

(Paper No. 2445.)

“Rao Shri Pragmalji Bridge, Mandvi, Kutch.”

By CLEMENT MORISCRIP SYKES, Assoc. M. Inst. C.E.

MANDVI, situated on the west bank of the Rukhmavati, is the most important town and the chief seaport in the province of Kutch. It has a large shipping trade with Zanzibar, the Persian Gulf, and the Indian Coast, but the inland traffic was until recently much impeded for want of a bridge. The Rukhmavati, like most Indian rivers, is nearly dry in the fair weather; but to cross it, even at that time of the year, is a work of great labour both to man and beast, as the bed is composed entirely of sand to a depth of from 6 to 12 feet. At high-water the cart-tracks are covered, so that it was necessary, in the absence of other means of transit, either to await the falling of the tide or make a long detour over the sand, and during the monsoon floods it was simply impassable.

The State, under the Presidency of Colonel A. M. Phillips, obtained the loan of the services of Mr. W. S. McClelland, M. Inst. C.E., from the Jamnagar State, in Kathiawar, and he, at the request of the Council, made a survey, and submitted designs for a bridge, of the following description:—

	Feet.
Twelve segmental arches with a span of . . . . .	44·00
Versed sine . . . . .	5·50
Radius for intrados . . . . .	46·75
Radius for extrados . . . . .	58·92
Depth of keystone . . . . .	2·00
Voussoirs at springing . . . . .	3·00
Height of piers . . . . .	15·00
Thickness of piers . . . . .	6·00
„ of abutment. . . . .	14·00
Width of roadway . . . . .	20·00

The total length of the bridge, including wing-walls, was 694 feet, and this was made up as follows:—

Twelve arches, 44 feet . . . . .	528
Eleven piers, 6 feet . . . . .	66
Two abutments, 14 feet . . . . .	28
Two wing-walls, 36 feet . . . . .	72
Total . . . . .	694

The highest flood observed was in 1884, when there was a depth of 17·79 feet of water under the arch at the east abutment. The banks of the river near the town are not well defined, more especially on the western side. The bed, as has been already mentioned, is sand, and below this there is a stratum of indurated clay, locally called "muram," which forms in some places a conglomerate of considerable firmness, and in others a sort of clay sandstone.

The work of the bridge was originally commenced under the guidance of the State Engineer, but it being thought advisable to have European skill and supervision on a work of such importance, Mr. McClelland, Engineer-in-charge of Harbour Works, was asked to take the work under his care, and the Author being then on the spot as assistant to the Engineer-in-charge, Harbour Works, Mandvi, was appointed Superintendent of Works. The Author had great difficulties to contend with. He not only had to see the works carried on, but at the same time to manage three different quarries—at considerable distances from one another and from the site of the bridge—for the stone required. Great endeavours were made to get contractors for material, but Kutch not possessing many men experienced in dealing with such large quantities, and the few there were banding themselves together, the Author was compelled to have the quarrying done by the department.

The stone used for foundations, piers, abutments, backing, spandrel and wing-walls, was a littoral concrete sandstone of very coarse grain—like sandstone grit. The nearest quarries were situated on the coast about 12 miles from Mandvi; but as the earliest month during which they could be worked was September, and no stone could be got after the setting in of the west winds in the beginning of March, it was found imperative to seek in other places, and the quarry ultimately chosen was the one at Kutri, 24 miles east of Mandvi, as the crow flies. This being up the Gulf of Kutch, is protected, so that the boats were able to ply till late in the season. The average quantity of stone brought in per month was 4,000 cubic feet. It was conveyed in boats, and thrown out about a mile from the site of the bridge—excepting at spring tides—and was then transported to the works by a light tramway on the river-bed. Besides the sandstone, a kind of yellow trap had to be worked for the arch-stones, parapet-walls, and cornice. It was obtained from a quarry at Ondote—a village under one of the Bhayats of the Rao—14 miles to the N.W. of Mandvi. There were no properly constructed roads to the place, which made it very difficult for the bullocks to drag the carts across

country with blocks weighing from 1,100 to 3,700 lbs., such as were required for the voussoirs at the haunches and skew-backs. The total quantity of stone quarried was 68,534 cubic feet, and the cost, landed at the work, was Rs. 50.75 for 100 cubic feet. Lime was also made departmentally. It was burnt in a flare-kiln and cost Rs. 19 4a. per 100 cubic feet.

While the stone and the other material was being got together, the excavations for the foundations were steadily progressing, and between November, 1883, and the middle of June, 1884, all the piers and the abutments were finished and left during the monsoon. An unprecedented flood from an abnormal rainfall of 64.95 inches<sup>1</sup> necessitated raising the piers 3 feet. The turning of the arches was commenced on the 17th of January, 1885, and on the 21st of May of that year, the last centering was struck. This gives an average of  $10\frac{1}{2}$  days for each arch, setting and removing, centering and fixing ahead for the next; but as the first took a longer time than the others, owing to the men being new to the work, the average may fairly be taken as 9 days for each arch. The foundations at the western abutment were 9 feet in sand, and 9 inches in muram, and the depth increased from this until at the eastern abutment they were 8 feet in sand and 6 feet in muram. To keep the water out of the last six piers and the abutment was a work of considerable difficulty; and a centrifugal pump, delivering 1,000 gallons per minute, had to be worked continually. The foundations up to the water-level—namely, a depth of 14 feet at the eastern abutment—were built in Portland-cement mortar in the proportion of 1 to 5. The piers are 15 feet from low-water level to the springing course, and 6 feet wide, the cut-waters being formed of starlings disposed along two sides of an equilateral triangle having the pier for its base. The masonry is rusticated block-in-course, with 1-inch chisel draft. The arches are of the yellow trap from Ondote, solid fine-dressed ashlar with  $\frac{3}{16}$ -inch joints. The impost, cornice and parapet wall is also of same stone, all fine-dressed.

The arches were turned on timber centering, of five ribs each; four sets were used to enable the work to be pushed on more rapidly for fear of floods. There were, however, none above the ordinary level that year, although some were sufficiently high to

---

<sup>1</sup> It is said that Kutch is visited by an extraordinary rainfall once in a cycle of forty years, but as there are no statistics going back so far as 1844, the validity of this assertion cannot be refuted. The average rainfall from 1848 to 1853 for Kutch is 12.59 inches. At Mandvi it is about 15 inches; so that the above fall is more than four times the usual amount.

have damaged the works had they not been finished betimes. The centering was supported on five trestles, with posts 8 or 9 inches in diameter ; these were all braced together by diagonals and made as stiff as possible ; over each set of uprights was a pillar-plate 10 inches by 5 inches, extending right across the arch and supporting, by means of cast-iron sand-boxes, the five ribs. To prevent the whole structure from settling into the sand a sill-plate 10 inches  $\times$  5 inches was fixed between the uprights ; and at each point of support, all the loose sand being dug away, large flat stones from 3 to 4 feet square were placed so as to distribute the load. This was found to be fairly firm, but it had to be wedged up occasionally by wedges put between the stone and the sill-plates—as spring tides always caused a slight amount of movement. The centres were struck as soon as the key-stone was placed in position, and the ultimate average settlement of all the arches did not exceed  $1\frac{1}{4}$  inch.

The cost of masonry, arching, parapet and cornice, is given in Appendix I ; and the cost of centering per arch in Appendix II. The bridge was declared open for traffic on the 19th of January, 1887, by H. E. Lord Reay, Governor of Bombay.

The Paper is accompanied by four tracings, and two pen-and-ink sketches.

## APPENDIXES.

## APPENDIX I.

	Rs.	As. P.
283,076 cubic feet excavation for foundation . . . . .	8,322	8 5
43,219 „ filling . . . . .	13,193	7 0
108,148 „ superstructure, sandstone . . . . .	25,568	11 11
3,078 „ impost cornice, and caps of cutwater of Ondote stone . . . . .	2,779	3 6
37,000 „ arching—Ondote stone . . . . .	40,605	14 11
11,767 „ backing . . . . .	2,394	3 3
16,968 „ cornice and parapet of Ondote	15,694	11 7
<i>Centering—four sets :—</i>		
Cost, with labour for setting up, &c. . . . .	10,399	10 11
Sand-boxes . . . . .	553	2 1
Road over bridge, and western approach . . . . .	4,392	5 2
	1,20,609	11 3
Contingencies . . . . .	5,405	14 5
Total rupees . . . . .	1,26,015	9 5

The sandstone used in the masonry cost per 100 cubic feet, delivered on the site, Rs.10 9a, and the Ondote quarry stone per 100 cubic feet, Rs.50 12a. The lamps and lamp-posts with fixing cost an additional Rs.3,419 3a.

## APPENDIX II.

	Rs.
Cost of centering, sand-box, with labour for shifting, &c., per arch . . . . .	912·74
Cost per cubic foot of arch . . . . .	0·295
Cost per running foot of span . . . . .	20·74