weight be water or a gun. If this reduction did not take place we should have something to explain which would be quite inexplicable. For suppose we have two ships alike in all respects as regards size, shape, weight, time of oscillation, &c., and situated on precisely the same seas, but one having all her weights properly secured, and the other with a weight capable of traversing the deck every time the ship rolls. If the two vessels were to roll to exactly the same extent we should have the sea not only rolling the ship with the loose weight to the same extent as the ship with all her

weights fixed, but the sea would, in addition, be doing all the work involved in the traversing of the heavy weight across the deck, which is quite impossible under the circumstances of perfect similarity we have supposed. The sea can only do the same work on both. In the one case that work consists entirely in rolling the vessel, in the other it consists partly of rolling the ship and partly in dashing the weight about. The rolling in the latter must therefore inevitably be less than in the former case.”

Dynamical stability is the “ work ” done or energy expended in heeling the ship from the upright to any inclined position. The unit of “ work ” employed in measuring dynamical stability is a foot- ton. When the vessel is gradually inclined the forces inclining her must do work depending upon the amount of the statical stability at the successive instantaneous inclinations passed through, and these are given by the curve of stability already described. Dynamical stability is of value as a means of comparing the resistance of ships to upsetting under the action of suddenly’ applied forces, such as squalls of wind. Illustrating this Mr White says :—

“Roughly speaking, it may be said that a force of wind which, steadily and continuously applied, will heel a ship of ordinary’ form to a certain angle will, if it strikes her suddenly when she is upright, drive her over to about twice that inclination, or in some cases further still. A parallel case is that of a spiral spring ; if a weight be suddenly brought to bear upon it, the extension will be about twice as great as that to which the same weight hanging steadily’ will stretch the spring. The explanation is simple. When the whole weight is suddenly brought to bear upon the spring, the resistance which the spring can offer at each instant, up to the time when its extension supplies a force equal to the weight, is always less than the weight ; and this unbalanced force stores up work which carries the weight onwards, and about doubles the extension of the spring corresponding to that weight when at rest.”

*Structure.*

The changes which have come about in materials and modes of construction within the last 50 years have been most remarkable. The first steamer built expressly for regular voyages between Europe and America was not built until 1837. Dr Lardner stated at about this date : “We have as an extreme limit of a steamer’s practicable voyage, without receiving a relay of coals, a run of about 2000 miles.” The “ Great Western,” built by Patterson of Bristol and engined by Maudslay of London under the superintendence of Sir I. K. Brunel, was the first such ship, and she was launched July 19, 1837. She was 212 feet long between the perpendiculars, 35 feet 4 inches broad, and had a displacement of 2300 tons. She was propelled by paddles. Iron vessels were built early in the present century for canal service, then for river service, and later for packet service on the coasts. In about the year 1838 iron vessels of small dimensions were built for ocean service. The largest iron vessel built up to 1841 was less than 200 feet long. In 1843 we get for the first time the ocean-going steamship in its present form, built of iron, " and propelled by’ the screw. This was the “ Great Britain,” 286 feet long, projected and designed by Brunel. Time has abundantly justified these bold enterprises on the part of Brunel, which he had to carry’ through in the face of great opposi­tion. He entered with equal boldness on another innovation in 1850, viz., the use of very large dimensions on the ground of economy of power. It was not until 1852 that he had the oppor­

tunity to put these views forward in a way to satisfy him. The different sizes of vessels discussed before the design was finally settled for the " Great Eastern ” were as follows :—

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | No. | Length. | Breadth. | Midship Section. | Draught. |
|  | 1 | 663 | 79∙9 | 1,646 | 24 |
|  | 2 | 634 | 76∙39 | 1,640 | 25 |
|  | 3 | 609 | 73 ∙5 | 1,639 | 26 |
|  | 4 | 730 | 87 | 2,090 | 28 |

The dimensions eventually settled were—length, 680 feet ; beam, 83 feet ; mean draught, about 25 feet ; screw engine, indicated horse-power, 4,000, and nominal horse-power, 1600 ; paddle, indicated horse-power, 2,600, and nominal horse-power, 1,000 ; to work with steam 15 lb to 25 lb ; speed of screw, 45 to 55 revolutions ; paddle, 10 to 12.

The “Great Eastern,” produced by the joint skill of Brunel and Scott Russell, remains in advance of present practice, although she has served as a model for the best of it. Her great size rend­ered it possible to give to her an amount of security’ against fatal injury to her hull which cannot be attained in smaller ships. It is a mistake to suppose that large ships are less secure than small ones. The large ship can receive without inconvenience a wound which would be fatal to a small one, and the possibilities of obtaining high speed increase with the size. Had a higher speed been aimed at in the “Great Eastern,” it might have altered the whole current of her history, and changed also the history of ship­building itself.

The question of bulkheads, on which Brunel insisted so much in this ship, is one which underlies all questions of construction. If the number of bulkheads in ships were increased as they ought to be, the numbers and sizes of the ribs or frames of the ship would be modified, and the system of construction generally would be changed, and become more like that of the “Great Eastern.” The question is therefore one which justifies some further consideration, so that it may’ be popularly understood.

Iron ships are commonly made with less than half their bulk out of water. If water enters such a ship, and the amount which enters does not exceed in bulk that portion of the bulk of the ship which is out of the water, *and which will, when immersed, exclude the water,* then the ship, if she does not turn over, will still float. If, however, the inflow cannot be stopped, but continues, the ship soon sinks.

Let us suppose the case of a ship 50 feet long, 10 feet wide, and 10 feet deep, divided into five equal parts by four watertight par­titions, and floating in water with half its bulk immersed (fig. 8). Suppose now that a

hole is made in the

middle of this ship

under the water, so

that water can flow

freely in, then the

part of the ship

which is shaded

ceases to have floating power. The water in this shaded place is no longer displaced, but is admitted, and if the ship is to continue afloat, the other parts of the ship must displace water to the amount by which this shaded part has ceased to do so. As it is one-fifth of the whole immersed bulk which is lost, the remaining four compart­ments must sink, so as each to support one-fourth of the whole, instead of one-fifth, as before; *i.e*., the draught of water, or im­mersion of the whole ship, will be increased, and the ship will, if she has stability enough to keep upright, finally’ float at rest again at this deeper immersion. The water will rise in the centre com­partment to the level of the water outside, and will then cease to flow in. The additional immersion, will be only’ one and a quarter feet, but in an ordinary’ ship, divided into compartments of equal length, there would be a greater increase of immersion by the injury of a centre compartment, because the end compartments are narrow, and must sink deeper in order to bear their share of the burden imposed by the loss of the buoyancy of the centre division.

Or it may be other than a central compartment which is damaged, and in that case the ship tips, and finds a new floating line, with the end towards which the damaged division lies depressed more than the other end.

If it should happen that the divisional partitions, or bulkheads as they are called, rise only a few inches above the water level which the ship floats at when undamaged, then, on the occur­rence of a bad leak filling one compartment, the tops of the bulk­heads are brought, by the increased immersion of the ship, beneath the water-level, the water will rise through the hatches, or open­ings in the deck, in the damaged compartment, will flow over the entire deck, and the ship will be lost, either by the filling of other compartments by the water passing down into them, or by the capsizing of the ship. This latter event will generally’ happen, although only one compartment is full, if the sea has free access to