THE GALVESTON HARBOR PROBLEM.

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The importance of securing a deep water harbor on the west coast of the Gulf of Mexico in developing the commercial, industrial and agricultural resources of the United States, and especially of the Trans-Mississippi region, can hardly be over-estimated.

The many elements affecting the problem in its commercial, and to some extent in its political, relations, have been ably stated in the recent paper on "Southwestern Commerce and Gulf Harbor," by Senator W. P. Frye, who presents the subject from the standpoint of the statesman, but it is quite as important that the question should be considered from the standpoint of the engineer, as it is upon this phase that the success of the project must depend.

The desirability of such an outlet for the products of the 1,000,000 square miles of tributary territory does not admit of doubt. The practicability of securing it has led to several animated discussions in the engineering world as well as in Congress, and while definite and positive conclusions have been reached by individuals, the great majority of legislators regard the problem as a huge "experiment," and are willing to defer formulating an opinion until results are obtained.

In engineering, as in legal practice, precedents are invaluable and failures teach more than successes, as they often determine the limits within which a given method may be applied with success. It is the purpose of this argument to apply this test to the locality in question, considering it first, *per se*, in the light of its own history, and second by comparison with existing conditions and results elsewhere so far as they may be applicable.

The peculiar difficulties and great importance of this question have given zest to the discussion and have

attracted the highest grade of talent to its consideration, hence its history will be found bristling with interest even to the unprofessional reader.

When, in 1869, the writer was on duty as Engineer Officer of the Fifth Military District (Texas), it was often impossible for the Morgan Line steamers, built expressly for the Gulf trade, to cross the bar at Galveston and other ports of Texas. Passengers, cattle, baggage and freight were frequently lightered ashore at great risk of being dumped into the water, or drenched by the breakers on the bar, and to this day, at many of these ports, no improvement has been effected in this tedious, dangerous and expensive mode of effecting a landing. Then, the outer bar at Galveston was three miles from Fort Point and had a channel depth across it varying from twelve to twelve and one-half feet, and vessels frequently had to "lay to" outside the bar for days awaiting a favorable wind and tide before undertaking an entrance. Having passed this barrier and rounded Fort Point a contracted channel was entered, which constitutes the harbor proper. This channel lies between Galveston and Pelican Islands, and is separated from the outer roadstead by a recent formation known as the inner bar.

In the report of Lieut. Stanton, made in 1868, it is said: "The harbor proper, obstructed by this bar, is 6,000 yards long and only 250 yards wide, measured within the 12-foot curves, affording to ships of 12 feet draught very scant space for turning about." Again, in the report of the Board of Engineers of January 21, 1886, occurs this statement: "On the north side of the island in front of the city of Galveston depths of 35 feet are found in a narrow channel. This area of 270 acres forms Galveston Harbor." * * "The main entrance to the bay * * has a present width of 8,200 feet." The depth here, in the "gorge," is 40 feet. "The interior of the bay, aside from the main entrance, has depths which do not exceed 11 feet at mean low water."

As great stress has been laid upon the capacity of the harbor for deep draught vessels, these facts assume con-

siderable importance, in view of the plans proposed for improvement, and particularly with reference to the exaggerated impressions which prevail, due, doubtless to a superficial inspection of the charts of Galveston Bay, with its 451 square miles of area.

One of the recent official reports * on this subject, guardedly states: "The entire area, inside the outer bar, containing a least depth of 30 feet, is 460 acres, and there are 1,300 acres with a least depth of 24 feet, but these areas can scarcely with safety be referred to as Galveston Harbor without explanation, because over 500 acres of the 1,300, with a least depth of 24 feet, lie outside the gorge."

In fact, these 1,300 acres are embraced in the deep pocket, situated between the two sandy barriers separating the bay from the Gulf, and the outer and inner bars. They constitute virtually an outer, open roadstead, separated from the deep waters of the Gulf by the outer bar with its present maximum depth of 13 feet, at only one point on its crest and exposed to the full force of the Gulf storms—a more difficult trap to escape from than that of Apia and one possessing very few of the requirements of the harbor, even of refuge. The "White Squadron" on its recent visit to Galveston, was unable to enter this "harbor," not deeming it safe to venture nearer than about ten miles. These physical features must be given due weight in any comparison of sites for a terminal for the great Northwest. The problem is not local, but national, and the law of transportation which most affects the site, viz: that the water carriage should be continued as far inland and the land transit be made as short and easy as possible, should not be violated.

The inner bar is of comparatively recent formation. The "oldest inhabitant" remembers when it had no existence, and where there were 30 feet of water, in 1841, the depth had shoaled to 12 feet in 1853, due to material being carried in from the outer shore of Galveston Island.

* *Ex. Doc. No. 56*, House of Rep., 51st Congress, 1st Session, dated Dec., 1889.

Up to September, 1854, the shoaling continued until the depth was but 10 feet, when a violent storm cut away its crest making a channel across it 15 feet deep. This depth remained very constant for eleven years, and in 1865, it was reported to be $14\frac{1}{2}$ feet, but in 1867 the Coast Survey found only $9\frac{1}{2}$ feet on the bar. *

The estimate submitted in 1868, for improving its depth so as to equal that of the outer bar, viz: 12 feet, was \$1,300,000.

Such were the physical conditions before any material improvements were started, but the necessity for increasing the depth on the inner bar and the dilatory measures of the Government compelled the city of Galveston to undertake the work of constructing a pile-jetty over a mile in length in 1869, resulting in an increased depth of two feet.

This jetty was destroyed in part by the storms of 1875, aided by the ship worm (*Teredo navalis*). The first Government appropriation was made July 11, 1870, \$25,000, followed by \$20,000 the next year, and the engineer officer in charge was directed to submit a project for excavating and preserving a channel 80 feet wide and 12 feet deep across the inner bar "by the ordinary method of dredging."

After the lapse of over a year consumed in surveys and futile efforts to let the work by contract and in building dredges and scows, the officer in charge reported that "the work is not susceptible of permanent completion."† The year following he reported on July 20, 1872, that the dredge boat, steam tug and two scows, procured with the previous appropriations, "were not needed or worked during the year, due to the good effect produced by the jetty constructed by the City of Galveston," which caused a channel on the inner bar equal in depth to that on the outer bar. Under the circumstances the plant was held in readiness to work in case the jetty should be destroyed.‡

* *Report Ch. of Eng'rs*, 1868, p. 509.

† *Report Ch. of Eng'rs*, 1871, p. 518.

‡ *Report Ch. of Eng'rs*, 1872, and was loaned to citizens to improve their docks.

The next appropriation of \$31,000, June 10, 1872, was to be expended in surveys and maintaining the Galveston jetty. The year 1873 was consumed in surveys and further considerations, resulting in a project for securing an 18-foot channel over the outer bar by means of two jetties composed of "gabions filled with sand," at an estimated cost of \$1,259,446.43. This project was submitted to the Board of Engineers at New York, who reported favorably in February, 1874, submitting a revised estimate, amounting to \$1,759,401.85. The plan provided *two paralleled and submerged* jetties extending outward into the Gulf over *two and one-fourth miles apart*, and having a total length of 37,000 feet or over seven miles; an average distance of three and one-half miles from shore. for various reasons work on the jetty was not commenced until April 14, 1877, and from that date to January 1, 1880, the North jetty had been extended to sea nearly two miles. An examination made during that year revealed the fact that "the gabionade (North jetty) had essentially gone down below the original bottom, consequently it could not serve to direct or confine the currents."

Thus a decade passed in beginning the series of experiments to improve the outer bar. In the meantime, attention being thus diverted from the inner bar, it was left to the natural forces to maintain, and in September, 1875, a violent storm occurred which cut a new channel 12 feet deep through it at a point where the depth was only 7 feet, without reducing that of the old channel. This natural cut continued to improve, and by the following June had deepened to 17 feet. This gale of September, 1875, having destroyed the greater portion of the plant and material to the value of \$50,000, several months were consumed in preparing to renew operations, by which time the appropriation was exhausted and that for the year 1876-77 being withheld, work was totally suspended until September, 1876, when a portion of it was released. Work on the inner bar was "completed" during that winter and then suspended until an equal depth on the outer bar should be obtained. The Fort Point gabionade having

been completed by June, 1877, it was observed that the deepening of the channel, started by the storm, still continued. The depths reported were in August, 1877, $16\frac{3}{4}$ feet; September, 1877, $18\frac{1}{4}$ feet; October, 1877, $19\frac{1}{2}$ feet; June, 1878, $20\frac{1}{4}$ feet. This increased result may be attributed to the interception by the jetty, of the sand formerly carried into the channel, rather than to any scour produced by contraction of the channel.

As to the work on the outer bar, it was found, as already stated, that the gabions, which were 6 feet high had sunk from 4 to 7 feet, and that, "contrary to expectations, they did not become covered with sand, but remained standing in a trench entirely uncovered,"* although submerged. These and other peculiarities led the Board of Engineers to reconsider their plans of 1879, and to abandon the gabionade in favor of brush and stone jetties, which it was affirmed would "undoubtedly succeed." "The theory upon which the Board relies is that of contraction of the outlet to force the outflow into a narrow channel directed upon the bar to effect its removal, and lessen, if not entirely prevent, for a long time to come, its reformation."†

Herein is where a fatal mistake was made in attempting to apply a theory which was inapplicable to the existing conditions. To produce scour by contraction the jetties must be so close as to co-act upon each other, that the trenches produced by their reaction may meet, and so prevent the formation of a middle ground. To secure this result at South Pass the distance between the jetties was contracted from 1,000 to 600 feet, and there the current is rapid and nearly continuous towards the Gulf. At Galveston it is intermittent and the ebb is dependent on the free admission of the flood to the inner bay. To place two jetties so close as to co-act and to scour by their reaction on the currents, would virtually have shut out the force available for scour and would have so obstructed the outlet to this bay that in great storms the city would have been endangered. In this

* *Report Ch. of Eng'rs*, 1879, p. 911.

† *Report Ch. of Eng'rs*, 1880, p. 1205.

dilemma, this board located the two jetties with an interval of over *two miles* between them, expecting by this plan "to force the outflow into a narrow channel," and to obtain a depth of at least 25 feet with a mean tide of only 14 inches. No precedent for such a plan exists in the history of the world, and yet the statement is made that after exhausting the literature of the subject "the application of this principle offers every guaranty of success."* "The suggestions as to details of construction are tentative only," and the Board recommended the trial of several methods of construction, among them that the line of "the South jetty should incline more to the North, so as to contract the opening between the two at their outer ends, but still remaining more than two miles apart;" and add "it has always been assumed that the Galveston jetties are to be submerged, but to what depth can only be determined by results produced during the progress of their construction. Should an average height of 5 feet above the sand bottom prove sufficient, it seems probable they can be constructed for \$40 per lineal foot."† The total estimate for a depth of 25 feet across the bar was \$1,825,813.

Under this project, as modified, work on the submerged brush-mattress jetties was commenced in July, 1880, near Fort Point, under the supervision of a new officer in charge, and continued as rapidly as the exigencies of the case would permit. Work on the North jetty was discontinued during the experiments on the other. By June 30, 1882, 20,777 feet of mattress work (nearly four miles) had been laid on the bottom and 10,130 feet of the second course was in place. These were ballasted by stone brought from a distance.

At this date, it was reported that "the effect of this work was not such as one unfamiliar with the physical phenomena of our locality would be led to expect." (The survey gave a depth on the bar of $11\frac{1}{2}$ feet.) During the succeeding year, 1883, it was stated by the civil engineering assist-

* *Report Ch. of Eng'rs*, 1880, p. 1205.

† *Ibid.*, pp. 1229-30.

ant that "the gulfward movement of the bar, without a corresponding increase in depth upon its crest, would seem to indicate the importance of an early and rapid construction of the North jetty." Yet, although attention was thus early directed to its importance, up to this date nothing has been done on this part of the project, whereby the rapid advance of the bar might have been prevented and great expense saved.

The survey of 1884 "brings out prominently the fact of the advance of the outer bar gulfward, which effect was sought to be prevented by the rapid construction of the jetties." * * "Slight changes are noticed upon the bar, but no benefit to navigation has resulted yet."

Channels dredged on the bar are quickly filled up by the drift of sand from the North. "The North jetty is absolutely required, if it is expected to secure deep water."

This North jetty, as designed by the assistant civil engineer, and which was the most promising feature of that period, was a detached, concave structure rising above high water, and placed so as to protect the channel over the bar from the drifting sand and waves, which is the requirement of prime importance in this problem. It was to have been about three miles in length, but was never built, although approved and recommended by the officers in charge.

The appropriation bill having failed, the city of Galveston again came to the rescue with a gift of \$100,000 to continue operations, and at this juncture Mr. Jas. B. Eads was induced to make a proposition to the Government to undertake the work on the basis of his offer made for the South Pass, of compensation only after results were obtained. To this end a bill was introduced into Congress, February, 1884,* authorizing him to undertake the securing of a 30-foot channel at a cost of \$7,750,000, payable by instalments for each foot or more of gain in depth.

This bill was defeated by such plausible arguments as these, submitted through and by the Chief of Engineers: "Nine hundred and seventy-five thousand dollars has been

* Senate, No. 1652.

expended upon the construction of the South jetty, and the construction of the North jetty will cost \$700,000. That the construction will give more than an additional two feet of depth in the channel connecting the harbor of Galveston with the Gulf is entirely certain." "The case can be plainly stated as follows: (The Government) with the expenditure of \$700,000 and two seasons' work will obtain an increase of depth exceeding 2 feet and probably reaching 5 or 6 feet, while Mr. Eads and associates promise, after a period of 2 years and 8 months after the passage of the bill, to gain 2 feet in depth for an expenditure on the part of the Government of \$2,000,000." "The North and South jetties placed according to the official plan can, by further extension into deep water and by the construction of auxiliary works, if needed, be made to develop all the depth of the channel which the nature of the locality will admit."

In view of these assurances, it may be well to look at the sequel as revealed by seven years of subsequent experience.

The bar has now barely 13 feet of water over its crest, which is nearly two miles further out in the Gulf than when the works were begun, and the conditions are by no means so favorable for success as they were in a natural state. The cost has been increased by requiring four additional miles of jetty work to be built at the outer end. Furthermore, the Government, having learned something from the hearings concerning the plans and methods of Capt. Eads, soon after re-convoked the Board of Engineers, who again modified the plans and estimates to include high-water stone jetties as being ultimately cheaper and more permanent than the mattress work, which was found to have subsided over sixty per cent., and which, if carried to the outer 30-foot curve, would cost \$7,000,000, provided "the money be freely supplied." Their aggregate length would be nearly 54,000 feet or over *ten miles*.

The width between them was always a difficult question upon which Capt. Eads does not appear to have furnished information further than to say in reply to a member of Congress, who asked if they should be 12,000 feet apart:

“That is a matter I should take into serious study before I should determine what particular width and direction I should give but *I do not take it to be over 2,000 feet.*”

In this reply, he kept within the limits of similar maritime works to be found in the world, with one slight exception, where, by dredging, a depth of about 21 feet is maintained, yet the present official plan provides for a width of 7,000 feet or nearly *one and one-half miles*, which will prove an egregious blunder.

The impression which is being fostered that the present plans are those endorsed by Capt. Eads, and which gave promise of success is, therefore, erroneous, for although the details of the jetties are those proposed by him, their plan, form and position are far from according with its views.

A distinguished writer, in reviewing the results of this work to date, remarks that “after a series of careful experiments, a width of 7,000 feet was determined upon, and has so far proved entirely satisfactory.”

As the history of these experiments shows that at no time was there more than a part of *one* jetty in existence, it is difficult to understand how a width of 7,000 feet between them could have proven satisfactory, as the result of careful experiments. No precedent for such construction is to be found in the annals of jetty building, since the world began. If Galveston be made the precedent, it will be an extravagant warning for future generations, as, instead of the deep and wide channel of a minimum navigable width of 2,000 feet at the surface and 600 feet at a depth of 30 feet, which a recent Board of Engineers have fixed upon as absolutely necessary for the contemplated port entrance, there will be merely the trenches bordering the flanks of the jetties and extending to a distance of a few hundred feet therefrom, produced by the lateral currents, and a middle ground with its prevailing depths of 12 to 13 feet between them. Jetties this far apart will be inert, and it would require two years to dredge a channel such as the above, even if the sea were to stand still and cease to supply sand to the bar for so long a period. Dredging has been tried and pronounced a failure, and no protection could be fur-

nished to a dredged channel, even if created, by jetties as now proposed, a mile and three-eighths apart, open to the storms and connected with the shore. It will be observed that the present width between jetties is a little more than half that originally considered necessary for the protection of the city.

Again, the fact that the volume of water passing out at each tide "exceeds by about 30,000 cubic feet a second the entire low-water discharge of the Mississippi River," is not reassuring as to the success of the work, since at the latter place the flow is practically constant, whereas at Galveston there must be an equal volume flowing *into* the bay. (The small land drainage being mainly consumed by evaporation does not sensibly affect the outflow.) There is, therefore, the very material difference that at Galveston the movements are virtually equal in volume, but opposite in direction, while they differ only slightly in velocity. Hence, the effects are due to the differentials between flood and ebb, while at the South Pass there is not this opposition of material forces, but a nearly constant outward discharge. If *two* jetties are built at Galveston sufficiently close to produce a scour by reaction between them, they will so reduce the influx of the tide as practically to destroy the only force available, and the problem becomes indeterminate. The only hope for Galveston is by a single jetty on the North flank of the bar, with possibly a short groin at Fort Point.

In the late animated discussion in Congress* concerning the special appropriation of \$6,200,000 to complete the work under Government supervision and plans, it was stated that the people of Galveston accepted Mr. Eads' proposition to guarantee 30 feet of water across the bar for \$7,500,000, and asked Congress not to give them any more money to be expended by Government engineers, in the hope that it would appropriate a lump sum, as it had done for the Mississippi, to be expended by Capt. Eads. "But Congress did not close with that proposition, and the engineers

* *Cong. Record*, March 30, 1890, p. 2874.

adopted nearly Eads' plan. They would not adopt it entirely, and whether we get deep water or not we shall at any rate have made an honest effort to do it, and if we fail, the failure will be such that its repetition will not be invited. For that reason, Mr. President, I think we ought to pass this bill."

This quotation is sufficient to show the animus of Congress in relation to these public works, of so great importance to the country. It is to remove the odium which has been placed upon this honorable body, for the failure of many of these works, on the plea of withholding appropriations. In this case at least the *onus* will be removed to the executive department having charge of the works, and it is risking nothing to say that unless the present plans are materially modified, this large sum will merely have benefited the workmen and others employed or interested in executing the project. The extension of the South jetty has intercepted the littoral drift moving southward, building a shoal in the site of the old channel and causing a rapid progression of the bar seaward, which alone has added to the cost of the work more than the price of the jetty without increasing materially the depth of the outer bar.

The last report, made by the late civil assistant engineer, states "that upon the crest of the outer bar there has been a pretty general shoaling of from one-fourth to one-half a foot. The depth in the jetty channel, however, still remains at $13\frac{1}{4}$ feet, but the bar has advanced very perceptibly gulfward.

* * * "The shoal immediately North of the jetty has continued its gulfward advances. * * * The indications are that the probable effect of the further building of the South jetty will be the obliteration of the jetty channel itself. * * *

"The gulfward advance of the bar is not an unexpected result of the extension of the jetty, and I think we may expect a continuation of this advance until the equilibrium has been restored, or the supply of sand exhausted. * * *

"The sand has accumulated on the North side of the

jetty and some has passed over the crest and settled next to the base. This is another indication of the loss of force in the littoral current at that point, and also shows from which direction the sand is moving that has caused the shoaling."

The foregoing report, stating the facts so strongly, was only produced by order of the House of Representatives, and the sequel of its publication was an order to discharge its author from further service on Government works, after about eighteen years of intelligent and faithful service at this harbor.

The problem is not, however, hopeless; the North jetty should be built at once, but of such form and in such position as to control the prevailing natural elements which maintain the bar.

It is said that time and money will remove mountains, and while the aphorism is true of mountains, *in situ*, it cannot be applied to those in motion where the incessant forces of nature are continually constructing a path whereby they may traverse a breach in the coast. The remedy is not to be found in twin jetties, for such physical conditions as exist at Galveston.

Thus, after more than twenty years of experiments, frequent changes of commanding officers, several modifications of plans, the expenditure of \$2,273,111.66 to June 30, 1890, and more than a quadrupled estimate of cost to complete, it may be said that the injuries caused by the works are greater than the benefits, and that the difficulties in the way of securing a deep water channel over the outer bar have been greatly increased rather than diminished, while it is proposed to apply \$6,200,000 to a continuation of these experiments on a plan which must prove fatal. Such is believed to be a frank, though greatly abridged, statement of the problem of securing deep water at Galveston, as it exists to-day.