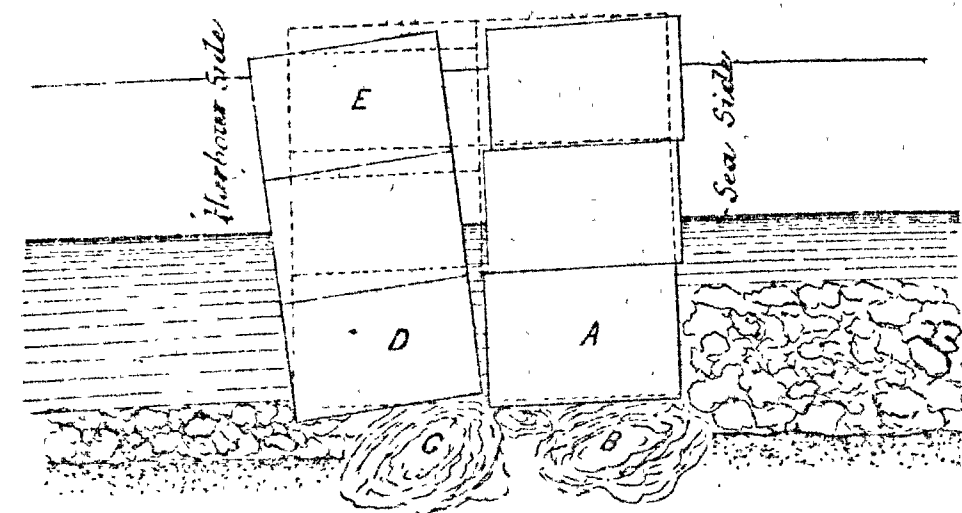
23. The following is a side view of the Kurrachee blocks:—



The block A is in *equilibrium* as respects block B, horizontally. If block B were removed, A would not by its own weight tend to occupy B's place. Blocks A and C are also in *equilibrium* horizontally as respects B and D. If B and D were removed, C would not by its own weight fall into the gap, although C is so nearly balanced on A that the slightest blow would cause it to do so. E presses horizontally on F, if D is removed, and all top blocks press against their neighbours to the shore. If the top course presses towards the shore and shortens itself, as has been stated, such operation must be at the expense of distortion in the angle of 14° at the outer end, as at H G K.

24. The opening of the centre joint on the top of the Manora Pier has been already referred to (page 4). This has been called a "Rift," and a good deal has been made of it in Newspaper paragraphs and elsewhere. As often as boulders of conglomerate rock cropped up through the sand on the line of the work, the foundations were sources of special trouble. The subjoined Cross Section at 210 feet from the shore explains the meaning of this:—

Cross Section at 210 feet.



When the block A was placed, two different parts of it rested on boulders of rock, B and C, and the rest of the block rested on artificial filling. After the wall was brought up and exposed to the sea of the south-west monsoon, the sea side moved forward and overhung. This let the water into the centre joint, and the continual blows of the sea pressed out the harbour side D E. This is the manner in which "Rifts," or openings of the centre joint have been formed at Kurrachee. A rift of some 50 feet in length, from 700 to 750 feet from the shore, now exists on the centre line at Manora; and, no doubt, this opening, which has a maximum width of 16 inches, will be filled up as soon as the action of settlement has ceased there. It should be observed that along the outermost, most expressed, and deepest half of the pier, under which the foundation was rather more favorable than elsewhere, the centre joint does not open; on the contrary, it becomes closer with time.

25. The leaning system of blocks on their edges applied at Kurrachee is proposed for the Piers at Madras. For a length of 500 feet next to the shore of each pier

Proposed Piers at Madras. AE, CF, on the accompanying plan, three courses in height are intended, namely, a wall 24 feet high by 24 feet wide, as at Kurrachee; and for the remaining lengths, AB, CD, 335.0 feet in each case, four courses in height are intended, making the outer portions of the walls 29 feet in height by 24 feet in breadth. The tops of the walls throughout are intended to be 5 feet above mean sea level.

26. It is also intended to dispense, at Madras, with bond on the cross sections of the pier walls, which are proposed to consist, as at Kurrachee, each of two walls 12 feet in thickness, placed back to back. It is further proposed to apply a system of joggles on the beds of the blocks for the purpose of preventing any block being drawn by the sea without bringing with it the block immediately below or above. The joggles are to be formed on the blocks themselves, a projection on the upper bed of each block, except those of the top course, fitting into a corresponding recess in the under bed of the block next above it. So far as I am aware, no provision has been made for tying the sea and harbour sides of the walls together, with a view to preventing openings in the centre joints. A Cross Section of the deep water piers, as proposed at Madras, is drawn on page 9.

27. On the question of bonding the two sides together, it happens that on 9th November last, in the Institution of Civil Engineers, "there was a strong concurrence of opinion of the highest authorities" in favor of such bonding; and Mr. Parkes himself goes minutely into the question on pages 50 to 52 of that discussion, to which I beg to refer you.

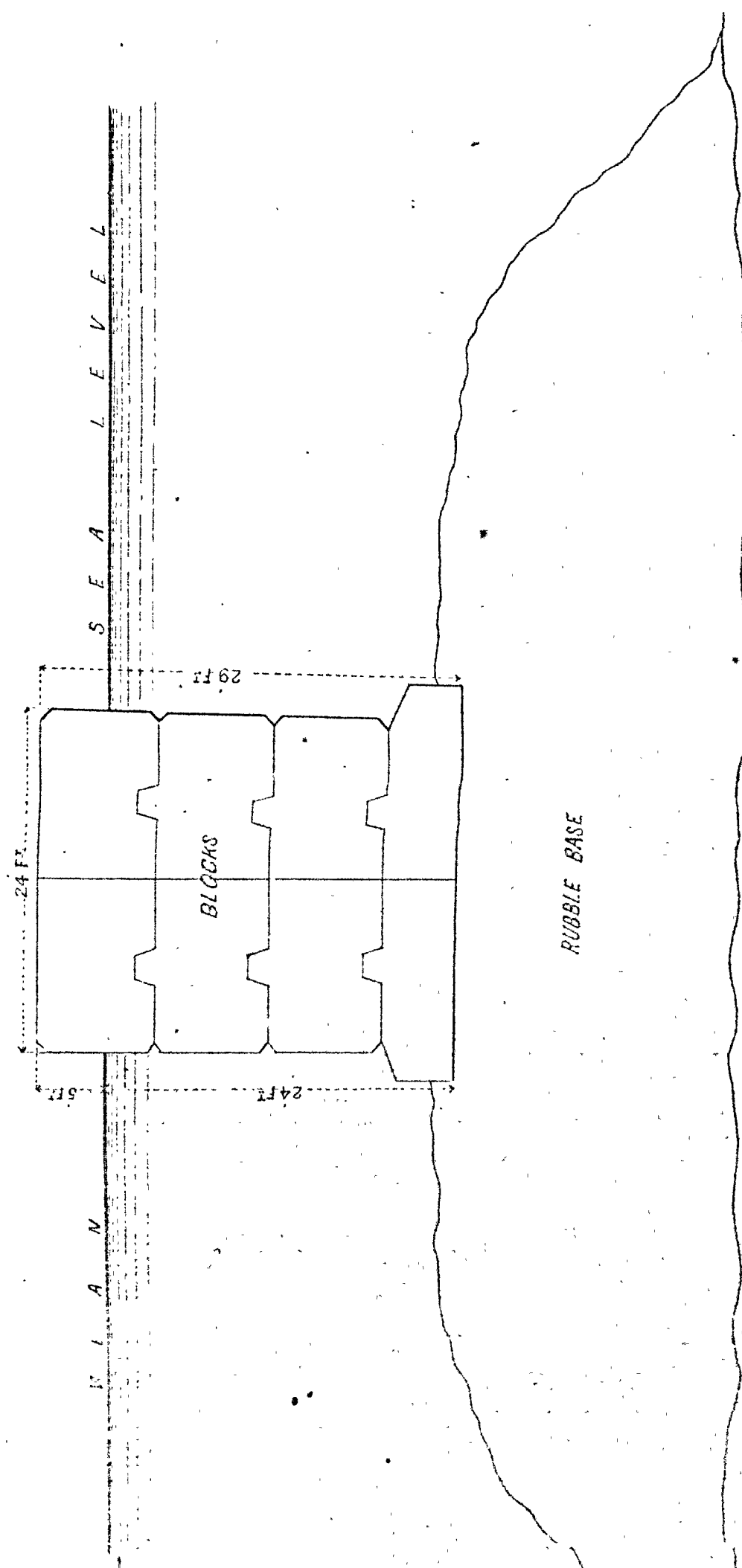
28. The natural Sea bottom of Madras Roads, although I am not yet in possession of full information on this subject, consists, speaking roughly, of loose sand from the shore to the line of 5 fathom water; and, outside the 5 fathom line, of a bed of clay. It is too soon to express an opinion on the extent to which the laterite rubble deposits in the foundations of the pier walls may sink into the sand and clay of the sea bottom. Whatever this may amount to, there are no protruding rocks in the lines of the piers, as in the case of Manora.

29. As regards the subsidence of the Madras Pier walls into the beds of rubble laterite which are to form their foundations, the conditions appear to be favorable, in consequence of the high specific gravity, and the closely packing nature of the laterite itself.

30. Mr. Price, the Superintendent at Kurrachee, has authorized me to quote his Paper read at the Institution of Civil Engineers on 2th November last. It is possible that I may have been led into some misstatements in consequence of limited information concerning the place; but I have endeavoured to describe the character of the work fairly, as it appeared to me the other day.

31. The following Papers accompany this to your address:—
Excerpt Proceedings, Institution of Civil Engineers, London, 2th November 1875.
Photo-lithographed Plan of proposed Harbour at Madras.

MADRAS HARBOUR.
SECTION OF PIERS



Proceedings of the Madras Government, Public Works Department,
20th April 1876.

No. 261. ORDER THEREON, 20th April 1876, No. 987.

CIVIL WORKS, No. 16-A.

Mr. May is thanked for his full and interesting Report on the Kurrachee Breakwater.

2. It would appear that though the nature of the ground on which the rubble foundations of piers will be deposited at Madras is probably such as to render lateral dislocations from the same causes which have existed at Kurrachee unlikely to occur, yet undoubtedly subsidence to a considerable extent may be anticipated in those foundations. And, considering the effect of the sea in moving large blocks, there appears to be room for apprehension regarding the unprotected rubble banks composed of small laterite stones which are to run out into $2\frac{1}{2}$ fathom water.

3. The report will therefore be communicated to Mr. Parkes, and that gentleman will be requested, through the Secretary of State for India, to state whether he considers it necessary to make any change in, or additions to, the structure as designed by him, in order to counteract the subsidence that may probably take place; and what precautions he proposes to take for the preservation of the sea-faces of the rubble banks between the shore and $2\frac{1}{2}$ fathom water, before next monsoon.

(True Extract.)

Colonel,

Offg. Under Secy. to Govt., P.W.D.

To the Superintendent, Madras Harbour Works.

Lt. Home 1st March 1876.

My Dear Mr. May,

13

You cannot be excused from writing a Report of the state in which you found the Breakwater at Kurrachee on the visit which you undertook at Mr. Parker's request and under sanction of Govt. Mr. Price's Report is already in the hands of Govt. & does not bring up the information to a later date than Jan'y 74.

We report unequal settlements every year, but no dislocation. It has however been rumoured that dislocation has since taken place. And it would no doubt be satisfactory to Govt. to learn from you that such dislocation was not of a nature or an extent likely to be permanently prejudicial to the work. Or, if it were, that you were prepared with expedients to obviate such dislocation in the Madras Harbour Piers; and counteract the evil effect of any settlements.

J

Have gone through Mr. Parker's letter
of 15th November again, and cannot find
a hard word said by him at your expense.
On the contrary he expressly says that
he casts no censure upon you; and
considers you to have acted a judicious
and conciliatory part. But you are
now called upon to state facts as to the
present condition of the Breakwater
at Kurrachee; and whether your state-
ment of facts be displeasing to Mr.
Parker or not, the Gov^t. is entitled
to have it. I did not gather from what
you told me of your trip that you
thought the Breakwater anything but
a success; though you appeared to think
that more intimately connecting one
Block with another would be an im-

provement. Mr. Parker need not to
think so, but I am inclined to modify his
opinion to some extent.

Yours &c.
H. G. Walker.

Harbour Works, Madras,
Feb. 29, 1876.

My dear General,

May I beg you will excuse me from a
Report on Kurrachee, at least for the present,
and for the following reason? -

Mr. Parker has applied some hard words at
my expense, in his letter of 15th November last to
the India Office, in an estimate of Madras Harbour
which was forced from me a few months before.
No one has qualified those words.

Any thing I could say of Kurrachee would,
I am sure, give further offence to Mr. Parker,
nor could it be so well said as the accompanying
Report from Mr. Price, the Superintendent, who
has passed half a life time at the place.

Very faithfully,
James Ellay

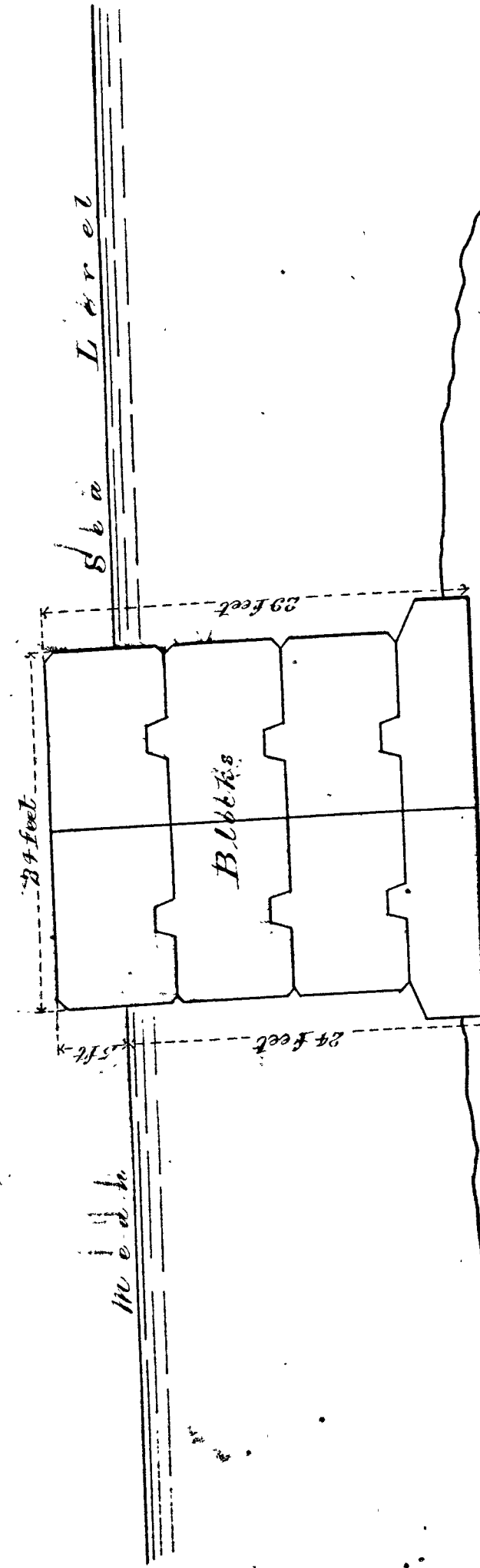
General Walker, R.E.,
&c. &c., Fort Saint George.

17/12

Vide letter copied
in Chief Engineer's
Book 17. 1st March 1860

Madras Harbour.

Section of Piers -

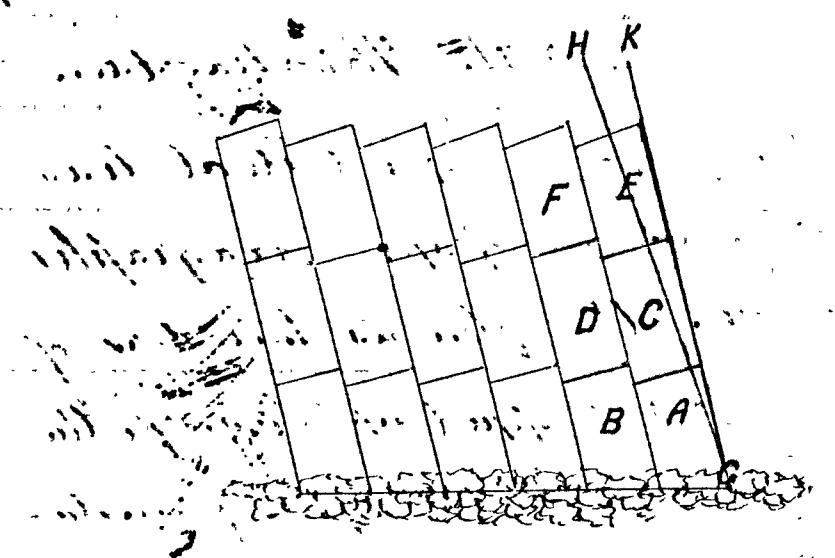


Rubble

against displacement by lifting, and proved
 of great service by causing the tiers to
 tighten together under the action of the sea.
 (Mr. Price's paper.)

Kurrachee
Blocks.

The following is a side view of the
 Kurrachee blocks.



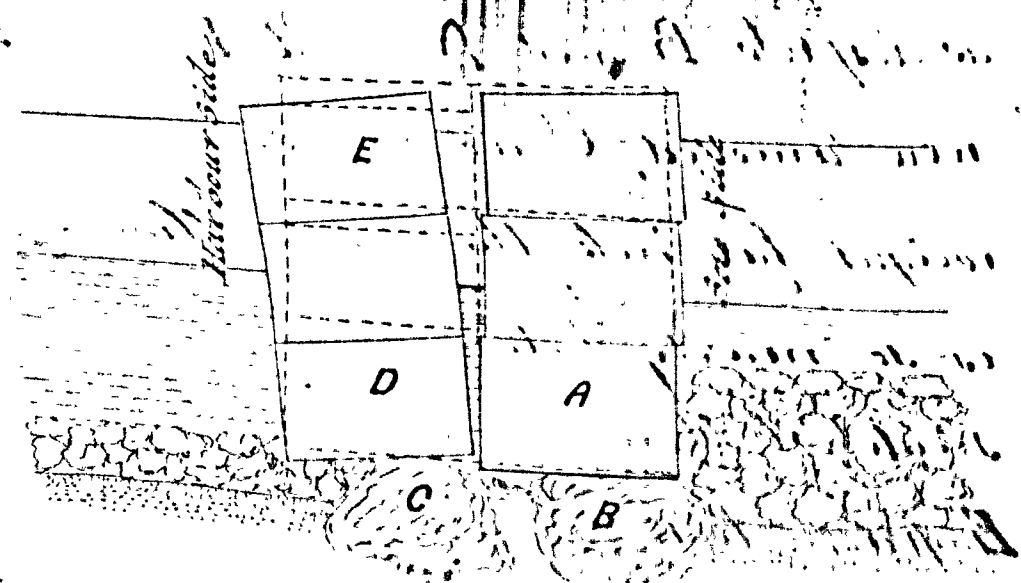
The block A is in equilibrium as respects
 block B, horizontally. If block B were
 removed, A would not by its own weight
 tend to occupy B's place. Blocks A and
 C are also in equilibrium horizontally
 as respects B and D. If B and D
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 blocks press against their neighbours to
 the shore. If the top course presses
 towards the shore and shortens itself,

as has been stated, such operation must be at the expense of distortion in the angle of 14° at the outer end, as at H. G. K.

The opening of the centre joint on the top of the Manora Pier has been already referred to (pages 10 & 11). This has been called a "Rift," and a good deal has been made of it in newspaper paragraphs and elsewhere. As often as boulders of conglomerate rock cropped up through the sand on the line of the work, the foundations were sources of special trouble. The subjoined cross section at 210 feet from the shore explains the meaning of this.

Centre Joint

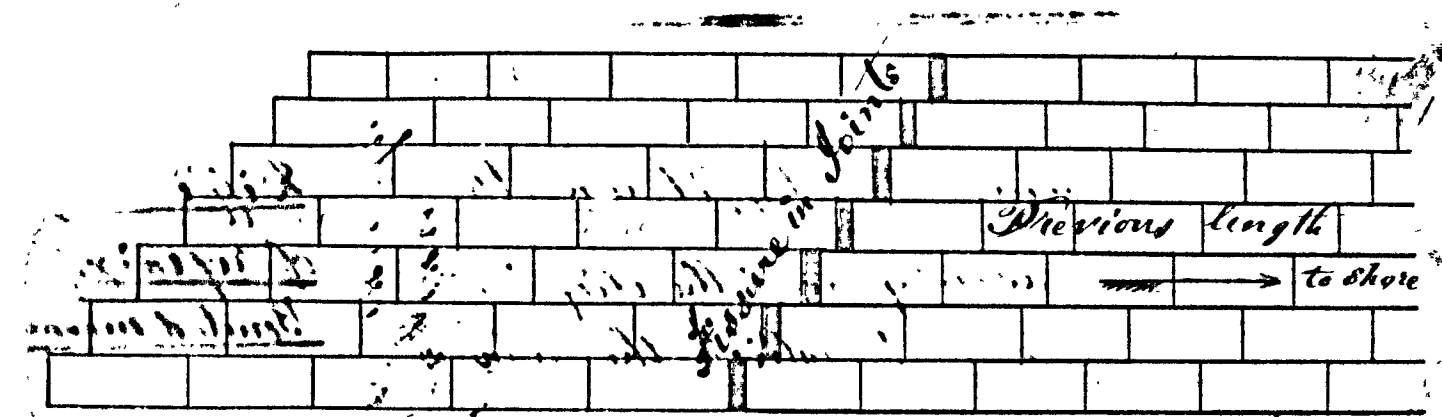
Cross Section at 210 feet



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"different dates," as if the newer work had drawn away from the older work longitudinally, shown by the sketch below:-

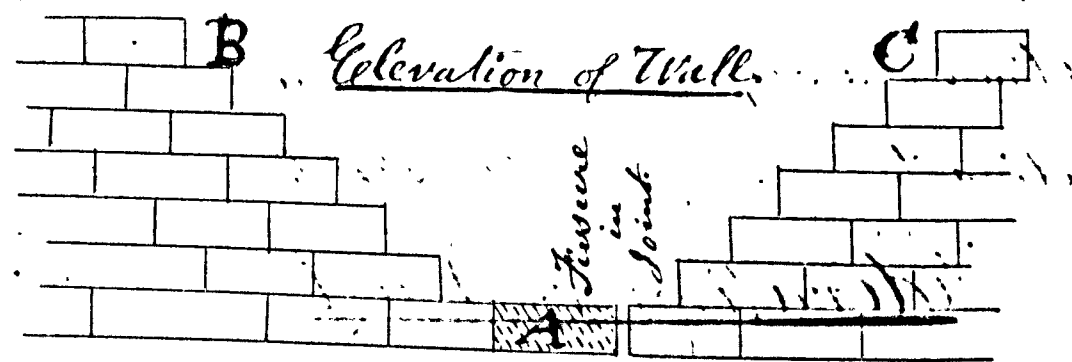
Elevation of Wall.



Repairs of
Fissures.

Various expedients were tried for the repair of these fissures, which measured from 3 to 12 inches in length, such as removing the facing stones from time to time and substituting larger stones, but the masonry was dislocated at the fissures, and they must always remain so many weak points. The subjoined sketch shows the difficulty of getting out the stone A in a bonded wall for the purpose of introducing a larger stone in the fissure at that point. - In order to remove the stone A from the wall, a formidable opening must be made in the courses above it, A. B. C. -

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Difficulty
of repair
Bonded masonry

Dislocation
of masonry

Advantage
claimed for
Kurrachee
system

Kurrachee Harbour

N. 46 W.

25

From

The Superintendent.

Madras Harbour Works.

To

The Secretary to Government,

Public Works Department,

Fort Saint George,

Madras 11th March, 1876.

Instructions.

I have the honour to report that, having been requested on several occasions last year by Mr. William Parkes, of Westminster, to visit the works at Kurrachee, and having been authorized by the Government Order N. 67, dated 13th January last, to undertake this journey, I left Madras, via Bombay, on the evening of 17th January, arriving at Kurrachee on the morning of 24th January.

Reasons for
Journey.

The reasons for this were two: first, the Manori Breakwater resembles in its construction the proposed Piers at Madras; second, there was a quantity of plant at Kurrachee available for Madras, and it became necessary to select the plant for shipment to this port.

Kurrachee

I passed five days, 24th to 28th January

inclusive, at Kurrachee, and Mr. W. R. Price the Superintendent, placed at my disposal the means of seeing the works, particularly the Breakwater or Pier at Minora, in which I was specially interested. I returned here on 2^d Ultimo.

The Minora Pier is one of a series of works for the improvement of Kurrachee Harbour projected by the late Mr. James Walker, whose Reports of 8th September 1856 to the Secretary to the East India Company and of 20th October 1858 to the Under Secretary of State for India, describe very nearly the existing state of things. A successful result has been attained: a good Harbour exists where a bad Harbour existed barely years ago, and a straight entrance channel has been made to a minimum depth of 30 feet below low water, being 6 feet deeper than the old tortuous channel. — This, as stated by Mr. Price, the Superintendent, "trebles the former capabilities of the entrance during the South West Monsoon, and doubles them in the fair season; renders the Harbour accessible to vessels of the largest class; greatly saves the use of Steam Tugs, and allows of the regular arrival and departure

Kurrachee Works.

Mr. Price's Paper.

1 vol.
18 111

Minora Point.

1 vol.

of the mail steamers. The Breakwater also enables native craft to use the port at all seasons. — The Breakwater cost rather less than £100,000, and a gross sum of about £450,000 has been expended on the Harbour improvements.

On 9th November last a paper by Mr. Price on the Minora Breakwater was read at the Institution of Civil Engineers of London, and a discussion followed the reading of the paper, in which various opinions were advanced, some in favour of, and others against, the Minora work. — Mr. Price's carefully prepared drawings have appeared in the printed Proceedings of the Institution. — The headland of Minora projects into the sea in a South Easterly direction, terminating by a nearly perpendicular bluff about 90 feet above sea level, falling towards the North West until it meets, within a short distance, a low reef of several miles in length connecting with the main land. — Minora Point consists of conglomerate on the top, underlain by a bed of stiff clay. — Before the construction of the Breakwater, Minora Point formed the west side of the entrance to Kurrachee Harbour. — It appears that the sea in the lapse of ages has undermined

the clay at the foot of the cliff (this process is still going on), and the rock at the top has fallen in great masses, which for about 700 feet from the shore, in a depth of water of from $1\frac{1}{2}$ to 4 fathoms, crop up thickly from the sandy bottom in irregular forms. - For the remainder of the length of the Breakwater, in a depth of water of 4 or 5 fathoms, a few boulders rise here and there through the sand. - Clay occurs at a depth of from 8 to 14 feet below the surface of the sand. (Mr. Price's paper, Inst. C.E. November 9, 1875.)

The sand through which the great masses of conglomerate crop up for about 700 feet from the shore, is described elsewhere as "quick sand", and than this there could not be a worse foundation. - The sand below the outward half was less unfavorable for receiving the work. -

The Breakwater or Pier springs from the shore at the foot of the cliff, and it is built for a length of 501 yards in a direction South by East to East nearly. -

The depth of the original bottom in the line of the Pier increased, as stated, from the shore to about 5 fathoms at the Head.

Sea bottom,
Line of Breakwater.

Sea bottom,
Line of Breakwater.

Sea bottom,
Line of Breakwater.

Breakwater.

South West Monsoon

The work is open to the South West Monsoon, which brings a very heavy sea, lasting with full force for about three months, from the middle of June to the middle of September. Though called the South West Monsoon, the wind is generally west, but the main body of the wave is more southerly than the wind, so that it meets the Breakwater at an angle of 40° . (See Price's paper.) It is further stated that storms are more known at this season, which is one of the limit of cyclones. - Some of them have occurred since the commencement of the work. -

Construction of Breakwater.

The mode of construction adopted at the Victoria Breakwater is peculiar to itself. - A base or foundation of rubble stone pieces, perches, about 100 feet in width at the top with natural slopes on both sides, was dropped on the sea bottom, and afterwards brought by helms and divers to a uniform level of 15 feet below low water. - Near the shore, where the original depth was less than 15 feet, the rubble stone deposits were levelled to 12 feet below low water. - Disregarding the shallow water section.

near the shore a wall built solid of concrete blocks, 24 feet in thickness by 24 feet in height, on the top of the rubble stone embankment formed the superstructure of the Pier. Breakwaters into masonry of any kind except in cases of repairs was avoided for the beds and joints of the blocks. Every block measured 12 feet by 8 feet by 12 feet, weighing about 27 tons each, and the joints were placed in the work, not on their flat beds, but on their edges. The lower beds or keels of the foundation courses blocks were embedded 3 inches in the mortar, the effect of this is that every block in the work, instead of being placed vertically on its edge, is inclined towards the shore at an angle of about 14° to the perpendicular. To build up a pier as the cross section of the Pier of which I am now showing a plan, blocks, two rows of three blocks in a height, were being placed along sides of the pier now. The superstructure may be described as two walls, each 24 feet high by 24 feet thick, placed back to back, with a central pier in between the top from end to end of the work. This system has been called the leaning block

NOTE
1870

system of Kurrachee. -

Levels of Pier.

For a distance of 108 feet from the shore, the top of the Pier is about 4 feet above high water level. - Thence the top gradually descends to about high water level in a length of 480 feet. - This last level was originally proposed for the remainder of the Pier; but, in consequence of subsidence, the outermost 900 feet in length of the work are now two to three feet below high water level. -

Progress of Work.

The base of rubble stones was thrown in chiefly by hand from boats, and afterwards levelled on the top to the required height by divers. - The work of depositing the base was commenced on 17th March 1869. Pecuniary difficulties interfered for a time, but block making on the shore commenced in August 1870, and on 1st November of that year the first 27-ton block was placed in the sea. - The blocks were lifted on the block ground and loaded on to trucks by a powerful steam travelling crane ("Goliath"), with a span of 50 feet, worked by an shore power engine. The trucks, each carrying one block, were run to the work by a tank locomotive engine, and the blocks

were placed in position by a travelling steam crane with a horizontal overhanging jib, specially contrived for the purpose of setting blocks in advance of itself. This crane has been called a Titan, and it was the first machine of its kind. The Goliath, the block trucks, and the Titan, are now being shipped at Rurrachee for the work at Madras.

The first working season at the Pier Walls extended from 1st November 1870 to 14th March 1871, in which date the end of the superstructure reached a point 570 feet from the shore.

The work of building was resumed on 28th October 1871, and it was continued until 23rd February 1872, the result of the second season having been 523 feet length of Pier walls, bringing the total end to a point 793 feet from the shore.

The third and last season commenced on 1st November 1872, and closed on 22nd February 1873. The amount of work done in this case was greater than in either of the previous seasons, namely: 710 feet in less than four months, and completing

First Season
Pier Walls.

Second Season
Pier Walls.

Third Season
Pier Walls.

the Pier walls to their present extent of 1503 feet from the shore.

The Breakwater walls had then been under construction for 20 months, of which a period of less than twelve months was occupied in setting blocks. It is stated that the full power of the Titan was never applied, because delays occurred either by the inadequate supply of blocks manufactured on the shore, or by the progress of the work.

Time required
for building
walls.

Sea damages
during progress.

Sea damages during progress appear to have been inconsiderable, and in this the Pier at Rurrachee will compare favourably with harbour works elsewhere. The heaviest blow occurred when the Pier walls were 793 feet in length, shortly after the burst-
ing of the monsoon in 1872, on which occasion 18 blocks were washed off the top course on the harbour side, in one length of 86 feet the middle of which was 622 feet from the shore. The second course on the Harbour side was also partly thrown off, and the two upper courses on the sea side at the same place were driven inwards more or less, the maximum of which motion was 12 inches. This damage is well shown by a Plan and cross sections

at A. & B. in Plate A. 2. accompanying Mr. Price's paper. It was repaired in the following spring by dressing off the partially displaced second course to low water level, filling the opening in the interior with rubble, and substituting new blocks for the top course on the Harbour side. The sea side blocks in this case remain as displaced by the sea, and, as a rule, blocks once moved by the sea have not been seen in their original places at Kurrachee in other sea damages of less importance occurred from year to year. They were limited for the most part to single blocks displaced at intervals from the top course and these gaps were chiefly repaired by hand with rubble and concrete.

Another effect of sea action first developed itself after the bursting of the masonry in 1871, when the Pier walls were advanced to 270 feet from the shore. In places where boulders had cropped up through the sand on the original sea bottom, the sea side blocks moved, twisted seawards on the top, causing the sea side to overhang on the face and

Opening of Centre Joint

opening a crevice along the centre joint. This opening has been called a "rift", and it will be afterwards referred to. The overhanging of the sea side is shown by Mr. Price's cross sections at 210 feet, at 450 feet, at 850 feet, and at 1400 feet from the shore, Plate 2.

Subsidence.

The sinking of the Pier walls into the rubble bank below them, added to the sinking of the bank itself into the original sea bottom, have together produced a considerable result at Kurrachee, shown on Plate 4 accompanying Mr. Price's paper. The sea side of the Pier walls in shallow water at 200 feet from the shore is now 24 inches below the level to which it was originally built, and the sea side of the Pier walls in 5 fathom water near the head is 36 inches below the level to which it was originally built.

Subsidence of walls built on Embankments of rubble stone.

This is such an important point in every structure of the nature described; and, as it must soon develop itself on a considerable scale in the Piers at Madras,

I beg you will excuse my dealing with it a little more particularly, by quoting two or three paragraphs from a report of mine to the English Admiralty on a work at which I passed several years in the Channel Islands. I venture to do this, because at the work referred to all the elements of sea difficulties were concerned, and each of them existed to an extent unknown elsewhere. In this case there was no leaning system: the beds of every stone in the work were horizontal and the joints were vertical.

Alderney Pier.

"The depth of the original sea bottom under the Pier increased from the shore to 130 feet below low waters of the lowest tides at the head. The depth of water in which the outermost 600 lineal yards of the pier were constructed was 105 feet below the lowest tide level on the average, and the original depth under the outermost 300 lineal yards of the work averaged 125 feet.

"The Pier is exposed to the whole force of the Atlantic, the wildest winds of which strike it at right angles, and the destructive power of the sea is greatly increased by

Depths of water.

Winds and tides

by the rapid tides surrounding this island. The current of the tides sets westerly against the storm for nine hours out of the twelve with a velocity second only (if it is second) on the coast of Europe, to that of the streams of the Pentland Firth. The rise of tide at ordinary springs is 17 feet, and at extraordinary springs 25 feet.

"Difficulty of work.

This stormy sea, rapid tides, and excessive depth of water have caused great difficulty in executing the work, and still more in maintaining it. The sea, the rapid streams, and the deep water may be found elsewhere, but the Pier, a mile in length, built out to meet them can be seen at Alderney alone.

"Construction.

The Alderney Pier consists of an artificial base of loose rubble stone of various sizes, 52 yards in width at the top, dropped on the bottom from hopper barges, towed by steam tug boats to the work, and on the top of the base a superstructure of masonry, founded 16 feet below low water level. The submarine courses of the superstructure were placed by helmet divers, and above them a solid wall was built of cyclopean strength and dimensions, set water tight

throughout with the same cement from the Isle of Wight. The Pier walls were built in short lengths of from 30 to 60 feet each fortnight, or rather each successive spring-tides, in the summer months, the measure of such lengths above low water depending on the weather and on the extent of submarine walls brought up to low water by the helmet divers in the previous fortnight. The work of building walls was suspended in the winter months, from October to April, and the annual rate of progress was 400 or 500 lineal feet.

Subsidence was the inevitable result of setting even a single course on the top of this great embankment. The walls by their weight compressed like a sponge the mass of loose stone below them. Subsidence continues to go on for several years after the walls are built, until it finally amounts to one seventh part (about 6 per cent) of the depth of the bank, but the greatest part of it takes place within the first month or two, and the consequence is that a crack, or fissure, or a opening of the joints, exists at each division or junction between walls of.

Pier Walls
built
in lengths.

Subsidence of
Walls.

C, and the rest of the block rested on artificial filling. After the wall was brought up and exposed to the sea of the South west monsoon, the sea side moved forward and overhung. This let the water into the centre joint, and the continued blows of the sea pressed out the harbour side, D. E. This is the manner in which Riffs, or openings of the centre joint, have been formed at Kurrachee. A rift of some 50 feet in length, from 700 to 750 feet from the shore, now exists on the centre line at Manora; and, no doubt, this opening, which has a maximum width of 16 inches, will be filled up as soon as the action of settlement has ceased there. It should be observed that along the outermost, most exposed, and deepest half of the Pier, under which the foundation was rather more favorable than elsewhere, the centre joint does not open: on the contrary it becomes closer with time.

Proposed Piers
at Madras.

The leaning system of blocks on their edges applied at Kurrachee is proposed

for the Piers at Madras. For a length of 500 feet next to the shore of each Pier *AE, CF*, in the accompanying Plan, three courses in height are intended, namely, a Wall 24 feet high by 24 feet wide, as at Kurrachee, and for the remaining lengths *AB, CD*, 3350 feet ~~in length~~ in each case, four courses in height are intended, making the outer portions of the walls 29 feet in height by 24 feet in breadth. The tops of the walls throughout are intended to be 5 feet above mean sea level.

It is also intended to dispense, at Madras, with bond on the cross sections of the Pier walls, which are proposed to consist, as at Kurrachee, each of two walls 12 feet in thickness placed back to back. It is further proposed to apply a system

of joggles in the beds of the blocks for the purpose of preventing any block being drawn by the sea without bringing with it the block immediately below or above it. The joggles are to be formed on the blocks themselves, a projection on the upper bed of each block, except those of the top course, fitting into a corresponding recess in the under bed of the block next above it. So far as

Cross Sections

I am aware, no provision has been made for tying the sea and harbour sides of the walls together, with a view to preventing openings in the centre joints. A Cross Section of the deepwater Piers, as proposed at Madras, is drawn on page 28.

Bond in Cross Section.

On the question of bonding the two sides together, it happens that on 9th November last, in the Institution of Civil Engineers, "there was a strong concurrence of opinion of the highest Authorities" in favour of such bonding; and Mr. Parker himself goes minutely into the question on pages 50 to 52 of that discussion, to which I beg to refer you.

Natural bottom, Madras Roads.

The natural sea bottom of Madras Roads, although I am not yet in possession of full information on this subject, consists, speaking roughly, of loose sand from the shore to the line of 5 fathoms water, and, outside the 5 fathom line, of a bed of clay. - It is too soon to express an opinion on the extent to which the laterite rubble deposits in the foundations of the Pier Walls may sink into the sand and clay of the sea bottom. - Whatever this may

amount to, there are no protruding rocks in the lines of the Pier, as in the case of Manora.

As regards the subsidence of the Madras Pier Walls into the beds of rubble latite which are to form their foundations, the conditions appear to be favourable, in consequence of the high specific gravity, and the closely packing nature of the latite itself.

Subsidence
of Pier Walls
in latite
deposits.

Mr Price, the Superintendent at Kurrachee, has authorized me to quote his paper read at the Institution of Civil Engineers on 9th November last. — It is possible that I may have been led into some mis-statements in consequence of limited information concerning the place, — but I have endeavoured to describe the character of the work fairly, as it appeared to me the other day.

The following papers accompany this to your address:—

Excerpt-Proceedings, Institution
of Civil Engineers, London,
9th November 1875.

Photo-lithographed Plan of
Proposed Harbour at Madras.

I have the honour to be
Sir,

Your most Obedient Servant,

James Ellery,

Madras Harbour

Works

Feb 1/76

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1 Semi-offl letter from Capt of Madras
Harbour Works of 29.3.76 & its reply from
the Secy of 1st March 1876.

PW 1876 Deptt
From No 1850-A
The Superintendent
Madras Harbour Works
To The Secretary to Government
Public Works Department
Fort Saint George.

Dated 11th
Dec 13th } March 1876
E-2⁺ No 116 W.

Submit Report on
Kurrachee Harbour Works

Cd 20 April 76 No 987

No 260

Cd 18-4-76: VTD-20-4-76.
Deps to Comm 18-4-76 R 2-4-76.

Cir 13-3-76

No 987. P. O. Deptt
Proceedings of the
Madras Govt
under date 20th April 1876.

Read the following
From Supt. Madras Harbour Works (H.S. No. 46 W d 11. March 76)

Mr. May is thanked
for his full and
interesting Report on
the Kurrachee Breakwater.
2. It would appear that
though the nature of the
ground on which the
piers are founded, will
be deposited at Madras
is probably such as
to render lateral dis-
-locations, unlikely to
occur, yet that an
-doubtedly subsidence
to a considerable extent
may be anticipated
in these foundations.
And, considering the
effect of the sea, in
moving large blocks,
there

Supt. Madras Harbour Works

12
Harb
the

there appears to be
room for apprehension
regarding the unprotected
Rubble bank composed
of small laterite stones
which are to run
out into $2\frac{1}{2}$ fathoms
water.

3. The Report will therefore
be communicated to Mr
Parker, and that further
action will be requested,
through the Secretary
of State for India,
to report whether he
considers it necessary
to ~~make any~~ ^{add to the height} make any change in
or ~~additions to~~ ^{of the structure as} the structure as
designed by him, in
order to counteract
the subsidence that
may be ~~reported to~~ ^{reported to} take place; and
what precautions he

would

Copied
Dup

Cin 13-3-76

07/15

proposes to take for
the preservation of the
sea faces of the
Rubble bank between
the shore and $2\frac{1}{2}$ fathoms
water, before next monsoon

Quesada

$\frac{23}{2}$

Sept. Mr. H. W. No. 1 Dept. 4-5-76
Maine Dept

1850 A.S.

Govt. of 1870: Madras.

PUBLIC WORKS.

To

100 Sept 22 76
the Dept. Madras Harbour Works

Dated

Issued

Recd

Encl.

G. O. 20th Sept 1876. No. 987

No. 2

Thurva chee Harbour

Works - Passing order

on the Report submitted

by Mr. [unclear]

For [unclear]