the Greenland coast, with the view to ascertain its capabilities as a cable station, would not be at all conclusive or satisfactory if it does not embrace, at the very least, eight or nine months' resident examination of the coast, both on its eastern and western sides; as the practicability of that route for telegraphic purposes must depend, not merely upon the bare possibility of laying a cable there during one particular month in a Greenland summer, but upon the probability of its remaining intact during the stormy seasons, and the facilities for rapidly repairing it when broken."

*On the Wave-line Theory.** By JOHN SCOTT RUSSELL, Esq., F.R.S.
Being an abstract from his Paper read before the Institution of Naval Architects, March 3, 1860.

After briefly recapitulating the chief portions of the Paper which he read at the Inaugural Meeting, two days before, the Author said his object in his present Paper was to consider the nature of the motion imparted to water when disturbed by a vessel pushed through it by motive power of any kind. It was in the investigation of this subject that he had seen some of the most important principles that guide us as to the general proportions of ships, as well as their shape, with reference especially to velocity.

The first inquiries to be made were,—what became of all the water which a ship removed out of her way? and how did it get out of the way? In prosecuting these inquiries the Author had first employed a small trough or canal, a foot wide, a foot deep, and of considerable length, and began with a very simple experiment. He supported a small heap of water above the level of that in the trough by means of a partition at one end, and then withdrew the partition to see what the water would do, and found that it assumed a beautiful wave-form of its own, ran along the whole length of the channel to the end, and left the surface of the water over which it passed as still as it was before. Had the end of the trough been just level with the surface of the still water, the wave would have jumped over and left the whole of the water in the canal perfectly undisturbed. This phenomenon is now known as the "solitary wave of translation." This wave would travel to an almost incredible distance. The Author had followed such a wave on horseback, and by other means, for miles. It leaves a little of itself, however, along the whole surface over which it passes.

The next fact ascertained was that, whenever the bow of a ship is moved through the water a wave of this kind is produced, and this is the "traveling" or "carrier wave," which gets rid of all the water out of the canal which the vessel has to excavate. The ship feels no more of it, for it spreads itself in a thin film all along the surface of the water ahead of the vessel—not behind the vessel, nor on each side of it—with a far greater velocity than that of the vessel itself. After having made experiments on a small scale, the Author took vessels on

* From the *Lond. Mechanics' Mag.*, April, 1860.

a large scale, had them dragged by horses, and in other ways, through the water, and by positive observations and measurement found that this was really what became of the water displaced by the bow of a boat. On one occasion he drew so large a number of boats along a canal in one direction, on a certain day, that the waves carried a great part of the water from one end of the canal to the other, and in the evening the water in the canal was found raised 18 inches at one end, and depressed to the same extent at the other. The velocity with which the traveling wave moved was found to depend entirely on the depth of the water.

At 3 feet deep the wave travels	6 miles an hour.
" 5 "	" 8 "
" 7 "	" 10 "
" 10 "	" 12 "
" 15 "	" 15 "
" 20 "	" 18 "
" 30 "	" 20 "
" 40 "	" 25 "
" 50 "	" 30 "

In addition to a constant velocity this wave has a constant shape, a drawing of which was exhibited by the Author. And a most extraordinary circumstance was that its form corresponded exactly with the form of bow which he had previously, and from altogether different considerations, constructed as the form of least resistance. Moreover, he found that what he had endeavored to do in constructing that form, viz : move the particles of water gradually out of the way from one position of rest to another, the traveling wave also did ; for on closely observing the water in the experimental trough under the action of such a wave, he observed that it lifted every particle of water over which it passed out of one place forward into another place, and there left it perfectly at rest. In the traveling wave, therefore, as in ordinary waves, the particles of water composing it were continually being replaced by others, while the wave itself advanced without apparent change. The foregoing facts convinced the Author that the form of bow which he had adopted, and which has since been called the "wave form," was analogous and conformable to the nature of water and of wave motion.

Like many others, the Author at first thought that the stern of a vessel ought to be of the same form as the bow ; but thought it proper to undertake a series of experiments with the view of ascertaining what happened when a hole in the water had to be filled up. Where did the water that filled it come from ? And how did it come ? He first found that the hollow made in the water had no tendency to travel with an independent velocity of its own, but moved just as fast, and only as fast, as the body which produced it. He then discovered that the currents of water rushing into such a hollow, from different directions, met and produced a wave, which he called the "following wave," or the "refilling" or "replacing wave," and which always moved with the velocity of the ship, and had nothing to do with the depth of the water. The "following wave" also repeated itself in

an endless series astern of the vessel. The Author explained that the nature of this wave required that the stern of the ship should be formed of cycloidal curves, and showed how this fact was applied in actual construction.

The Author might be asked (reverting to the wave at the bow)—what became of the water at the bow supposing he dragged the boat faster than the water could spread itself? The answer was—With only a moderate force at his disposal the boat could not be made to travel faster; but if he had force enough to compel it to go in spite of the water, the water would rise up and stand on both sides of the boat until the load had passed, and then fall down into the hole left behind it. In a shallow canal in Scotland, where the carrier wave traveled only seven miles an hour, he had compelled a boat to go ten miles, and he found that the water not only rose up, but lifted the boat with it, so that she drew less water than before, and actually went easier at ten miles an hour than at five. Had not railways come into fashion just at the time, the country would have been covered with little troughs, and people would have been riding on the tops of these waves in an easier and cheaper mode than by any other means then known.

After explaining the different results which are sometimes obtained at trials in the Thames, owing to the velocities of the traveling wave varying with the depths of the water, the Author described the best means of observing the wave on rivers and other like places, and then proceeded to the application of some of the principles before laid down to practice. First, he said it was a delightful circumstance that the wave principle did not meddle at all with the form of a ship's mid-ship section, but left the conductor entirely free to adopt any form of section he pleased. Next, it did not tie him down to any proportion of depth to breadth. It was, therefore, a plastic thing, and could be applied to any general form of ship whatever. The third and most important proposition was, that the wave-line prescribed the exact length of ship for every speed at which you wished a ship to go, and explains why a long ship is indispensable to speed. To go six miles an hour, your vessel must be at least 30 feet long; for eight miles an hour, 50 feet long; for 10 miles, 70 feet; for 12 miles, 100 feet; for 15, 150; for 18, 200; for 20, 300; for 25, 400; and for 30, 500. The Author had himself tried to obtain higher velocities than these with shorter vessels; and he had got them, but at such a fearful waste of power that it was insanity and folly not to lengthen the vessels for the purpose. The wave-line theory also told you that the length of the bow should be to that of the run as 3 to 2. The cause of this was explained.

The lines of the Great Eastern, the Author said, were neither more nor less than an exact copy of the wave-lines. The length of the bow was 330 feet; the length of the run 226 feet; and having got this length of entrance and run, and feeling that more capacity was wanted, it was of no use lengthening the bow or the run, because there was already provision for greater speed than the 15 miles an hour which

the power to be put into her could be expected to give; 120 feet of parallel body were therefore put into her amidships. The great ship might be of less fine-lines and still go with the same velocity.

There was a very valuable conclusion for practical ship-builders to be drawn, independently of what had been stated about the lines. It was this: that proportionate length and breadth were not necessary at all for a fast vessel. It was not necessary for a fast vessel that she should be a narrow, thin, long vessel in proportion to her size. The Author had taken vessels on the wave-line principle 200 feet long, and had made them of every variety of breadth, and as long as they were 200 feet long and had the lines belonging to 15 or 16 miles an hour, so long they had gone at that velocity with a given power. Further, the resistance which a vessel experiences from the sticking of water to the skin was a most formidable element of her whole resistance; and greater velocity in proportion to power would be got out of a vessel which was shorter than another, and also broader and deeper than another, providing length enough for the velocity aimed at were got at starting.

The Author's paper next contained remarks upon the effects of the wave-line upon the stability of ships—its bearing upon the load-water line—how it affected the form of the deck—how it should affect the structure of the vessel—how vessels should be built upon it so as to have a maximum of capacity—how the various proportions of length, breadth, and depth affected resistance—how the whole form could be so managed as to properly arrange the balance of the ship—how the wave-line affected the navigable qualities of a ship—how it affected the materials of which the ship should be built—and how it influenced the properties of sailing ships, paddle-steamers, and screw-steamers, respectively. But these considerations could not then be gone into. They would, however, appear in the Institution's forthcoming *Transactions*.

It was the duty of the Author, however, to say a word or two on the history of the subject, and the degree of novelty or non-novelty to which it pretended. And he begun with saying that he did not claim to be the inventor of hollow bows. They had existed as far back as he could trace steam navigation. When he had first discovered what he believed to be the principles of nature which bore on this subject, he felt that the form of vessel which accorded with them could not be new, and he set about examining all classes of vessels. He found proofs immediately; so many that he felt astonished that the books and treatises on naval architecture had not all told them to do nothing but make hollow bows from the beginning. He showed that it must have been impossible for barbarous men to have made a rough boat from two flat planks without forming such a bow. But the old tonnage laws had compelled builders to make ships of the greatest possible capacity compatible with certain measurements. Hence the bluff bow was made a matter of necessity. When, during the wars, we captured Spanish ships or privateers with fine and often hollow lines below—vessels which sailed admirably under their origi-

nal trim, in which they were down by the stern, we invariably found that they proved but dull sailers in our hands, owing undoubtedly to the fact that we not only overloaded them with weights, but trimmed them nearer to an even keel, and so brought the bluff upper part of their bows down into the water. The boats of the London watermen illustrated the same principle. The Author next alluded to the *Vesper*, built from Mr. Ditchburn's design by Fletcher and Fearnall, in which, on coming to London in 1836 or 7, he found a confirmation of the views which he had embodied in the *Wave* in 1835. He also referred to a boat built by the late Mr. Assheton Smith, and to several other vessels built successively by himself and others.

The Author concluded by stating that the rapid advancement of confidence in the wave principle was owing very much to the British Association for the Advancement of Science, which had placed at his disposal large means for the prosecution of scientific researches into this subject, and had every year enabled him to publish to the world the progress which he was making in the investigation.

*State of Railways in Spain.**

At the close of the year 1859, the following was the state of railways in Spain, with their annual receipts:—

	Kilometres in length.	Receipts 1859. Reals vellon.
Madrid to Alicante,	482	44,228,893
Madrid to Saragossa,	57	2,126,720
Cordova and Seville,	131	4,259,146
Valencia and Almansa,	138	6,430,425
Alar and Santander,	91	8,540,372
Barcelona to Saragossa,	37	2,905,680
Barcelona to Martorell,	27	2,083,765
Barcelona to Arenys,	36	4,185,787
Barcelona to Granollers,	29½	2,742,050
Jerez to Trocadero,	27½	3,717,408
Langres and Gijon,	39	
Tarragon,	14	761,198
Totals,	1109	81,981,444

The Langres and Gijon line, in 1858, received 1,832,071 reals vellon (1l.=96 reals vellon).

On the Decay and Preservation of Building Materials.† By Prof. ANSTED.

Prof. Ansted commenced by directing attention to the state of the stone in many of the principal buildings in England and on the Continent, illustrating the extreme irregularity with which various materials, and even various samples of the same material, resist the action of the weather and fall into decay. He then described the chief building

*From the London Builder, No. 893.

† From the Lond. Athenæum, May, 1860.