THE OBSTRUCTION TO THE NAVIGATION OF RIVERS CAUSED BY THE PIERS OF BRIDGES.

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Before proceeding to the discussion, to which this article will be principally devoted, for the sake of comparing the method usually adopted for determining the hight of *remou* with that recommended in this series, I will here give D'Aubuisson's formula:—

$$x = Q^2 \div 2g\,[\,(1 \div m^2\, l_2\, h^2\,) - 1 \div L^2\,(h+x)^2]$$

where x is the value of the hight of *remou*; m a variable co-efficient; and the other quantities are constants to be determined for each particular case. It will be observed that x enters both sides of the equation, and that on one side its square is in the denominator. Hence, to obtain an expression for the value of x, in which its own value does not enter, requires the solution of a complicated equation of the third degree. D'Aubuisson recommends, instead of this, the introduction of experimental values for x into both sides of the equation, until one is found which will fulfill its requirements; which is, in fact, a solution of the equation by gradually *approximating* to the value of x. Whoever attempts this will find himself involved in a labyrinth of figures, from which he will gladly escape to the more simple and *more accurate* method I have indicated.

In the suit alluded to in the first article of this series, a distinguished engineer quotes D'Aubuisson's formula as above, and states that for a certain stage of water the velocity will be increased from 5.9 feet per second to 6.36 feet per second, and the corresponding hight of *remou* will be $2\frac{1}{2}$ inches. This value of the hight of *remou* is more than twice as great as is required to produce such a change. Inconsistencies like this, between the changes of velocity and hight of *remou*, which are extremely liable to creep into investigations made under such complicated formulæ, are entirely guarded against in the method now recommended. The change in velocity and hight of *remou* being made to depend directly upon each other, both being arrived at by a short series of easy approximations, each acts as a check on the other, and renders error in calculation almost impossible to escape detection. There are some circumstances influencing the results already given which I do not deem it necessary to describe, because their influence is so small that it would not materially affect the result, in such cases as generally occur, while to treat them in detail would crowd out more important matter. One other element affecting the value of the hight of *remou*, I had intended to discuss, but have since concluded merely to make this illusion to it, thinking that any engineer competent to carry on investigations to that degree of refinement, implied by the introduction of this element into the investigation, would himself readily see how it was to be introduced. The element to which I allude is the effect of the water impinging upon the starling of the pier, and causing a loss of head by impact, to regain which would require an increase in the hight of *remou*.

Having indicated the method of determining the increase of velocity between the piers, and the hight of *remou* or back-water, we now pass on to another branch of the subject—the actual obstruction offered to the ascent of a steamboat through the draw. It is evident that when the boat is in the draw, the water-way of the river will suffer an additional contraction, equal to the greatest cross section of the submerged portion of the boat. This additional contraction of the water-way will cause an increase in the velocity between the piers, and an increased hight of *remou*. Hence, in determining the maximum values of velocity and hight of *remou*, we must add to the cross section of the submerged portion of the piers and abutments, the greatest cross section of the submerged portion of the largest boat liable to attempt the passage of the draw—that is, the boat is to be treated as if it were an immovable floating pier.

We have now determined the greatest velocity and hight of *remou* which can oppose the passage of a steamboat. What is the measure of the obstruction offered to the passage of an ascending boat? Is it the velocity of the water in the draw? I answer: *the velocity of the current passing through the draw is no criterion whatever of the obstruction to navigation caused by the intervention of the draw*. In a subsequent article it will be shown that of two draws, constructed precisely alike, both having the lines of their piers parallel to the current, it may require *less power* for any boat to ascend through one of them, where the velocity is *six* miles per hour than for the same boat to ascend through the other, where the velocity is *one* mile less or *five* miles per hour.

The true key to the solution of the problem is this:—Is the velocity of the current one that is *increasing* at the point where it is to be resisted; or is the current moving on *uniformly* with a velocity acquired at some point above? Where the longitudinal surface of a river is horizontal, or in other words, where the velocity of the current is uniform, having been acquired at some point above, the measure of the resistance offered to an ascending boat may be taken as the velocity of the boat plus the velocity of the current. Hence, if a boat ascends at the rate of five miles an hour against a current of three miles an hour, the power expended in propelling it is the same as would be required to move it at the rate of eight miles per hour in still water.

It is evident that the surface of the water above the piers is higher than the surface of the water between the piers, and that this difference in level is measured by b, the hight of *remou*. A boat in ascending the draw must then, besides resisting the current, lift itself from the lower to the upper level. This rising of the boat takes place gradually, not abruptly; hence we may compare the ascent to one up an inclined plane whose hight is b, What is the length of the inclined plane up which the boat ascends? Let a represent the horizontal distance within which the surface of the water passes from the upper to the lower level; then $b \div a$ represents the tangent of the angle which the inclined surface makes with the horizontal, and measures the steepness of the inclined plane formed by the water. If the boat could be regarded as a material point, then as it moved upon the surface of the water it would follow every undulation of the surface, and $b \div a$ would measure the steepness of its ascent from the lower to the upper level. But we cannot regard the boat as a material point; we cannot neglect its length. When the bow of an upward-bound boat is at the *foot* of the inclined surface of the water, then the whole boat is floating in the lower level, and is just on the point of commencing the ascent to the upper level. When the stern of an upward-bound boat is at the *head* of the inclined surface of the water, then the whole boat has just completed the ascent to the upper level. Is it a violent supposition to consider that an uniform ascent between these two points is equivalent to the actual ascent? Granting this, and representing the length of the boat by l; then $l + a$ will represent the horizontal distance passed over in making the ascent, b, and $b \div (l + a)$ will represent the inclination of the plane up which the ascent has been made. The quantity, a, is however so inconsiderable, when compared with l, that the difference between $b \div (l + a)$ and $b \div l$ will not be of material consequence. Hence if we *divide the hight of the remou in feet, by the length of the boat in feet, the quotient will give the tangent of the angle, which the line of ascent of the boat makes with the horizontal.*

If, as before, v represent the velocity of the current above the piers, and V the velocity between the piers, then a boat, in ascending the inclined plane of the *remou*, passes from water whose velocity is V into water whose velocity is v. Taking the arithmetic mean of these two, as the equivalent mean velocity of the water through which the ascent is made, and representing it by v°, we have $v^{\circ} = (V + v) \div 2$.

The condition of the boat is then reduced to this: in moving its own length (l) it ascends the height of the *remou* (b), through a current whose velocity is v°. They who measure the power required to ascend through a draw, by the power required to resist a horizontal current V, plus the power required to lift the boat vertically from the lower to the upper level, greatly underrate the real power.

[To be continued.]

THE SHEATHING OF SHIPS.

We pay to England, annually, $111,698 for copper and $183,394 for brass sheathing; and as one or the other is employed on all our ships and steamers, useful information relating to the subject is of interest to our shipbuilders and merchants. In recent numbers of the London *Mechanics' Magazine*, we find a history of the applications and patents granted for ships' sheathing. It stated that, as far back as the reign of Edward the III.—in 1336—several compositions containing pitch, tar, sulphur and oil were employed for coating the hulls of ships to prevent the attack of sea worms and the adherance of barnacles and sea weeds. It was also a common practice to use a thin planking, secured by nails, over the main planking, in those olden times. In 1625, a patent was granted to one William Beale, in England, for a composition not described, but the object of which was to render the hull and rigging incombustible. In 1670, a patent was granted to Sir Philip Howard and Francis Watson, for sheathing ships with milled lead. These inventors state that they had discovered they could draw out lead into thin sheets by passing it between rollers, which was a very valuable invention. After this, many of the English ships were sheathed with thin lead fastened by copper nails, and it continued in moderate use for about a century. It was better than nothing, but was too soft for the purpose. In 1727, Benjamin Robinson and Francis Hanksbee obtained a patent for sheathing ships either with thin copper, brass, tin or iron plates. This was the first application of brass and copper to the purpose; but it was not until 1761 that copper sheathing was applied to any war vessel. In that year, the *Alarm* (a 32-gun frigate) was sheathed with this metal, and she soon afterwards made a voyage to the West Indies—the very place to test the sheathing completely. Upon her return to England, the metal was found clean, and as good as when it was put on; but the iron straps of the rudder were rusted almost entirely off, and when some of the copper sheets were removed for examination, the naval authorities were surprised and alarmed to witness all the iron fastenings corroded to a dangerous extent. To prevent this in other vessels which were afterwards coppered, the holes at the outer ends of the iron bolts were filled with pitch, and over these pieces of canvas were laid, then the copper on the top; and the rudder braces were covered with lead. These measures all failed to prevent considerable deterioration of the iron fastenings when copper sheathing was used, and it therefore became a question whether to use some other fastenings than iron, or else give up the use of copper sheathing. The former course was adopted, and brass and copper bolts were employed in 1783. The reason why the iron fastenings corroded so rapidly, in connection with the copper, was unknown in these days; but since the discovery of the galvanic battery, the cause has been obvious to scientific men. A simple galvanic battery is composed of two plates of different metals (the one more oxydizable than the other), and when they come in contact with moisture, such as sea-water, a galvanic action at once ensues, at the expense of the rapid destruction of the positive or most oxydizable metal. Iron-fastened and copper-sheathed ships generate galvanic action when the two metals are connected, and, as a consequence, the most oxydizable metal (the iron) corrodes rapidly.

The green oxyd formed on copper sheathing is a benefit rather than an injury, because, although it is a sign of slight decay in the metal, the oxyd prevents the adhesion of barnacles because it is very poisonous. The copper of ships may be kept perfectly bright by connecting it with small plates of zinc; the latter are decomposed and the former remains perfect. This was a discovery of Sir Humphrey Davy; and it was supposed that by it the copper of a vessel might be made to last forever, with only the expense of some zinc plates. Such hopes, however, proved fallacious.

An important question arises, namely, what is the best metal, as a whole, for sheathing ships? Copper possesses the advantage that, no matter how old it may be, the sheets will sell for only about five cents less per pound than when new. On the other hand, it is not very durable, while it is very dear. By experience, it has been found that the purest copper sheets decay most rapidly; some of the sheets will wear into holes in one year, while sheets of alloys endure much longer. In 1800, M. Collins secured a patent in England for alloys to make sheathing more durable. These consisted, first, of 8 parts of copper and 1 of zinc, which could be rolled cold; the second consisted of 180 of copper and 80 of zinc, which required a low red heat to work; and a third was composed of 16 of tin, 16 of zinc and 1 of copper. In 1817, he obtained another patent for a bronze sheathing, composed of 80 of copper and 20 of tin. In 1823, John Revere secured a patent for a brass sheathing composed of 95 of zinc and 5 of copper. Subsequent to this (in 1832), the Muntz metal was patented, which is simply a brass sheathing composed of copper and zinc, and had been previously patented by Collins, but, for all this, it made a fortune to Mr. Muntz.