

Crossing the River

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CROSSING the RIVERS



NOTABLE BRIDGES ON THE B.B. & C.I. ROUTE

When the project of connecting Ahmedabad and Bombay by a line of railway was first conceived it may be imagined that the projectors, on consulting their maps, must have instantly realized that, as far as the "lie of the land" was concerned, the route was more favourable than the routes of the lines projected to lead eastward, north-eastward and south-eastward from Bombay, the lines that, at all costs, had to be driven through the Ghats. Parallel with the west coast, it was apparent that the southward line to Bombay would, throughout its entire length, be unimpeded by any considerable geological tumuli. So far as that particular source of obstruction was concerned, its path was fairly clear. The terrain was favourable.

There remained, however, for recognition the unvarying fact of physical geography that, usually, rivers, however remote their source and however tortuous their course, eventually find their way to the sea; and thus a line of railway extending along a littoral tract for a great distance must naturally be carried over a number of seaward flowing streams at the widest part of their courses.

Examination of the position must have shown that although the Western Ghats could be evaded by the proposed line, the rivers draining the Vindhya, the Satpura, and the Aravalli hills, would have to be bridged at the lower end of their courses, and only a short distance from the point where they disembogue into the sea.

It must have been clear then that river-bridging would constitute the chief engineering work on this particular section of railway, for if the shortest and easiest route were to be followed, there was no apparent alternative to the crossing of several creeks and large rivers within estuarial limits.

THE FIRST BRIDGES

But if sixty or sixty-five years take us back to the beginning of the B.B. & C.I. Railway, the same period also takes us back to an early, if not the earliest, phase of what is called the Railway era; and it must be remembered that in those days the bridge-builder had not the advantage of the record of accumulated experience available to the engineer of the present day. The science of railway-bridging had not yet been fully developed, and so, in the circumstances, it would not be surprising if there had been some miscalculations in the design and construction of many of the largest river bridges. Disadvantaged as they thus were, compared with the bridge architects of the present time, it must be generally agreed that, as pioneers, they, nevertheless, accomplished very good work.

Nowadays the bridges have to bear a much heavier load, and the vastly increased traffic has put a much greater strain on the stability of the structures, even if we reckon without the water's action on piers and abutments, Doubled, and even trebled, locomotive weights demand bridges with a corresponding increase of

strength, the fact further emphasizing the truth of the saying that the bridges are the keys of a railway. They are the regulators of the traffic situation.

This fact is of special significance in view of the increasing need for accelerated services, and consequently, the employment of a heavier and more powerful type of locomotive. And here it will not be beside the point to remark that in India, bridges with speed restrictions are responsible to an appreciable extent for the apparently low speed averages registered on the longer runs.

BRIDGE VERSUS RIVER AND TRAFFIC

A bridge carrying a line of railway across a very wide river can scarcely ever be regarded as a permanent structure. It is subject to two sources of deterioration. In the first place it has to withstand the stress of heavy and continuous rail traffic, and, secondly, the action of the river's currents or tides on the piers and abutments. But, whereas the strain from traffic may be regarded as ordinary wear and tear, the action of the river, particularly at flood times, may be a positive danger. Structurally, the bridge may be all that



Balaram Bridge MG

could be desired, may be theoretically and practically sound, yet its security may be sapped in the course of a night by a violent flood.

Even the soundest type of bridge in such circumstances needs watching, and, furthermore, it is clear that the engineers concerned must necessarily be students of the ways of rivers, for, after all, it is the character of the river that determines the design of the bridge by which it is to be spanned, and the action of the river periodically and constantly must be the main determinant in gauging its strength and durability.

BRIDGE TYPES

Apparently there are as many types of railway bridges as there are recipes for making sauce. The adoption of a standard design is scarcely feasible. The engineer plans to suit local requirements and, in the circumstances, aesthetic consideration may be out of the question, yet it cannot be denied that several of the railway bridges that span the great Indian rivers are really impressive when viewed from certain aspects, and make fine pictures, although picturesque effects were not sought in the design. Further, it is well to observe that the great river bridges of India add a good deal to the tourist interest of the railways.

“RESTRICTIONS”

As we know, trains while passing over the Nabada and other bridges invariably reduced speed to a minimum – almost to a “crawl”. To the average person it may seem that the reason for the reduced speed was simply that the bridge was not quite safe for fast trains. This, however, would be an erroneous assumption, for had the bridge been actually unsafe, no train would have been allowed to pass over it.

Without the use of mathematics it may, however, be simply explained that the slow speed of trains not only ensures a wide margin of safety, but directly conduces to the longevity of the bridge. The slow speed in such cases is not to be taken as a direct indication of the bridge's strength. It would perhaps be nearer the truth to state that it rather indicated a desire not to subject

the structure to unnecessary strain.

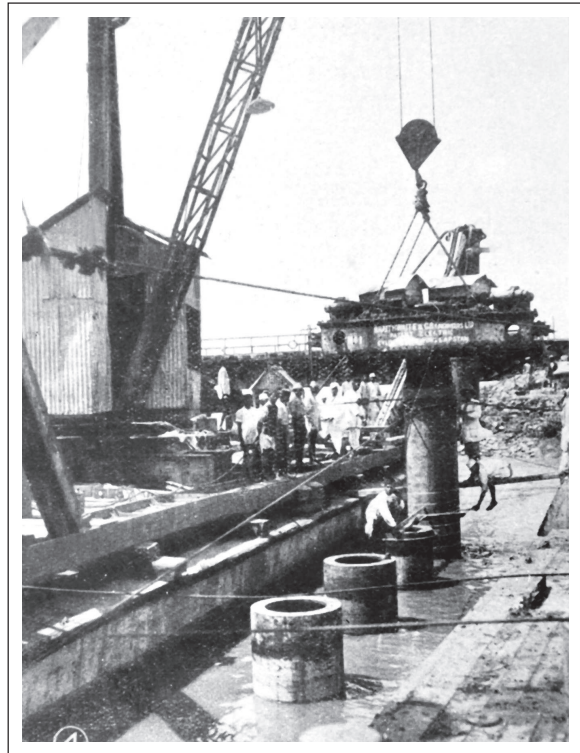
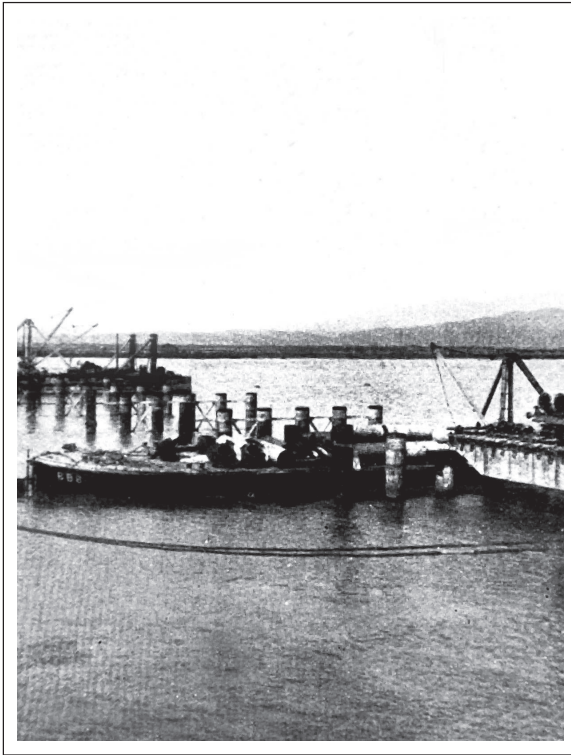
It is here we get in contact with the question of “stresses”, on the subject of which an observation made by Sir B. Baker in 1885 may be worth quoting. Addressing the British Association he declared that “hundreds of existing bridges which carry twenty trains a day with perfect safety would break down quickly under twenty trains an hour.”

A RAILWAY WITH MANY BRIDGES

Each of the leading Indian railways can point to at least one admirable specimen of bridge work. The Bombay, Baroda and Central India Railway can point to several, for, as already indicated, it is a railway system, of many bridges; and the design, building, and strengthening of these has constituted the company's chief engineering concern since the construction of the line.

In the course of a railway journey from Bombay to Ahmedabad, Agra or Delhi, one can scarcely fail to note the extent of this bridging work. Proceeding northwards from Colaba we may note that a simple structure suffices to carry the line across the waterway that separates the island of Bombay from Salsette. Further northward, where the train takes us out of the island of Salsette and into the mainland, we encounter what we may regard as the first considerable obstacle on the route, in consequence of the line having to traverse a coastal tract, and this strip of territory being indented in some places by the Arabian Sea. At this point the indentation assumes the form of a tidal creek which separates the island of Salsette from the mainland through a historic district. Three centuries have completely changed the face of Bassein, at one time a flourishing Portuguese town and port, and famous for its shipbuilding. Describing the place a historian writes :

“With straight streets, large squares, stately two-storied dwellings graced with covered balconies and large windows and many rich and magnificent churches. Bassein, was next to Goa, the largest and richest of the Portuguese settlements.”



Rebuilding Bassein Bridge: The Pile Screw Capstan at work

CROSSING THE CREEKS

The crossing of the insulating creek of Bassein, or Thana, has involved the construction of two separate bridges, advantage being taken of the island of Panjoo, which, besides affording facilities for construction, enables a division being made of the bridging work into two independent sections which otherwise might be one continuous structure extending from shore to shore. As it is, it will be seen that the South Bassein bridge is only 394 feet shorter than the Narbada bridge. It is thus the second longest bridge on the B.B. & C.I. system. But in one sense both structures might be regarded as a combined work, seeing that one is really a continuation of the other in the complete project of carrying the line across the creek, or rather creeks. Looked at in this respect, it would of course be the most extensive bridging work on the company's system, besides being one of the longest bridges in India.

The Bassein creeks are tidal, the difference between the highest and lowest tides being 15 feet, and the depth of water at the highest tides varies from 15 to 41 feet. The south bridge is 4,312'-6" and the north 1,562'-6" long. Borings show that the beds of the creeks consist of silt, mud, and sand, overlying a bed of stiff clay at depths varying from 50 to 80 feet below the surface.

THE OLD BASSEIN BRIDGES

The old bridges were opened to traffic in 1864, and consisted of double spans of 60-foot deck Warren girders, carried on 2'-6" diameter cast-iron screw piles, screwed to depths varying from 20 feet to 72 feet below bed level. The piers are 62'-6" centres, and each pier consisted of three piles 14-feet centres, braced together and surmounted by bearing girders 14 feet long. The south creek was crossed by 69 such spans, and the north creek by 25. The method of screwing employed was to fix a capstan to the top of the pile having radiating poles 40 feet long to which 16 yoke of oxen were harnessed. These walked round in a circle on rafts securely moored in the desired position.

In course of time both the girders and the foundations were found to be weak for the increasing loads, and between the years 1896 and 1902 it was found necessary to strengthen these bridges. The Warren girders were replaced by the existing fish-bellied plate girders, and at the same time the foundations were strengthened by the addition of 2'-6" diameter screw piles to each pier, one on the east, and the other on the west, and the introduction of a continuous girder over the five piles.

The method of screwing these additional piles was a slight improvement on the use of oxen. Here the capstan had radiating arms forming a circle, 12 feet in diameter, round which two wire ropes were wound in opposite directions and the falls fastened to hand winches.

THE NEW BASSEIN BRIDGES

It was soon found that the strengthened bridges were not up to the increasing traffic and loads, and investigations for replacing the bridges by new structures were started. At the same time speed restrictions of 15 miles an hour for locals, and 8 miles an hour for through trains, were imposed. This necessitates the following times for crossing the bridges :

	South	North
15 M.P.H.	3 mins. 16 secs.	1 min. 11 secs.
8 M.P.H.	6 mins. 7 secs.	1 min. 11 secs.

Various alternative crossings were considered, and eventually it was decided that the new structures should be built 120 feet east of the existing ones so as to avoid the stone pitching which has been dumped round the old piers. They are to have the same number and length of spans as the old bridges, but the superstructure will be of a strength up to the B.B. & C.I. standard, loading of 1916.

The piers will be of braced cast-iron screw piles. Each pier will consist of six piles spaced 9 feet centres. Five of these piles will be 3 feet in diameter, with a 5'-8" diameter cast steel blade, whilst the westernmost, or fender pile, will be

2'-6" in diameter, with a 4'-6" diameter blade. The easternmost pile is being kept 3 feet in diameter so as to allow of the future widening of the bridges when the line is quadrupled to meet the increasing suburban traffic.

The piles are to be founded on the stratum of hard clay previously mentioned. It is believed that the screwing of such large screw piles to such depths has not been attempted before. In

where the main stacking yard, power house, stores, etc. are situated, and from which work will be carried on in both creeks simultaneously. Preliminary work on the formation of approach banks and stacking yards, etc., was commenced at the beginning of 1920, but it was not till the beginning of 1923 that any preparatory work for the actual bridges was taken in hand. It was at first expected that all plant would be ready for



Tapti Bridge consisting of ten 187'-6" Spans

order to obtain the necessary penetration, a solid nosed cast steel screw has been adopted. This will also save the removal of soil from the interior of the piles.

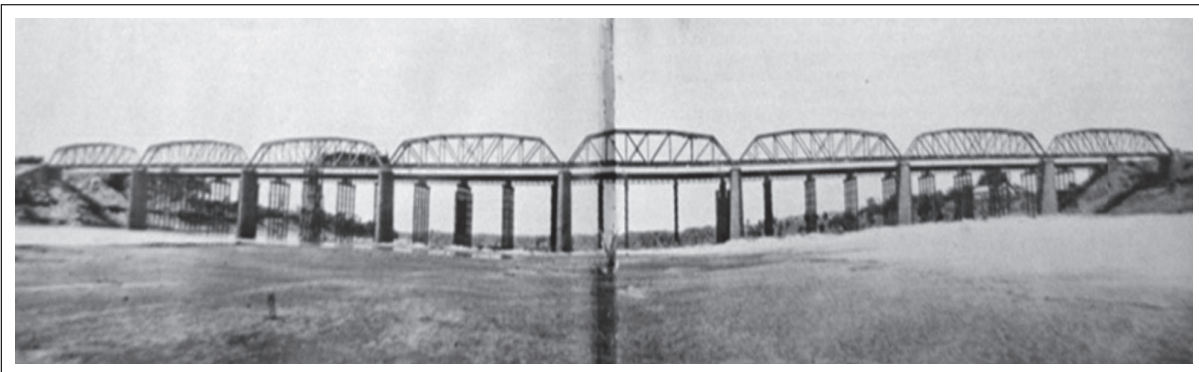
The screwing of the piles will be done off barges suitably moored; four electric capstans patented by Messrs. Braithwaite and Company, Ltd., West Bromwich, being used. After being screwed to complete depth the piles will be filled with Portland cement concrete, braced and capped to receive the main girders. These latter will be assembled and riveted complete on land and then floated into their final position.

The island of Panjoo is the base of operations

work in the creeks for the working season 1923-24, but non-delivery of electrical and other plant delayed the whole programme, and it is estimated now that the completion of the bridges will take till the year 1926.

VAITURNI RIVER AND BRIDGES

Fifteen miles north of Bassein, and forty-five miles from Bombay, the B.B. & C.I. line crosses the first considerable river on its northward route, the Vaitarani, or Vaiturni river. It is mentioned in the Mahabharata as one of the four sacred streams, and was said to have been brought by Parashuram, the sixth incarnation of Vishnu. Its source is in the Trimbak hills in the



Mahi Bridge consisting of eight 220' Spans

Nasik district, opposite the source of another river noted for its sanctity, the Godavari, which rising within fifty miles of the Arabian Sea, after rambling through primeval Deccan jungle, and one of the least explored regions of India, flows into the Bay of Bengal after a course of 900 miles. The fact is worth mentioning that a short distance before it reaches the sea this famous stream is crossed by the Madras and Southern Mahratta Railway, the bridge, 1¾ miles in length, being the second longest in India.

Of the Vaiturni, which is navigable for about twenty miles from its mouth, it is said that

“the sacredness of its source, so near the spring of the Godaveri, the importance of its valley, one of the earliest trade routes between the sea and the north Deccan, and the beauty of the lower reaches of the river, brought to the banks of the Vaiturni some of the first of the Aryan settlers. Many seers, among them Narad, Vashistha and Indra, resorted to it, and, for bathing and sacrifice, came the super human Yakshas, Ghandharvas and Kinnars.”

The two arms of the river are crossed by similar bridges to those at Bassein, the southern one having 20 and the northern 23 spans, each span being 60 feet clear. The channels are tidal, but, during the monsoon, carry large additional volumes of flood water. The ordinary variation in water level due to tides is 13 feet, and the depth of water at high tide varies from 12 to 28 feet.

NEW VAITURNI BRIDGES

The construction of the new bridges will be taken in hand on the completion of the work at Bassein. The new alignment will be 120 feet west of the existing one, and the bridges will be similar in design to those at Bassein.

“IN FORMER TIMES”

Digressing from the subject of rivers and bridges here, it may again be noted that the line from Bassein onwards to Surat and Broach still takes us through “a land of story”. Research will, doubtless, discover that every stream and creek,

hill, valley, and village, in this tract has its tale of the past, a past that goes back to India’s epic age.

It is a region wherein Moguls, Portuguese, and Mahrattas formerly strove for supremacy; and although centuries have brought oblitative changes, even at the present day we can realize how the tropical richness of this strip of sea border was such as might have conducted to strife for its possession. It is not to be wondered that it had an attraction for the inland invader as well as for the maritime adventurer.

Much has been heard concerning the pirates of Malabar; much less, perhaps, has been heard concerning the incursions of the Arab pirates into the sheltered creeks and river estuaries of the coast from Bombay to the Gulf of Cambay. We can imagine that the B.B. & C.I. route at some points would have been quite within the area of their depredations.

TAPTI RIVER AND BRIDGE

Almost immediately after leaving Surat station the train brings us in sight of the river Tapti and one of the B.B. & C.I.’s big bridges. As the bridge had to be built to suit the Tapti, a brief description may here be necessary to give an idea of the general features and character of this important river.

Rising in the Betul district of the Central Provinces the Tapti has a course of 450 miles, in the early part of which it cuts a way between the spurs of the Satpura mountains, the Chikalda hills of Berar on the left, and the wilder range of Kalibhit on the right. At the narrow passages known as the Deer’s Leap, or *Haranphal*, the river descends from Khandesh to the plain of Gujarat.

Leaving the Dang forests, the Tapti enters on its last stage - the passage across the Surat plain to the sea, a distance of about seventy miles. The tidal section extends through the fertile plain that forms the central part of the district of Surat. Only for a few miles before it falls into the sea are the lands on either side liable to be submerged by the tide. Below Surat, the river

stretches to the south-west till about four miles from its mouth it turns to the left, and, gradually widening, flows southwards into the sea.

Between the villages of Waracha and Phulpara the Tapti, in times of flood, has overflowed its left bank and inundated the town of Surat. Below tidal limits the bed of the river is covered by a layer of mud. This deposit varies in depth from a few inches, where the tide runs strong, to as much as four feet in the still bends of the river. Opposite the city of Surat, at Umra, two miles, and at Magdala, four miles further to the west, the sand washed down in times of flood has formed banks and shoals, especially at the mouth of the river where the antagonistic currents of the stream and tide have, across almost the entire breadth of the river, thrown up alternate layers of sand and clay.

SCENE OF A SEA FIGHT

Well known in the early days of commerce with India, the port of Swally (Suwali), the scene of a famous sea-fight, was situated at the mouth of the Tapti. It is now deserted, and its approaches have completely silted up.

The Tapti has a drainage area of about 30,000 square miles, and carries to the sea a volume of water estimated to vary from an hourly discharge of 120,000,000 cubic yards during the seasons of high flood, to 25,000 cubic yards towards the close of the dry weather months.

Before the days of the railway it was at one time thought that the river might be made the highway for the carriage of the produce of Khandesh and the Central Provinces to the sea. The survey of the river, which was made with this object in 1852, extended over a distance of 232 miles from the city of Surat to the confluence of the Wagher.

A 1915 BRIDGE

The original Tapti bridge of 30 spans, built when the line was constructed, was on 2'-6" piles, and consisted of 60-ft. Warren girders. The new bridge, which was opened in 1915, consists of 10 spans of girders which carry double line

track and are supported on masonry piers built on well foundations. Unlike conditions at the Narbada, there is no scour caused by floods or tides. Trains pass over the bridge at full speed.

THE NARBADA

Arrived on the banks of the Narbada, and within sight of the old port and city of Broach, a casual observer from the railway carriage window can scarcely fail to comprehend the magnitude of the task involved in the bridging of one of the great sacred streams of India. The slow movement of the train enables the passenger to get a clear view of the river's noble expanse, where it flows past the elevated, fortress-like town on the north bank, once so much associated with maritime trade and adventure, and now commercially identified with the "land of the cotton."

FROM AMARKANTAK TO THE SEA

Issuing from a small tank at Amarkantak, a massive flat-topped hill, 3,493 feet above sea-level, the Narbada has a remarkably varied course of 800 miles. It is one of the great rivers of India, second in sanctity to the Ganges, and is traditionally regarded as the boundary between Hindustan proper and the Deccan. The total area of its drainage basin is estimated at 36,400 square miles, and its maximum flood discharge has been calculated at 2,500,000 cubic feet per second. Throughout its entire course, the Narbada drains, rather than waters, the country through which it flows.

At the edge of the Amarkantak plateau the river falls over the black basaltic cliff in a cascade of seventy feet, called Kapila-Dhara. Further on is the smaller fall known as Shudhdhara, or the "Stream of Milk," the myth being that here the river once ran with milk instead of water.

After descending some hundreds of feet by falls and rapids from the heights of Amarkantak, the Narbada enters the Central Provinces and flows along the valley shut in between the parallel ranges of the Vindhya and Satpura

mountains. During its passage through this region its course is interrupted by several falls and the river is fed by numerous tributaries.

At Makrai, the Narbada leaves the tableland of Malwa to enter the plain of Gujarat. For the first 30 miles it separates the Gaekwar's territory of Baroda on the right from the state of Rajpipla on the left, and then, for the remaining 70 miles of its course, including many windings, it intersects the fertile district of Broach. Its average breadth here varies from a mile to about half a mile. Below Broach city it widens into an estuary whose shores are 13 miles apart where they fall away into the Gulf of Cambay. The influence of the tide is felt as far up as Rayanpur, about 25 miles from Broach.

THE "GOLDEN BRIDGE"

The bridge, which is 4,675 feet in length, is the longest in the company's system. It is indeed the B.B. & C.I.'s bridge of bridges, and the scope of the problem of its construction and maintenance may be realized from the fact that a "Selection of Correspondence and Notes Regarding the B.B. & C.I. Railway Bridge over the Narbada Bridge at Broach, 1898-1899" is the title of quite a bulky publication issued by the Railway Board. Although it does not give us the entire history of the bridge, the compilation reveals the diverse aspects of an engineering problem which evidently has been as much concerned with the action of the river as with the bridge itself.

In the training of this broad tidal river, subject periodically to overwhelming floods, the object sought by the bridge engineer is aptly expressed in a note by the Consulting Engineer for Railways, Bombay in 1899. He states that "the ideal condition would be : all spans of the bridge used and a straight flow through the bridge."

SCOUR

In the case of the Narbada, as of other rivers, "Scour" is the engineer's great bogey, but, doubtless, its destructive effects are not fully comprehended by the average layman. Readers

of Mark Twain's "Life on the Mississippi" will recall the humorist's observations on the phenomena of that great river with which the author, as steamboat pilot, had a thorough acquaintance. Here, however, it will be preferable to quote from an engineering authority regarding the remarkable effects of the Mississippi's scour. The facts related are somewhat identical with conditions at the Narbada bridge.

George L. Vose, the author of a "Manual for Railroad Engineers," observes :

"The bed of a river, composed of material easily moved by the water, such as sand and gravel, is liable to change of form from time to time which it is important to regard in putting down foundations. Where the bottom scours badly, wooden piles are liable to be washed out : and even a rip-rap protection by decreasing the water-way will often bring on a scour and be the means of undermining itself. A scour will often occur on one side of a pier and not on the other; thus throwing a heavy side strain upon the masonry. This movement of the bottom is especially notable in the Mississippi."

Regarding the scour of the Narbada, an extract from a letter written in 1898 by the officiating Consulting Engineer for Railways, Bombay, may here be worth quoting, as it discloses the difficulties which confronted the bridge engineers :

In 1876 when 25 spans at the south end of the bridge were swept away by a flood running at eight miles an hour (2 miles per hour less than the possible velocity reported to Sir John Hawkshaw) and rising, it is stated, to a height of 52 feet above low-water level, the Consulting Engineer, Bombay, wrote as follows : "All the circumstances of the failure appear to me to indicate as the cause of the failure a deepening of the river bed by scour..... on the risk of deepening of the bed of this portion of the Narbada river, there was much discussion prior to 1870, the opinion which I urged having been that scour was probable and should be provided for. There has already, in late seasons, and more

particularly in the flood of this month, been a considerable alteration in the southern shore line of the river which has already changed much to the south and will require measures to prevent a still greater change in the river course."

The writer further observes :

There is abundant evidence to be gleaned from the past correspondence on the earlier bridges to show that both experience and expert opinion point to the advisability of mistrusting the capability of the clayey substrata of the river-bed to resist scour from high velocities, to the paramount necessity for keeping the piers out of reach of scour, and to the consequent necessity for constant checks upon the river's action.

OLD AND NEW STRUCTURES

The old bridge, the first structure to span the Narbada, was built about sixty-four years ago, when the line was constructed. It appears that it was on 2'-6" piles and had 60 Warren girders and a roadway. The method of construction was probably the usual one of screwing the piles. This bridge, which had 24 spans, was washed away by a flood in 1876. Details are not available regarding the character of the temporary structure over which trains passed during the period which intervened from the destruction of the old bridge until the completion of the new one.

The construction of the existing bridge which was designed by Sir John Hawkshaw began on the 7th December, 1877, and was finished on the 16th May, 1881. The bridge consists of 25 spans of girders of the type known as the "Whipple Murphy Truss." These girders are 187 feet in length overall, have a clear height of 16 feet between rail level and the underside of top bracing and carry a single track. The piers which consist of twin cast iron cylinders 10 feet in diameter were designed with the intention of carrying girders for a double line; with the increase in loads and running dimensions that has developed in recent years, it would not now be feasible to place a second track on the existing piers. To ensure that the structure may not suffer

from the train loads now running it is necessary to impose a speed restriction of 5 miles per hour over the bridge which is 4,675 feet long and the passage of a train occupies some 10 ½ minutes.

Some 20 years ago the erosion of the south bank of the river was the cause of much anxiety and for a time it appeared as if the south approach to the bridge was in danger. On the advice of Mr Spring a heavy stone groyne was constructed almost at right angles to the line at the south abutment. This groyne, of which the length was subsequently increased to about 2,000 feet, had the desired effect of checking further erosion of the south bank. Behind the groyne an extensive deposit of silt has developed and the main stream now flows straight through the bridge. While the groyne has been effective in checking erosion of the bank it has been the cause of the development of what is known as a "pot hole" in the river bed between the end of the groyne and the bridge. This "pot hole," which is the result of eddies formed by the flow from round the end of the groyne, varies in depth time to time, but is usually some 50 to 60 feet deep below the adjacent river bed.

In the dry season the normal depth of water in the channel is 20 to 25 feet. The highest flood on record was 35 feet above mean low water level.

LEGEND AND THE BRIDGE

According to local legend, it was believed that the goddess of the Narbada would never suffer her stream to be crossed by a bridge. That there was justification for the origin of the local name, the "Golden Bridge," will be seen from the following extract from the district gazetteer :

Their (B.B. & C.I.) first bridge near the city of Broach, begun in 1860, was seriously damaged by a flood in 1864, and though the repairs then required suffered from another flood in 1868, by 1871 the bridge again stood complete, after a total expenditure of £ 470,000. The unprecedented flood of 1876, which rose to a height of 35 feet above high water mark, washed away 26 spans, or 1,600 feet out of a total length of 4,250 feet. The traffic was carried on a



Present Mahi bridge with the river in flood



View of the old Mahi bridge taken from present one



Mahi Bridge at Sevalia

temporary structure, and a new bridge was commenced about 100 yards further up-stream and completed at an estimated cost of £ 375,000. Altogether the bridging of the Narbada cannot have cost this company much less than a million sterling.

THE MAHI RIVER AND BRIDGE

North of Baroda, and onwards to Ahmedabad and the Kathiawar region, the railway has still more than "one more river to cross." The most important is the Mahi, which flows into the Gulf of Cambay. After the Narbada and Tapti, it is the largest river in Gujarat, and the fifth largest in the Bombay Presidency. It has a course of from 300 to 350 miles, and an estimated drainage area of 15,000 to 17,000 square miles. The limit of the tidal flow is Verakhandi, where the stream is 120 yards wide, with an average depth of 18 inches. About 30 miles nearer the sea the river enters the Broach district from the east, and forms an estuary. The distance across its mouth from

Cambay to Kavi is five miles. During the spring tides a bore is formed at the estuary, and a wall-like line of foam-topped water rushes up for 20 miles to break on the Dehvam sands.

A venerated stream, the Mahi, according to the legend, is the daughter of the Earth and of the sweat that ran from the body of Indrayuma, the king of Ujjain. "The height of its banks, the fierceness of its floods, and the deep gullies through which the traveler has to pass on his way to the river," are believed to account for the origin of the saying : "When the Mahi is crossed there is comfort."

The B.B. & C.I. bridge, which carries the line across the river, is a structure of considerable importance. The old bridge, which was built in 1858, was on 2'-6" pile piers some 80 feet in height with Warren girders. The construction of the new bridge commenced in 1910, and finished in May, 1913. It consists of eight spans of 220 feet, girders carrying a single track on

stone masonry piers.

THE JUMNA BRIDGE

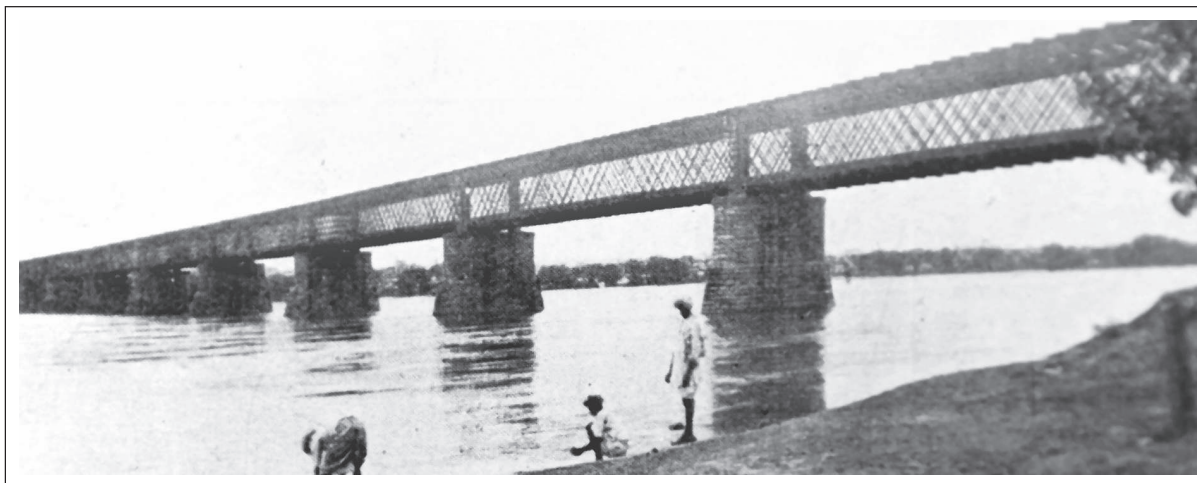
It will, doubtless, be understood that what has been written up to this stage has by no means exhausted the subject covered by the title of this article. There still remain several B.B. & C.I. bridges worth more than a cursory reference. Descriptive details would, however, exceed the limits of available printing space.

Of the remaining bridges on the broad and metre gauge systems, those exceeding 1,000 feet in length include the Chambal (1,652 feet) and the North Purna (1,070 feet). On the metre gauge both the Narbada and Jumna rivers are crossed, the former by a 2,836-ft. bridge near Mortakka, and the latter by a 1,146-ft. bridge near Muttra Cantonment, and by another fine bridge situated within sight of the "Dream in Marble," and the world's greatest tomb.

After the bridges that span the west coast rivers and creeks the most interesting and important (though not the longest) is doubtless this well-known Jumna bridge which connects Agra Fort with Tundla. Over this great bridge pass not only the metre gauge trains of the B.B. & C.I. , but also the broad gauge trains of the Great Indian Peninsula and East Indian Railways, the rails of the metre gauge being laid

inside those of the broad gauge. For those unacquainted with the "City of the Taj" it may be necessary to point out that a short distance higher up the railway is again carried across the Jumna by the E.I.R. bridge.

Writing of the Jumna, an authority mentions that Agra, like Delhi, owes much of its importance in both historical and modern times to the commercial and strategic advantages of its position on the Jumna, the river being "the natural highway for the traffic of the rich delta of Bengal to the heart of India, and it formed, moreover, from very ancient times, the frontier defence of the Aryan stock settled in the plain between the Ganges and the Jumna against their western neighbours, hereditary freebooters who occupied the highlands of Central India. The river formed an unfordable barrier and also a means of communication." It is unnecessary to explain how the commercial and strategic aspect of the Jumna "as an unfordable barrier" and "means of communication" have been altered by the advent of the railway, and the construction by the B.B. & C.I. Company of the magnificent 2,427 ft. bridge, which, while of prime utilitarian importance to Agra and neighbouring towns, adorns the famous river that flows by the historic seat of the Great Moguls.



Jumna Bridge at Agra
